50TH

Fiftieth Annual Meeting

OF THE

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

ABSTRACT BOOK

50th Annual Meeting

November 16-19, 2022

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

James S. Harrop, MD, MSHQS, *President*

Zoher Ghogawala, MD, FACS • Brian K. Kwon, MD, PhD, FRCSC • Neill M. Wright, MD, *Scientific Program Co-Chairs*

Thomas E. Mroz, MD • Jefferson Wilson, MD, PhD, FRCSC, *Instructional Course Program Co-Chairs*

www.csrs.org

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Table of Contents

Continuing Education Credit ..... Inside Front Cover
About CSRS 2
2022 CSRS Committees 3
Abstract Sessions Schedule 8
Alphabetical Participant Disclosure List 20
Podium Presentations 34
E-Posters 237
In Memoriam 314
Donation Form 315
51st Annual Meeting & 28th Instructional Course ..... Back Cover

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About CSRS

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Origins of the Society

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

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

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

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

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

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

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

J. William Fielding, MD

Mission Statement

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

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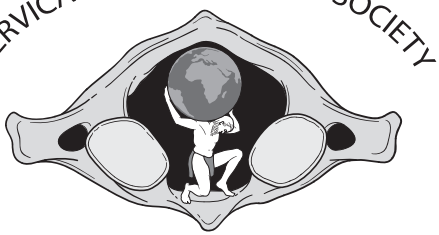

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MANCHESTER GRAND HYATT SAN DIEGO, CA

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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.

Thursday 11/17/2022	**7:20am - 8:40am** Harbor Ballroom G-I **Abstract Session 1: Trauma**
	Moderator(s): Gregory Schroeder, MD; Jefferson R. Wilson, MD, PhD
7:20am - 7:25am	Introduction *Gregory Schroeder, MD; Jefferson R. Wilson, MD, PhD*
7:25am - 7:30am	PAPER #1 The Impact of Frailty on Patient Reported Outcomes After Cervical Spine Surgery *Saad Javeed, MD*
7:30am - 7:35am	PAPER #2 Surgeon Experience and Subspecialty Do Not Affect the Reliability of the AO Spine Upper Cervical Injury Classification *Mark J. Lambrechts, MD*
7:35am - 7:40am	PAPER #3 Prognostic Factors for Cervical Spinal Cord Injury Without Major Bone Injury in Patients Aged 65 years or Older: Japan Association of Spine Surgeons with Ambition (JASA) Multicenter Study *Hideaki Nakajima, MD*
7:40am - 7:45am	PAPER #4 Unilateral Cervical Spine Facet Fractures: Radiographic Predictors of Instability *Erisha K. Tashakori, MD*
7:45am - 7:50am	PAPER #5 A Machine Learning Model Predicting Ambulation in Patients With Spinal Cord Injury Based on Data From 3196 Cases *Satoshi Maki, MD, PhD*
7:50am - 8:02am	Discussion
8:02am - 8:07am	PAPER #6 Association Between Geriatric Odontoid Fractures and In-Hospital Outcomes: Analysis From the American College of Surgeons Trauma Quality Improvement Program *Zamir Merali, MD, MSc*
8:07am - 8:12am	PAPER #7 Intraoperative Sensory Signals Predict Prognosis for Patients with Traumatic Cervical Spinal Cord Injury *John R. Renehan, MD*
8:12am - 8:17am	PAPER #8 To Operate or Not to Operate? Mortality in Unstable Cervical Spine Fractures in the Elderly Population *Karen Malacon, BS*

Thursday 11/17/2022	*Continued* **Abstract Session 1: Trauma**
8:17am - 8:22am	PAPER #9 Utility of Novel Acute Spinal Cord MRI Protocol at Level-1 Trauma Center *Sohaib Hashmi, MD*
8:22am - 8:27am	PAPER #10 Anticoagulation Therapy in Cervical Spine Fractures: Insights From a Large Healthcare Database Analysis *Neil Patel, BS*
8:27am - 8:40am	Discussion

	10:05am - 11:25am Harbor Ballroom G-I **Abstract Session 2: Outcomes I**
	Moderator(s): John G. Heller, MD; Elizabeth M. Yu, MD
10:05am - 10:10am	Introduction *John G. Heller, MD; Elizabeth M. Yu, MD*
10:10am - 10:15am	PAPER #11 Which Radiographic Parameter Can Aid in Deciding Optimal Allograft Height Used for Anterior Cervical Discectomy and Fusion? *Sehan Park, MD*
10:15am - 10:20am	PAPER #12 Nerve Transfers in Spinal Cord Injury: Analysis of Factors Influencing Motor Recovery *Saad Javeed, MD*
10:20am - 10:25am	PAPER #13 Expectations of Clinical Improvement Following Corrective Surgery for Adult Cervical Deformity Based on Functional Disability at Presentation *Peter G. Passias, MD*
10:25am - 10:30am	PAPER #14 Sleep Impairment in CSM: Prevalence and Postoperative Outcomes – An Analysis from the QOD *Praveen V. Mummaneni, MD*
10:30am - 10:39am	Discussion
10:39am - 10:44am	PAPER #15 Metabolic Bone Disorders are Predictors for Two-Year Adverse Outcomes in Patients Undergoing 2-3-Level Anterior Cervical Discectomy and Fusion for Cervical Radiculopathy or Myelopathy *Niel V. Shah, MD*

Thursday 11/17/2022	*Continued* **Abstract Session 2: Outcomes I**
10:44am - 10:49am	PAPER #16 Unemployment and Education Level Are Important Drivers of 90-day Readmission Rates after PCDF. *Samuel Reyes, BS*
10:49am - 10:54am	PAPER #17 Identifying Clinical Predictors of Increased Postoperative Health Utilization After ACDF Using a Machine Learning Approach *Rushmin Khazanchi, BA*
10:54am - 10:59am	PAPER #18 Does Posterior Longitudinal Ligament Resection During Cervical Artificial Disc Replacement Affect Clinical or Radiographic Outcome? *Hyun Wook Gwak, MD*
10:59am - 11:04am	PAPER #19 Two-Level Anterior Cervical Diskectomy and Fusion Versus Anterior Cervical Corpectomy: Does One Treatment Strategy Demonstrate Superiority? *Stephen R. Barchick, MD*
11:04am - 11:09am	PAPER #20 Clinical Significance of C2 Slope After Multilevel Cervical Spine Fusion Surgery *Namhoo Kim, MD*
11:09am - 11:14am	PAPER #84 Long-Term Survivorship of Cervical Spine Procedures; a Survivorship Meta-Analysis and Meta-Regression *Markian Pahuta, MD*
11:14am - 11:25am	Discussion

	12:45pm - 1:45pm Harbor Ballroom G-I **Abstract Session 3: Complications - Avoidance and Management**
	Moderator(s): Barrett I. Woods, MD; James S. Harrop, MD, MSHQS
12:45pm -12:46pm	Introduction *Barrett I. Woods, MD; James S. Harrop, MD, MSHQS*
12:46pm - 12:51pm	PAPER #21 Accuracy of Cervical Pedicle Screw Insertion Using the Freehand Technique: The Deviation Rate for C7 is Unexpectedly High *Masataka M. Miura, MD*
12:51pm - 12:56pm	PAPER #22 Are All Cervical Cages Created Equal? A Comprehensive Analysis of a Decade of Adverse Event Reports in the US *Victor Ungurean, Jr., HSDG*

Thursday 11/17/2022	*Continued* **Abstract Session 3: Complications - Avoidance and Management**
12:56pm - 1:01pm	PAPER #23 Spinal Cord Shift May Not Be a Cause of C5 Palsy After Cervical Laminoplasty: Protective Effect of Medial Gutter *Woon Tak Yuh, MD*
1:01pm - 1:06pm	PAPER #24 Epidural Steroid Injection and Infection Risk Following Posterior Cervical Surgery *Tara Shelby, BS*
1:06pm - 1:11pm	PAPER #25 Optimal Timing of Referral for Nerve Transfer Surgery for Postoperative C5 Palsy *Yamaan S. Saadeh, MD*
1:11pm - 1:15pm	Discussion
1:15pm - 1:20pm	PAPER #26 Risk Factors, Incidence and Mortality of Patients of Vertebral Artery Injury in Patients Undergoing Anterior Cervical Corpectomy: A Retrospective Large National Data Base Study *Jamila Godil, BS*
1:20pm - 1:25pm	PAPER #27 Surgical Complications and Insufficient Canal Widening of the Vertebral Body Sliding Osteotomy for the Treatment of Cervical Myelopathy *Sung Tan Cho, MD*
1:25pm - 1:30pm	PAPER #28 Low Preoperative Serum Calcium Levels Predict Perioperative Medical Complications and Healthcare Utilization in Patients Undergoing ACDF *Anitesh Bajaj, BS*
1:30pm - 1:35pm	PAPER #29 Is Complete Correction of Cervical Sagittal Malalignment Necessary During 4-Level Anterior Cervical Discectomy and Fusion Surgery in Patients With Kyphosis? *Qingxin Song, MD*
1:35pm - 1:40pm	PAPER #30 Identifying the Impact of Body Mass Index on Surgical and Patient Outcomes for Cervical Spine Surgery *Anant Naik, BS*
1:40pm - 1:45pm	Discussion

Thursday 11/17/2022	**3:25pm - 4:45pm** Harbor Ballroom G-I **Abstract Session 4: Diagnostics - Imaging**
	Moderator(s): Sanford E. Emery, MD, MBA
3:25pm - 3:30pm	Introduction *Sanford E. Emery, MD, MBA*
3:30pm - 3:35pm	PAPER #31 Adverse Clinical Outcomes After Anterior Cervical Discectomy and Fusion Correlate Better with Degree of Facet Distraction Measured Using Computed Tomography Than Using Radiography *JooYoung Lee, MD*
3:35pm - 3:40pm	PAPER #32 Analysis of the Implications of Cervical Spine Alignment on Lumbopelvic Alignment *Taryn Ludwig, MD, PhD*
3:40pm - 3:45pm	PAPER #33 Surgical Threshold Measurements for Cervical Spinal Stenosis: Post-Myelogram Computed Tomography Versus Magnetic Resonance Imaging *Charles H. Crawford, III, MD*
3:45pm - 3:50pm	PAPER #34 Evaluation of Axonal Injury With Filtered Diffusion Weighted Magnetic Resonance Imaging in Cervical Spondylotic Myelopathy *Saman Shabani, MD*
3:50pm - 3:55pm	PAPER #35 Hounsfield Unit Measurement Method and Related Factors That Most Appropriately Reflect Bone Mineral Density on Cervical Spine Computed Tomography *Ho Jin Lee, MD, PhD*
4:00pm - 4:07pm	Discussion
4:07pm - 4:12pm	PAPER #36 Analysis of Parameters That Can Predict the Cervical Sagittal Vertical Axis in Cervical Fusion Surgery *Ho Jin Lee, MD, PhD*
4:12pm - 4:17pm	PAPER #37 Real-Time Operative Radiation Exposure Levels of Spine Surgeons *Hasan Ahmad, BS*
4:17pm - 4:22pm	PAPER #38 Linking Patterns of Intraoperative Neuromonitoring (IONM) Alerts to the Odds of a New Postoperative Neurological Deficit: Analysis of 27,808 Cervical Spine Procedures From a National Multi-institutional Database *William B. Wilent, PhD*

Thursday 11/17/2022	*Continued* **Abstract Session 4: Diagnostics - Imaging**
4:22pm - 4:27pm	PAPER #39 Diffusion Basis Spectrum Imaging Predicts Comprehensive Clinical Outcomes Following Surgery For Cervical Spondylotic Myelopathy *Justin K. Zhang, BS*
4:27pm - 4:32pm	PAPER #40 Diffusion Basis Spectrum Imaging Correlates with Baseline Severity and Long-Term Clinical Outcomes in Cervical Spondylotic Myelopathy *Justin K. Zhang, BS*
4:42pm - 4:45pm	Discussion

Friday 11/18/2022	**7:20am - 8:40am** Harbor Ballroom G-I **Abstract Session 5: Deformity**
	Moderator(s): Christopher P. Ames, MD; Han Jo Kim, MD
7:20am - 7:25am	Introduction *Christopher P. Ames, MD; Han Jo Kim, MD*
7:25am - 7:30am	PAPER #41 Which Patients Benefit From a Combined Anterior-Posterior Approach in Cervical Deformity Surgery? *Shaleen Vira, MD*
7:30am - 7:35am	PAPER #42 Comparative Analysis of the Occurrence and Clinical Impact of Dramatic Global Kyphosis in the Unfused Thoracic Spine Relative to Distal Junctional Failure Following Adult Cervical Deformity Surgery *Virginie Lafage, PhD*
7:35am - 7:40am	PAPER #43 Best Realignment Strategies in the Radiographic Parameter Toolbox: Hierarchical Approach to Surgical Planning in Adult Cervical Deformity Surgery *Virginie Lafage, PhD*
7:40am - 7:45am	PAPER #44 Predictive Survival Analysis of Adult Cervical Deformity Patients with Ten-Year Follow-Up *Peter Tretiakov, BS*
7:45am - 7:50am	PAPER #45 The Additional Burden of the Existence of Baseline Cervical Deformity When Undergoing Thoracolumbar Adult Spinal Deformity Corrective Surgery *Heiko Koller, MD*
7:50am - 8:02am	Discussion

Friday 11/18/2022	*Continued* **Abstract Session 5: Deformity**
8:02am - 8:07am	PAPER #46 Achievement and Maintenance of Optimal Alignment and Functional Improvement Following Cervical Deformity Surgery: A 2-Year Outcome Analysis *Renaud Lafage, MS*
8:07am - 8:12am	PAPER #47 Surgical Management of Adult Cervical Deformity: Are We Getting Better at Optimal Realignment? *Peter G. Passias, MD*
8:12am - 8:17am	PAPER #48 Semispinalis Cervicis Sarcopenia is Associated With Worsening Cervical Sagittal Balance and Junctional Alignment Following Posterior Cervical Fusion for Myelopathy *Zachariah W. Pinter, MD*
8:17am - 8:22am	PAPER #49 Surgical Treatment of Dropped Head Syndrome: Range of Fixations and Postoperative Complications *Tetsutyu Mitsuyama, MD, PhD*
8:22am - 8:27am	PAPER #50 Do Flare-Ups in Systemic Disease Activity Correlate to Cervical Deformity in Patients With Rheumatoid Arthritis? *Anna Baukje Veldman, BSc*
8:27am - 8:40am	Discussion

	10:45am - 12:15pm Harbor Ballroom G-I **Abstract Session 6: Top 10 Papers**
	Moderator(s): Zoher Ghogawala, MD, FACS; Neill M. Wright, MD
10:45am - 10:49am	Introduction *Zoher Ghogawala, MD, FACS; Neill M. Wright, MD*
10:49am - 10:54am	**FIRST PLACE RESIDENT/FELLOW RESEARCH AWARD** PAPER #51 Do Patients With Preoperative Marijuana Use Have Similar Outcomes Following Anterior Cervical Discectomy and Fusions? *Mark J. Lambrechts, MD*
10:54am - 10:59am	**FIRST PLACE CLINICAL RESEARCH AWARD** PAPER #52 Long-term Outcomes of Vertebral Body Sliding Osteotomy for the Treatment of Cervical Myelopathy: A Minimum of 5-year Follow-Up *Dong-Ho Lee, MD, PhD*

Friday 11/18/2022	*Continued* **Abstract Session 6: Top 10 Papers**
10:59am - 11:04am	**FIRST PLACE BASIC SCIENCE AWARD** PAPER #53 Serum GFAP and NF-L are Biomarkers of Injury Severity and Predictors of Recovery After Acute Cervical Spinal Cord Injury *Brian K. Kwon, MD, PhD, FRCSC*
11:04am - 11:09am	**THIRD PLACE RESIDENT/FELLOW RESEARCH AWARD** PAPER #54 Motorized Robotic Cervical Traction: Proof of Concept *Brandon A. Sherrod, MD*
11:09am - 11:14am	**SECOND PLACE RESIDENT/FELLOW RESEARCH AWARD** PAPER #55 Comparing Those Most Satisfied Versus Least Satisfied Following Surgery for Cervical Spondylotic Myelopathy: Are there Differences in Baseline Characteristics? *Andrew Chan, MD*
11:14am - 11:32am	Discussion
11:32am - 11:37am	**SECOND PLACE BASIC SCIENCE AWARD** PAPER #56 Spinal Cord Reconstitution of Chronic Complete Injury by Hepatocyte Growth Factor-Releasing Scaffold and Human Stem Cell Enhances Functional Recovery *Shogo Hashimoto, MD*
11:37am - 11:42am	**THIRD PLACE BASIC SCIENCE AWARD** PAPER #57 Circulating microRNAs May be Predictive of Degenerative Cervical Myelopathy *Srikanth Divi, MD*
11:42am - 11:47am	**SECOND PLACE CLINICAL RESEARCH AWARD** PAPER #58 A Multi-Center, Randomized, Placebo-Controlled, Double-Blinded Trial of Efficacy and Safety of Riluzole in Acute Spinal Cord Injury Study (RISCIS) *Michael G. Fehlings, MD, PhD*
11:47am - 11:52am	**THIRD PLACE CLINICAL RESEARCH AWARD** PAPER #59 Contemporary Practice Patterns in the Treatment of Cervical Stenosis and Central Cord Syndrome: A Survey of the Cervical Spine Research Society *Erick Kazarian, MD*

Friday 11/18/2022	*Continued* **Abstract Session 6: Top 10 Papers**
11:52am - 11:57am	PAPER #60 Current Practice Patterns of Surgical-Site Drain Usage in Cervical Spine Surgery: A Survey of the Cervical Spine Research Society *Sonal Sodha, MD*
11:57am - 12:15pm	Discussion

	3:30pm - 5:00pm Harbor Ballroom G-I **Abstract Session 7: Motion Preservation and Outcomes**
	Moderator(s): Andrew C. Hecht, MD; Rex A.W. Marco, MD
3:30pm - 3:35pm	Introduction *Andrew C. Hecht, MD; Rex A.W. Marco, MD*
3:35pm - 3:40pm	PAPER # 61 Revisions and Removals of Cervical Total Disc Replacement Devices in a Single Institution Consecutive Series of 1,473 Patients Beginning With the First Case Experience in 2003 *Jack E. Zigler, MD*
3:40pm - 3:45pm	PAPER # 62 Which Open Side is Better in Cervical Unilateral Open-Door Laminoplasty, Compressive Side or Symptomatic Side? *Kyung-Chung Kang, MD*
3:45pm - 3:50pm	PAPER # 63 Accuracy of Navigation Assisted Pedicle Screw Placement in Cervical Spine *Kentaro Yamane, MD*
3:50pm - 3:55pm	PAPER # 64 Complications, Readmissions, Reoperations and Patient-Reported Outcomes in Patients with Multiple Sclerosis Undergoing Elective Cervical Spine Surgery- a Propensity Matched Analysis *Amir M. Abtahi, MD*
4:00pm - 4:05pm	PAPER # 66 Is Severe Mechanical Neck Pain a Contraindication to Performing Laminoplasty in Patients with Cervical Spondylotic Myelopathy? *Zachariah W. Pinter, MD*
4:05pm - 4:20pm	Discussion
4:20pm - 4:25pm	PAPER # 67 Prosthesis Design and Likelihood of Achieving Physiological Range of Motion After Cervical Disc Arthroplasty: Analysis of Data From Seven IDE Clinical Trials *Avinash G. Patwardhan, PhD*

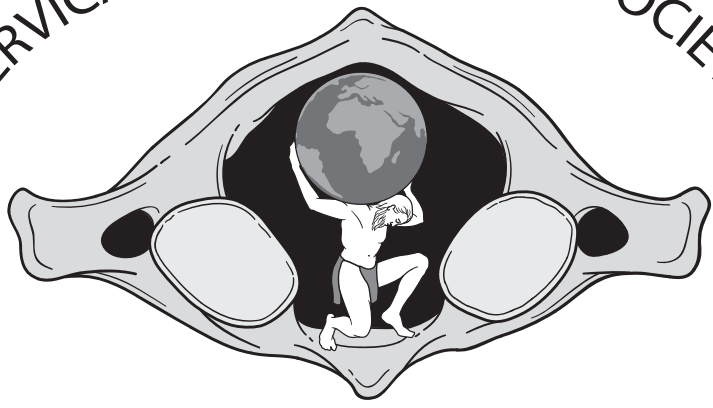
Friday 11/18/2022	*Continued* **Abstract Session 7: Motion Preservation and Outcomes**
4:25pm - 4:30pm	PAPER # 68 The Impact of Motion on Adjacent Level Degeneration After Cervical Disc Arthroplasty: Results of Post-hoc Analysis From a Prospective Study With 7-Year Follow-up *Alexander M. Satin, MD*
4:30pm - 4:35pm	PAPER # 69 Analysis of the Effects of Intraoperative Neurophysiological Monitoring on Anterior Cervical Surgery: A Michigan Spine Surgery Improvement Collaborative (MSSIC) Study *Philip Zakko, MD*
4:35pm - 4:40pm	PAPER # 70 3-Level vs. 4-Level Anterior Cervical Discectomy and Fusion: Differences in Complications and Perioperative Characteristics *Samuel K. Cho, MD*
4:40pm - 4:45pm	PAPER # 71 Change in Physical and Mental Well-Being Between the Short and Mid-term Periods After Cervical Surgery for Myelopathy: A Retrospective Cohort Study With Minimum 5 Year Follow-up *Koji Tamai, MD, PhD*
4:45pm - 5:00pm	Discussion

Saturday 11/19/2022	**9:35am - 10:55am** Harbor Ballroom G-I **Abstract Session 8: Science, Outcomes, & Effectiveness**
	Moderator(s): Andrew T. Dailey, MD, FAANS; Eeric Truumees, MD
9:35am - 9:37am	Introduction *Andrew T. Dailey, MD, FAANS; Eeric Truumees, MD*
9:37am - 9:42am	PAPER # 72 Risk Factors for Progression of Ossification of Posterior Longitudinal Ligament in Asymptomatic Subjects *Toru Doi, PhD*
9:42am - 9:47am	PAPER # 73 The Association of the Time-Dependent Response of Microglia Activation at the Injured Spinal Cord and Brain With Neuropathic Pain After Spinal Cord Injury *Arisa Kubota, MD*
9:47am - 9:52am	PAPER # 74 Prevalence and Prognosis of Gait Dysfunction in Patients Operated for Cervical Spondylotic Myelopathy *Andrew Chan, MD*

Saturday 11/19/2022	*Continued* **Abstract Session 8: Science, Outcomes, & Effectiveness**
9:52am - 9:57am	PAPER # 75 Earlier Tracheostomy Reduces Complications in Complete Cervical Spinal Cord Injury: Analysis of a Multi-Center Cohort of 2004 Patients *Christopher Witiw, MD, MSc, FRCSC*
9:57am - 10:02am	PAPER # 76 Similar Rates of Revision Surgery After Anterior Cervical Discectomy and Fusion Using Interbody Cage and Structural Allograft *Joshua Olexa, MD*
10:02am - 10:07am	PAPER # 77 Elective Primary Anterior Cervical Decompression and Fusion for Degenerative Spondylotic Cervical Myelopathy is Associated With Decreased Resource Utilization Versus Posterior Cervical Decompression and Fusion *Jerry Y. Du, MD*
10:07am - 10:16am	Discussion
10:16am - 10:21am	PAPER # 78 Vitamin K Supplementation Reduces Spinal Hyperostosis and Amerliorates Locomotor Impairment in a Mouse Model of Cervical Ossification of the Posterior Longitudinal Ligament *Atsushi Kimura, MD, PhD*
10:21am - 10:26am	PAPER # 79 Reducing Opioid Prescriptions for 707 Patients Following Cervical Spine Surgery Using a Novel, Patient-Centric, Individualized Calculation Tool *Vijay Letchuman, BA*
10:26am - 10:31am	PAPER # 80 Glutamate Activates a Proliferative and Astrogliogenic Program in Spinal Cord Ependymal Stem Cells: Implications for Regenerative Therapeutic Translation *Laureen D. Hachem, MD*
10:31am - 10:36am	PAPER # 81 Assessing Correlations Between NASS Patient Satisfaction Index and Patient-Reported Outcomes (PROs) at 3-month, 12-month, and 24-month Timepoints in Patients Undergoing Cervical Spine Surgery Using the QOD Registry *Mark M. Zaki, MD*
10:36am - 10:41am	PAPER # 82 Therapeutic Effects of Combined hiPSC-NS/PCs Transplantation and Rehabilitative Training in Chronic Spinal Cord Injury *Takahiro Shibata, MD*

Saturday 11/19/2022	*Continued* **Abstract Session 8: Science, Outcomes, & Effectiveness**
10:41am - 10:46am	PAPER # 83 The Effect of Posterior Cervical Laminoplasty With Dome Laminotomy on Cervical Alignment and Disability in Patients with Cervical Spondylotic Myelopathy Patients *Sung Hoon Choi, MD, PhD*
10:46am - 10:55am	Discussion

CERVICAL SPINE RESEARCH SOCIETY



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Truumees, Eeric (MD)	Investigator relationship with Medtronic; Investigator relationship with Stryker; Investigator relationship with SKK; Boar Member relationship with NASS; Royalty relationship with Stryker
Ungurean, Victor (HSDG)	No Relevant Financial Relationships
Veldman, Anna Baukje (BSc)	No Relevant Financial Relationships
Vickery, Justin (MD)	No Relevant Financial Relationships
Vira, Shaleen (MD)	No Relevant Financial Relationships
Wang, Jeffrey (MD)	royalties relationship with Zimmer-Biomet; royalties relationship with Seaspine; Stock Shareholder relationship with surgitech; royalties relationship with Depuy Synthes; investment relationship with electrocore; investment relationship with bone biologics; options relationship with Pearldiver; Consultant relationship with Precision OS
Wei, Feng (MD)	No disclosures as of October 25, 2022
Wilent, William (PhD)	VP of Quality relationship with Specialtycare; Board Member relationship with American Board of Neurophysiologic Monitoring; President-Elect relationship with American Society of Neurophysiological Monitoring
Wilson, Jefferson (MD, PhD, FRCSC)	Consultant relationship with Stryker; Consultant relationship with Stryker Canada
Witiw, Christopher (MD, MS)	Research Grant Overall Principal Investigator relationship with Cerapedics
Wolinsky, Jean-Paul (MD)	Educational Course Faculty relationship with AO North America
Woods, Barrett (MD)	Education relationship with Stryker; Product Design relationship with Medtronic; Consultant relationship with Altus
Wright, Neill (MD)	Royalties relationship with Nuvasive; Scientific/Medical Advisory Board Member relationship with Ulrich medical USA; Speakers Bureau relationship with Zimmer Biomet; Scientific/ Medical Advisory Board Member relationship with Cerapedics; Consultant relationship with Orthofix; Consultant relationship with Alphatec

Name	Disclosure
Yamane, Kentaro (MD)	No Relevant Financial Relationships
Yoon, S. Tim (MD, PhD)	No disclosures as of October 25, 2022
Yu, Elizabeth (MD)	Research Grant Site Principal Investigator relationship with Empirical Spine
Yuh, Woon Tak (MD)	No Relevant Financial Relationships
Zaki, Mark (MD)	Consultant relationship with GC Therapeutics; Consultant relationship with Viz.Ai
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Zhang, Angie (MD)	No Relevant Financial Relationships
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Zigler, Jack (MD)	Consultant relationship with Aesculap; Consultant relationship with Centinel Spine; Consultant relationship with Orthofix; Consultant relationship with Simplify; Patent Holder relationship with Zimmer
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Podium and E-Poster Presentations

PAPER 1

The Impact of Frailty on Patient Reported Outcomes after Cervical Spine Surgery

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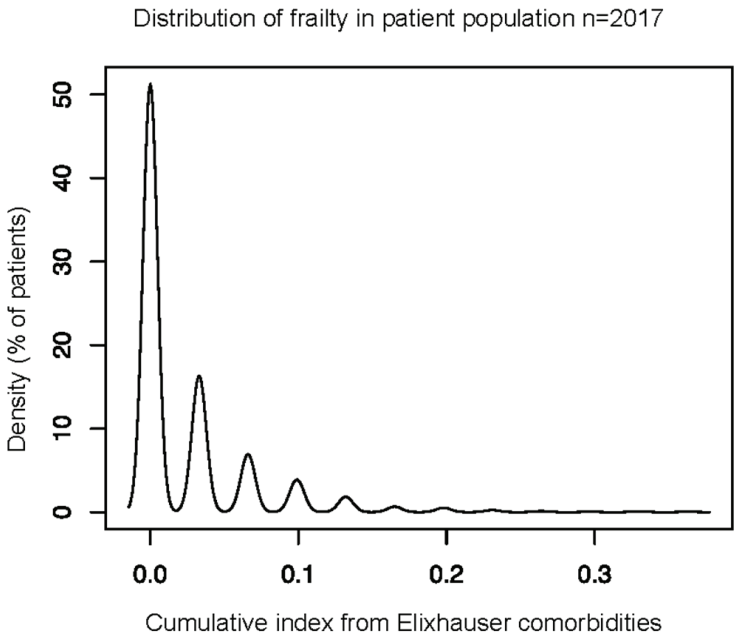
Introduction: Frailty is known to be associated with an increased risk of adverse events, morbidity, and mortality in patients undergoing cervical spine surgery.[1] However, little evidence exists for the effect of frailty on patient-reported outcomes (PROs) and quality-of-life following cervical spine surgery.[2] The aim of this study was to evaluate the association of preoperative frailty and clinical outcomes in patients undergoing cervical spine fusion surgery.

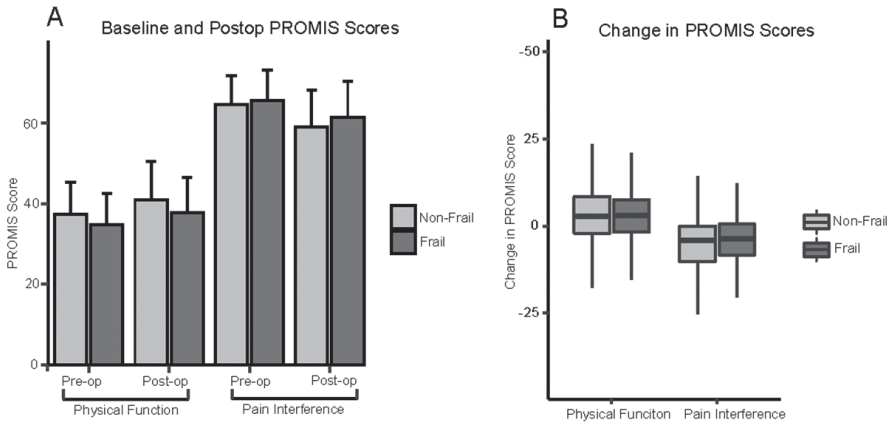
Materials and Methods: This retrospective study included adult patients 18 years of age who underwent cervical spine surgery from 2015 to 2018 at a single institution. Patient demographics, comorbidities, operative details, and PROMIS scores—physical function (PF) and pain interference (PI)—were extracted. A cumulative deficits approach was used to quantify frailty based on 30 items on the list of Elixhauser comorbidities as the secondary diagnoses in patient records.[3,4] The frailty ranged from 0.03 to 1 (Figure 1). Patients were classified as non-frail (<0.03) and frail (>= 0.03). Mean follow-up was 6 +/- 4 months. The effect of frailty on the baseline and postoperative PROMIS scores was assessed using multivariable linear regression models adjusted for known covariates. Missing data were handled using multiple imputations by chained equations (MICE) approach.

Results: In total, 2017 patients (mean age 57 +/- 13 years and 55% male) were included in the analysis. Frail patients reported worse PROMIS PF and PI scores as compared to non-frail patients at baseline (mean difference PF: -2.56, [95% CI] -1.25, -3.86, p<0.001 and PI: 1.01, [-2.25, 0.25], p=0.1) and postoperatively (mean difference PF: -3.1, [-1.57, -4.6], p<0.001 and PI: 2.37, [-3.87, -0.86], p=0.002) (Figure 2). Frail patients experienced less improvement in PROMIS PF and PI scores between baseline and follow-up measures as compared to non-frail patients, but the difference was not statistically significant (Figure 2). On multivariable regression, adjusting for known factors that influence outcomes (e.g., opioid use, baseline severity), frailty was significantly associated with baseline and postoperative PROMIS PF and PI scores, but was not significantly associated with the change in PROMIS PF and PI scores.

Conclusion: Although increased frailty was significantly associated with baseline and postoperative physical function and pain interference, frail patients experienced similar gains in functional status following cervical spine fusion surgery. Baseline frailty may help stratify patients requiring preoperative health optimization to maximize clinical outcomes.

PAPER 1 continued





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

PAPER 2

Surgeon Experience and Subspecialty do not Affect the Reliability of the AO Spine Upper Cervical Injury Classification

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Introduction: Widespread acceptance of fracture classifications requires multiple validation steps prior to adoption. The injury classification should be applicable to the majority of surgeons regardless of experience level and subspecialty. The AO Upper Cervical Spine Injury Classification was recently proposed and is based on injury level (I. occipital condyle and craniocervical junction, II. C1 and C1-C2 joint, and III. C2 and C2-3 joint) and type of injury (A-bony injury, B-tension band injury, C-fracture dislocation). Thus the purpose of this study was to determine surgeon specific variabilies (surgeon type and experience level) that may affect the intraobserver reproducibility, interobserver reliability, and % agreement with gold-standard (as determined by members of the AO Spine Knowledge Forum Trauma) for the AO Spine Upper Cervical Injury Classification.

Materials and Methods: An open call to members of AO Spine community was initiated to participate in a live, online AO Spine Upper Cervical Injury Classification assessment. A total of 25 consecutive upper cervical spine computed tomography (CT) videos, which included axial, sagittal and coronal videos, were played at a rate of 2 frames/second. A REDCap survey was used to capture all participants classification grades. The assessment was then repeated three weeks later with the cases re-randomized. Pearsons chi square test was used to compare the effect of surgeon experience and surgeon subspecialty on % agreement with the gold-standard. Significance was set at $p<0.05$. Fleiss' kappa (k) was used to identify the interobserver reliability and intraobserver reproducibility (k=0-0.20 was categorized as slight, 0.21-0.4 was fair, 0.41-0.60 was moderate, 0.61-0.8 was substantial and 0.81-1.0 was excellent).

Results: Physicians with <5 years experience had the greatest agreement with the gold standard on assessment 1 (82.2% versus 79.3%, 78.4%, and 78.5%, p=0.029) compared to those with 5-10, 11-20, and >20 years experience. However, there was no significant difference in % agreement on assessment 2 (p=0.53) (Table 1). The interobserver reliability was substantial on both assessment 1 (k=0.67, 0.62, 0.61, 0.62) and assessment 2 (k=0.62, 0.61, 0.61, 0.59) for physicians with <5, 5-10, 11-20, and >20 years experience, respectively. Further, the intraobserver reproducibility was substantial regardless of experience level (k=0.74, 0.69, 0.69, 0.70), respectively (Table 2). When evaluating physician specialty, 61.1% of participants were orthopaedic spine surgeons, 36.4% were neurosurgeons, and 2.5% were "orther" physicians. Neurosurgeons (79.2%) and orthopaedic spine surgeons (80.5%) had a greater % agreement with the gold-standard compared to "other" physicians (64.8%) on assessment 1 and assessment 2 (78.5. 79.7, 62.7%, respectively). The interobserver reliability was also greater for neurosurgeons (k=0.63) and ortho spine surgeons (k=0.64) compared to "other" physicians (k=0.43) on assessment 1 and assessment 2 (k=0.63, 0.62, 0.36, respectively). However, the

PAPER 2 continued

intraobserver reproducibility (k=0.69, 0.71, 0.68, respectively) was substantial regardless of physician specialty (Table 3).

Conclusion: Similar % agreement with the gold-standard, interobserver reliability and intraobserver reproducibility were found based on surgeon experience level when evaluating the AO Spine Upper Cervical Injury Classification. Spine surgeons, regardless of type (neurosurgeon vs. ortho spine) demonstrated similar interobserver reliability and intraobserver reproducibility.

Table 1. Absolute agreement and percent agreement of validation members compared to the gold standard committee based on years of surgical experience and surgical subspecialty

	Assessment 1									
	Years of surgical experience					Surgical Subspecialty				
	< 5 years N (%)	5-10 years N (%)	11-20 years N (%)	>20 years N (%)	P-value	Orthopaedic Spine Surgery N (%)	Neurosurgery N (%)	P-value	"Other" surgeon N (%)	P-Value
Global	1303 (82.8)	1406 (79.3)	1440 (78.4%)	787 (78.5)	**0.03***	3019 (80.5)	1825 (79.2)	0.26	92 (64.8)	**<0.001***
IA	105 (84)	125 (88.7)	119 (80.4)	66 (80.5)	0.23	258 (85.7)	151 (82.1)	0.35	6 (54.5)	**0.017***
IC	117 (91.4)	125 (88)	137 (92.6)	78 (97.5)	0.10	280 (93.3)	168 (90.3)	0.30	9 (75)	0.05
IIA	210 (82.7)	219 (77.4)	223 (76.6)	131 (82.4)	0.20	485 (81.2)	286 (77.9)	0.24	12 (52.2)	**<0.001***
IIB	182 (71.4)	202 (70.9)	201 (67.9)	103 (64)	0.36	425 (70.5)	250 (67.4)	0.34	13 (56.5)	0.25
IIC	86 (67.2)	89 (62.7)	93 (62.8)	47 (58.8)	0.66	194 (64.7)	116 (62.4)	0.68	5 (41.7)	0.26
IIIA	230 (90.9)	230 (80.7)	247 (83.7)	130 (81.8)	**0.01***	511 (85.2)	312 (84.6)	0.87	14 (60.9)	**0.007***
IIIB	134 (70.2)	161 (75.6)	144 (66.1)	75 (62.5)	0.05	309 (68.5)	192 (70.1)	0.72	13 (76.5)	0.73
IIIC	239 (95.2)	255 (90.1)	276 (94.5)	157 (97.5)	**0.01***	557 (92.8)	350 (95.6)	0.10	20 (95.2)	0.20
	Assessment 2									
	Years of surgical experience					Surgical Subspecialty				
	< 5 years N (%)	5-10 years N (%)	11-20 years N (%)	>20 years N (%)	P-value	Orthopaedic Spine Surgery N (%)	Neurosurgery N (%)	P-value	"Other" surgeon N (%)	P-Value
Global	1000 (79.9)	1214 (79.1)	1310 (78.5)	735 (77.4)	0.53	2620 (79.7)	1545 (78.5)	0.33	94 (62.7)	**<0.001***
IA	77 (75.5)	108 (87.8)	107 (79.9)	58 (76.3)	0.08	210 (79.2)	132 (83.5)	0.34	8 (66.7)	0.26
IC	93 (92.1)	106 (86.9)	119 (88.8)	70 (92.1)	0.53	241 (91.3)	139 (88.5)	0.45	8 (66.7)	**0.020***
IIA	163 (82.3)	200 (81.3)	219 (82.6)	126 (82.9)	0.97	439 (83.9)	253 (80.6)	0.25	16 (66.7)	0.06
IIB	136 (68)	171 (70.7)	181 (67)	95 (62.5)	0.41	365 (69.8)	206 (65)	0.17	12 (50)	0.06
IIC	64 (64.6)	78 (63.9	79 (58.5)	52 (68.4)	0.51	168 (63.9)	100 (63.7)	1.00	5 (41.7)	0.29
IIIA	171 (85.9)	202 (81.8)	228 (86.4)	120 (78.9)	0.15	441 (83.8)	267 (85.6)	0.57	13 (54.2)	**<0.001***
IIIB	119 (77.8)	134 (72.4)	147 (73.1)	75 (65.8)	0.19	304 (76.4)	158 (66.7)	**0.01***	13 (72.2)	**0.029***
IIIC	177 (88.5)	215 (87)	230 (86.8)	139 (91.4)	0.50	452 (86.1)	290 (92.1)	**0.01***	19 (79.2)	**0.014***

PAPER 2 continued

Table 2. Interobserver reliability of the AO Spine Upper Cervical Injury Classification System based on years of surgical experience and surgical subspecialty.

Assessment 1							
	Years of surgical experience				Surgical Subspecialty		
	< 5 years *k*	5-10 years *k*	11-20 years *K*	>20 years *k*	Orthopaedic Spine Surgery *k*	Neurosurgery *K*	"Other" surgeon *k*
Global	0.67	0.62	0.61	0.62	0.64	0.63	0.43
IA	0.76	0.80	0.70	0.73	0.77	0.73	0.31
IC	0.85	0.83	0.86	0.91	0.88	0.83	0.61
IIA	0.63	0.54	0.56	0.62	0.60	0.59	0.31
IIB	0.51	0.48	0.45	0.43	0.50	0.47	0.27
IIC	0.50	0.46	0.42	0.38	0.44	0.48	0.13
IIIA	0.76	0.67	0.66	0.66	0.69	0.69	0.40
IIIB	0.58	0.56	0.49	0.49	0.53	0.54	0.47
IIIC	0.84	0.77	0.80	0.77	0.78	0.82	0.83
Assessment 2							
	Years of surgical experience				Surgical Subspecialty		
	< 5 years *k*	5-10 years *k*	11-20 years *k*	>20 years *k*	Orthopaedic Spine Surgery *k*	Neurosurgery *k*	"Other" surgeon *k*
Global	0.62	0.61	0.61	0.59	0.62	0.63	0.36
IA	0.63	0.79	0.71	0.64	0.69	0.75	0.38
IC	0.86	0.82	0.82	0.86	0.86	0.85	0.43
IIA	0.59	0.58	0.61	0.59	0.61	0.61	0.31
IIB	0.47	0.47	0.43	0.40	0.47	0.43	0.23
IIC	0.49	0.49	0.40	0.49	0.46	0.48	0.27
IIIA	0.69	0.65	0.70	0.62	0.67	0.70	0.38
IIIB	0.59	0.51	0.54	0.48	0.56	0.53	0.48
IIIC	0.74	0.76	0.77	0.80	0.74	0.83	0.52

Table 3. Intraobserver reproducibility of the AO Spine Upper Cervical Injury Classification System based on years of surgical experience and surgical subspecialty.

Overall Classification							
	Years of Experience				Surgical Subspecialty		
	< 5 years k (std)	5-10 years k (std)	11-20 years k (std)	>20 years k (std)	Orthopaedic Spine Surgery k (std)	Neurosurgery k (std)	Other k (std)
Reproducibility	0.74 (0.17)	0.69 (0.22)	0.69 (0.19)	0.70 (0.16)	0.71 (0.22)	0.69 (0.15)	0.68 (0.13)
Injury Location							
	Years of Experience				Surgical Subspecialty		
	< 5 years k (std)	5-10 years k (std)	11-20 years k (std)	>20 years k (std)	Orthopaedic Spine Surgery k (std)	Neurosurgery k (std)	Other k (std)
Reproducibility	0.90 (0.12)	0.87 (0.24)	0.89 (0.22)	0.90 (0.13)	0.87 (0.22)	0.89 (0.14)	0.89 (0.08)
Injury Type							
	Years of Experience				Surgical Subspecialty		
	< 5 years k (std)	5-10 years k (std)	11-20 years k (std)	>20 years k (std)	Orthopaedic Spine Surgery k (std)	Neurosurgery k (std)	Other k (std)
Reproducibility	0.70 (0.20)	0.65 (0.25)	0.67 (0.22)	0.66 (0.18)	0.68 (0.24)	0.66 (0.18)	0.62 (0.14)

Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

PAPER 3

Prognostic factors for cervical spinal cord injury without major bone injury in patients aged 65 years or older: Japan Association of Spine Surgeons with Ambition (JASA) multicenter study

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University of Fukui[1] Kanazawa University[2]

Introduction: In the current aging society, there has been a marked increase in the incidence of cervical spinal cord injury (CSCI) without major bone injury. In the recent nationwide survey in Japan, CSCI without major bone injury accounts for 70.7% of CSCI cases and is often caused by minimal trauma due to events such as a fall on a level surface, which increases with age. Factors affecting the prognosis for motor recovery after SCI have been identified, but few studies have focused on CSCI without major bone injury. This multicenter study aimed to identify predictors of neurological improvement in patients aged 65 years or older with CSCI without major bone injury and examine therapeutic interventions for increased neurological improvement.

Materials and Methods: A multicenter study was performed by the Japan Association of Spine Surgeons with Ambition (JASA) as a retrospective analysis. The participants were 591 patients aged 65 years or older with CSCI without major bone injury from 33 medical centers between 2010 and 2020, with a minimum follow-up period of 3 months. Neurologic status was defined using the American Spinal Injury Association (ASIA) impairment scale (AIS). The patient background, imaging findings, comorbidity, treatment, and post-injury complications were obtained. Univariate and multivariate analyses were performed to identify prognostic factors for walking recovery (recovered to AIS D or E) in AIS A-C cases and full upper extremity motor recovery (AIS motor score = 50) in AIS D cases. A sub-analysis of AIS B-C cases was also performed based on the influence of data for AIS A cases on the results.

Results: Among AIS A-C cases at admission, 154 patients (55.0%) (11.8% in AIS A, 22.6% in AIS B, and 66.5% in AIS C) had walking recovery at follow-up. In AIS D cases at admission, 64 patients had a full upper extremity ASIA motor score (50). Of the remaining 247 AIS D cases, 107 (43.3%) patients recovered with full upper extremity motor function at follow-up. In AIS A-C cases, body mass index (odds ratio (OR): 1.112), magnetic resonance imaging signal change (OR: 0.240), AIS on admission (OR: 3.497), comorbidity of dementia/delirium (OR: 0.365), and post-injury pneumonia (OR: 0.194) were identified as independent prognostic factors for walking recovery. The prevalence of ossification of the posterior longitudinal ligament (OPLL) (OR: 0.494) was also found to be an independent prognostic factor in AIS B and C cases only. The rate of patients with OPLL was higher (34.3%) than the general prevalence. In AIS D cases, age (OR: 0.937), upper extremity ASIA motor score on admission (OR: 1.230 [per 5 scores]), and operation (OR: 0.519) were independent prognostic factors for full motor recovery.

Conclusion: The severity of paralysis on admission has a major impact on functional outcomes, but the promotion of rehabilitation through measures to reduce cognitive changes, post-injury pneumonia, and unhealthy body weight changes can also contribute to greater neurological improvement in AIS A-C cases. In AIS D cases, careful consideration of the need for surgical treatment is required for motor recovery.

PAPER 4

Unilateral cervical spine facet fractures: radiographic predictors of instability

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Introduction: Isolated subaxial cervical spine facet fractures make up less than 5% of symptomatic cervical spine injuries. There is much controversy regarding treatment of these injuries, and management is typically based on the neurological status of the patient and perceived stability of the injury. Since it has been shown that the degree of ligamentous instability can help predict instability and the need for surgery, MRIs are increasingly being used to evaluate these injuries. While there are many studies that evaluate radiographic characteristics of facet fractures on CT, there are few that specify which CT findings predict instability on MRI and vice versa. The purpose of our study is to identify CT characteristics of unilateral cervical spine facet fractures that are predictive of instability on MRI. We hypothesize that there are discrete parameters on CT and MRI that will predict fracture instability and the need for surgery.

Materials and Methods: Retrospective review of 48 patients with unilateral cervical facet fractures during a 7-year period from a level I trauma center. All patients had CT and MRI performed at the time of injury. Measurements of fracture fragments size (absolute height, absolute width, percent height, percent width, percent articular height), anterolisthesis, displacement, and extension were obtained from CT scans. MRIs were thoroughly examined by an independent radiologist and assigned an objective instability score based on injury to the seven ligaments at the fracture level. Demographic data and follow-up information were recorded. These CT measurements analyzed in previous studies were then compared to the MRI instability score help determine which parameters were predictive of the need for operative stailization. A linear regression model was implemented in our analysis.

Results: 48 patients were identified with unilateral cervical spine facet fractures, 7 of which had unilateral fractures in two consecutive levels. 22 fractures required operation, and 34 required no operation. Only one patient in our study failed nonoperative management. The average instability score in the operative group was 3.34, versus 1.06 in the conservative treatment group ($p<0.001$). Fracture displacement ($p=0.013$), multi-fragmentary fractures ($p<0.001$) and MRI instability score ($p<0.001$) were correlated with a statistically significant increased likelihood of operative necessity. When comparing CT characteristics to MRI, multi-fragmentary fractures and increased displacement had significant correlation with higher instability on MRI, whereas percent height of fracture fragment on CT had negative correlation with MRI.

Conclusion: To date, this is the largest study looking at isolated subaxial cervical spine fractures including CT and MRI imaging to help determine stability. Previous studies have shown that ligamentous injury on MRI can help predict the need for operative stabilization, and others have looked at the size of fractures, comminution, and displacement on CT scans to do so. In our study, fracture size did not correlate ligamentous injury, but rather displacement and multi-fragmentary fractures on CT scan were found to have highest correlation with instability scores on MRI. This suggests that patients presenting with subaxial cervical facet fractures benefit from analysis with both CT and MRI scans to help determine the need for operative stabilization.

PAPER 5

A machine learning model predicting ambulation in patients with spinal cord injury based on data from 3196 cases

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Introduction: Predicting the functional prognosis of patients with spinal cord injury (SCI) at the time of discharge from the rehabilitation hospital enables us to set rehabilitation goals and prepare an appropriate environment after discharge. However, the functional prognosis of SCI is multifactorial and difficult to predict. Machine learning is one of the methods of artificial intelligence, and it is possible to find rules from a large amount of data and create a model with high prediction accuracy. The purpose of this study is to create a model for predicting the acquisition of walking ability at the time of discharge from a rehabilitation hospital for patients with spinal cord injury using machine learning.

Materials and Methods: The machine learning model was built using 3196 patients after excluding patients with non-traumatic injuries and patients with missing data on FIM locomotion at admission and discharge, and patients with FIM locomotion of 6 or higher who were already able to walk independently at admission. The average age of the patients was 51.2 years, the average number of days from onset to admission was 77.9 days, and the ASIA impairment scale at admission was A34%, B11%, C27%, and D23%. The distribution of NLI was 72% for the cervical spine, 17% for the thoracic spine, and 8% for the lumbar spine. CatBoost showed the highest accuracy of 78.8% and AUC 0.87 in the prediction of gait ability acquisition at discharge (Table 1). Of the features, age, the number of days from onset to admission, and FIM locomotion at admission had high Shapley values and were of high importance in predicting results (Fig. 1).

Results: The machine learning model was built using 3196 patients after excluding patients with non-traumatic injuries and patients with missing data on FIM locomotion at admission and discharge, and patients with FIM locomotion of 6 or higher who were already able to walk independently at admission. The average age of the patients was 51.2 years, the average number of days from onset to admission was 77.9 days, and the ASIA impairment scale at admission was A34%, B11%, C27%, and D23%. The distribution of NLI was 72% for the cervical spine, 17% for the thoracic spine, and 8% for the lumbar spine. CatBoost showed the highest accuracy of 78.8% and AUC 0.87 in the prediction of gait ability acquisition at discharge. Of the features, age, the number of days from onset to admission, and FIM locomotion at admission had high Shapley values and were of high importance in predicting results.

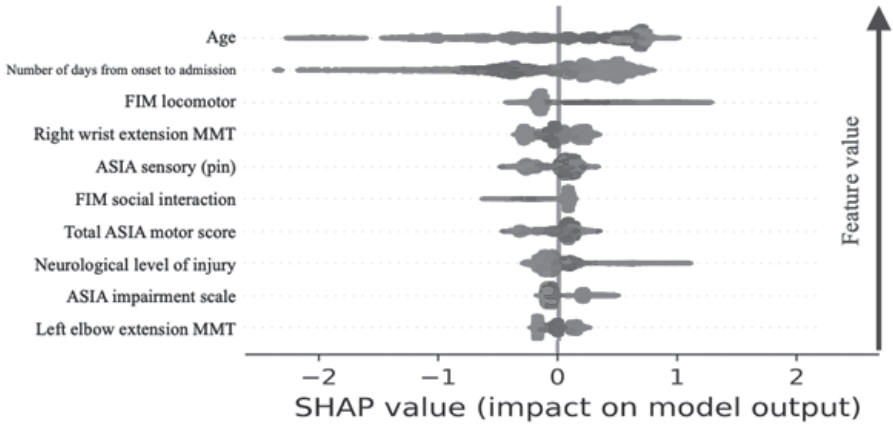
Conclusion: From the parameters at the time of admission, it was feasible to create a machine learning model that predicts ambulation at the time of discharge from a rehabilitation hospital with high accuracy for patients with SCI in the acute to subacute stage.

PAPER 5 continued

Accuracy and AUC for each model

Models	Accuracy (%)	AUC
CatBoost	**78.8**	**0.868**
XGBoost	77.7	0.858
LightGBM	77.9	0.858
Gradient Boosting	77.7	0.856
Ada Boost	76.8	0.842

Shapley values of CatBoost model



PAPER 6

Association between Geriatric Odontoid Fractures and in-hospital outcomes: Analysis from the American College of Surgeons Trauma Quality Improvement Program

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Introduction: Fractures of the odontoid process of C2 are increasingly prevalent in the aging population and associated with high morbidity and mortality. There exists uncertainty about the optimal management strategy. In this study we investigated the association between surgical management of odontoid fractures and in-hospital mortality and complications in a large multi-center cohort of older adults.

Materials and Methods: In the American College of Surgeons (ACS) Trauma Quality Improvement Program (TQIP) dataset, we identified patients 65 years or older with an Abbreviated Injury Scale (AIS) code corresponding to an odontoid fracture. We excluded patients with penetrating injuries, severe injuries in other body regions, neurological injury, or significant thoraco-lumbar fractures. Patients who had surgery for a C2 fracture were identified using International Classification of Diseases (ICD) procedure codes. Primary outcome was in-hospital mortality. Secondary outcomes were composite measures of in-hospital complications, routine discharge and hospital length of stay. We used generalized estimating equation models to compare outcomes between the patients who had and those who did not have surgery.

Results: Among the 15033 patients who met eligibility, 1100 (8.3%), were treated surgically. The risk of mortality in-hospital did not differ between the surgically and non-surgically treated groups, after accounting for patient and hospital characteristics (OR: 0.94, 95%CI: 0.55 – 1.60, $p<0.0001$). The risks of major complications and immobility-related complication were twice as high among the surgically treated compared to the non-surgically treated cohorts (adjusted OR: 2.12, 95%CI: 1.53 – 2.94; and OR: 2.24, 95%CI: 1.38 – 3.63, respectively). Patients who had surgery stayed for an extended period in-hospital than those treated nonoperatively (N=641, 84.1% versus N=3063, 35.9%; OR: 8.39, 95%CI:6.33 – 11.11). Patients from facilities treating most patients surgically (i.e. highest quartile for surgery) experienced no difference in risk of mortality in-hospital, primary complications and immobility related complications than their counterparts from facilities treating all patients nonoperatively. (adjusted OR for mortality, 1.07, 95% CI: 0.71 – 1.60). Patients from facilities treating most patients surgically had a 48% higher risk of extended stay in hospital than patients who were treated at facilities managing all patients conservatively (adjusted OR, 1.49, 95%CI: 1.20 – 1.86).

Conclusion: This study did not demonstrate a benefit of surgery to improve mortality in-hospital following fractures of the odontoid process of C2 vertebra among the elderly. The likelihood of higher complications during the hospital admission further reinforces the need for a nuanced approach to the surgical management of the elderly with this type of fractures.

PAPER 7

Intraoperative Sensory Signals Predict Prognosis for Patients with Traumatic Cervical Spinal Cord Injury

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Introduction: Traumatic cervical spinal cord injury (tCSCI) is a devasting life altering event. Prognosis is largely determined by the formal neurological assessment known as International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI), which is graded using the American Spinal Injury Association Impairment Scale grade (AIS grade). Many studies have shown that AIS grades are a predictor for neurologic recovery and functional status post-injury with AIS-A associated with the worst prognosis. However, the timing of the ISNCSCI exam and AIS grade can greatly influence the reliability of the prognosis.

Intraoperative neuromonitoring is routinely used during spine surgery to detect injuries to the spinal cord or nerve roots by measuring signal transmission. However, in patients with SCI, the role of intraoperative neuromonitoring as a potential prognostic tool has not been studied. The purpose of this study was to assess if detected signals during intraoperative neuromonitoring portends a greater likelihood of recovery for patients with tCSCI.

Materials and Methods: Patients who underwent decompression and surgical fixation following tCSCI were retrospectively reviewed at a high-volume, academic level I trauma center. Improvement in ASIA motor score and AIS grade conversion rates at final follow-up were compared between patients with detectable intraoperative neuromonitoring upper extremity somatosensory evoked potential (SSEP) signals and those without detectable signals.

Results: A total of 49 patients with tCSCI who underwent decompression and surgical fixation received intraoperative neuromonitoring with a mean age of 47 years and 82% male. Seventeen patients with AIS-A and 32 patients with AIS-B or C on admission were included in the study with a mean follow-up of 14.3 months. Patients with incomplete tCSCI had detectable lower extremity SSEPs more often compared to patients with complete tCSCI (56.3% vs. 23.5%, $p = 0.028$). However, there was no difference in detectable upper extremity SSEPs between complete and incomplete tCSCI (65.6% vs. 58.8%, $p=0.638$).

Of the 17 patients with complete tCSCI, patients with detectable upper extremity SSEPs cohort had greater ASIA motor scores on admission (25.9 vs. 5.4, $p=0.002$) and at final follow-up (54.0 vs. 8.9, $p=0.002$) with greater overall improvement (26.1 vs. 3.4, $p=0.021$) compared to the non-detectable cohort. Furthermore, the detectable upper extremity SSEPs cohort had a higher rate of AIS grade conversion compared to the non-detectable cohort (80.0% vs. 28.6%, $p = 0.034$). Meanwhile, complete tCSCI patients with detectable lower extremity SSEPs had similar ASIA motor scores on admission (21.5 vs. 16.2, $p=0.609$) but higher ASIA motor scores at final follow-up (57.5 vs. 27.1, $p=0.041$) compared to the non-detectable cohort.

Of the 32 patients with incomplete SCI, there was no difference in AIS grade conversion or ASIA motor scores between the detectable and non-detectable SSEP cohorts.

PAPER 7 continued

Conclusion: The presence of upper extremity SSEP signals in patients who present with complete tCSCI portended a better prognosis with greater improvement in ASIA motor scores and likelihood of AIS grade conversion at final follow-up. These results demonstrate an objective and measurable marker of prognosis that can be used for clinical decision making and patient counseling regarding neurologic recovery.

PAPER 8

To Operate or Not to Operate? Mortality in Unstable Cervical Spine Fractures in the Elderly Population

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Introduction: The decision to operate in the setting of unstable cervical spine fractures is one not taken lightly, and many factors are taken into account including age, comorbidities and severity of fracture. Whether the benefits of surgery outweigh the risks in the elderly population is a question few studies have investigated. Understanding the clinical outcomes in elderly patients who receive surgical versus conservative treatment can help inform future clinical practice. The objective of this study is to utilize a national administrative claims database to identify and compare patient demographics and clinical outcomes in patients over 65 with unstable cervical fractures who received surgery versus those who did not.

Materials and Methods: The Optum Claims Database was used to extract all patients 65 and older between 2016 and 2021 that were diagnosed with unstable cervical fractures using ICD-10 codes. Demographic and clinical outcomes variables were identified, and univariate analysis was performed using Student's t-test and chi square test.

Results: 3,018 elderly patients with unstable cervical spine fractures were identified and of these patients, 881 (29.2%) underwent spine surgery and 2,137 (70.8%) were treated conservatively. The average age of patients was greater in the nonoperative group compared to the operative group (82.1 versus 77.2) and the mean CCI was also higher in the nonoperative group (7.9 versus 7.0). Patients who received surgery had a longer average length of stay in the hospital (9.4 versus 6.5 days) and were more likely to be readmitted within 30 days (20.3% versus 16.7%). However, patients in the operative group had lower mortality rates after 30 (5.7% versus 18.4%), 60 (8.6% versus 22.0%), and 90 (10.2% versus 24.8%) days of admission compared to the nonoperative group, after propensity scoring. This was true across all age stratifications.

Conclusion: While elderly patients with an unstable cervical spine fracture who undergo surgery have longer length of hospital stay and a higher chance of being readmitted to the hospital compared to those patients who underwent conservative treatment, they also experience lower mortality rates after 30, 60, and 90 days. This suggests that the benefits of operating on the elderly with unstable spine fractures may outweigh the risks and should be considered as a treatment option.

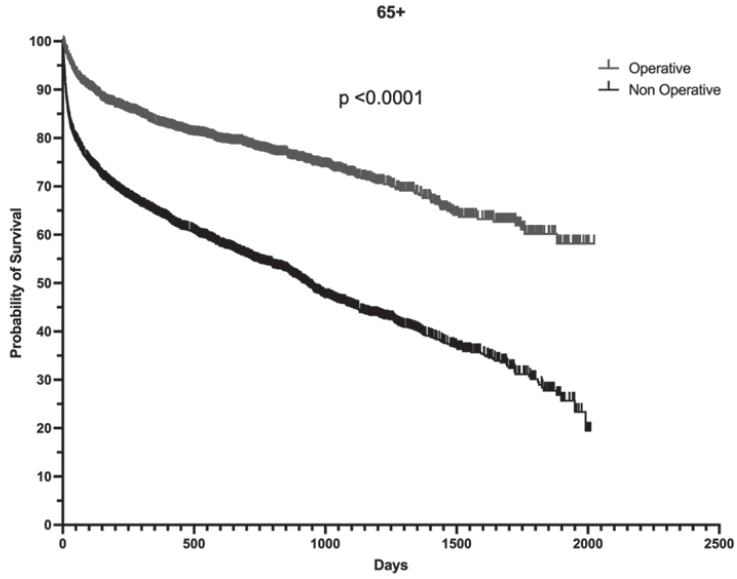
PAPER 8 continued

ICD-10 UNSTABLE FRACTURES CERVICAL	Operative N (%)	Nonoperative N (%)	P-values
NO. OF PATIENTS OVER 65	881 (29.2)	2137 (70.8)	
Age (Mean ± SD)	77.1 ± 7.0	82.1 ± 7.1	<0.001
Sex			
Female	444 (50.4)	1291 (60.4)	<0.0001
Male	437 (49.6)	846 (39.6)	
Charlson Comorbidity Index (Mean ± SD)	7.0 ± 3.2	7.9 ± 3.1	<0.001
Breakdown by Age			
65-69	157 (17.8)	161 (7.5)	<0.0001
70-79	370 (42.0)	521 (24.4)	<0.0001
80-89	336 (38.1)	1210 (56.6)	<0.0001
90+	18 (2.0)	245 (11.5)	<0.0001
Charlson Comorbidity Index (Mean ± SD)			
65-69	5.2 ± 2.9	4.8 ± 2.3	0.0143
70-79	6.7 ± 3.0	7.2 ± 3.0	>0.9999
80-89	8.1 ± 2.9	8.6 ± 2.0	>0.9999
90+	9.0 ± 3.1	8.6 ± 2.8	0.6963
Osteopenia			
65+	86 (9.8)	220 (10.3)	0.9545
65-69	14 (8.9)	8 (5.0)	0.1608
70-79	37 (10)	56 (10.7)	0.8482
80-89	34 (10.1)	133 (11.0)	>0.9999
90+	1 (5.6)	23 (9.4)	
Osteoporosis			
65+	283 (32.1)	823 (38.5)	0.0010
65-69	34 (21.7)	36 (22.4)	0.9090
70-79	113 (30.5)	167 (32.0)	0.7608
80-89	128 (38.1)	518 (42.8)	0.0959
90+	8 (44.4)	102 (41.6)	>0.9999
Length of Stay in Hospital (Mean ± SD)			
65+	9.4 ± 9.4	6.5 ± 7.8	<0.0001
65-69	8.7 ± 10.6	7.3 ± 8.8	<0.0001
70-79	9.1 ± 8.5	7.3 ± 9.1	<0.0001
80-89	9.8 ± 9.8	6.2 ± 7.5	<0.0001
90+	11.7 ± 7.1	5.4 ± 5.4	0.0012

PAPER 8 continued

ICD-10 UNSTABLE FRACTURES CERVICAL	Operative N (%)	Nonoperative N (%)	P-values
NO. OF PATIENTS OVER 65	881 (29.2)	2137 (70.8)	
Mortality (30 Days)			
65+	50 (5.7)	394 (18.4)	<0.0001
65-69	4 (2.5)	9 (5.6)	0.0500
70-79	14 (3.8)	71 (13.6)	<0.0001
80-89	27 (8.0)	176 (14.5)	<0.0001
90+	5 (27.8)	138 (56.3)	0.0156
Mortality (60 Days)			
65+	76 (8.6)	471 (22.0)	<0.0001
65-69	5 (3.2)	11 (6.8)	0.0154
70-79	20 (5.4)	86 (16.5)	<0.0001
80-89	43 (12.8)	217 (17.9)	0.0017
90+	8 (44.4)	157 (64.1)	0.0828
Mortality (90 Days)			
65+	90 (10.2)	531 (24.8)	<0.0001
65-69	7 (4.5)	12 (7.5)	0.1188
70-79	27 (7.3)	91 (17.5)	<0.0001
80-89	46 (13.7)	254 (21.0)	0.0001
90+	10 (55.6)	174 (71.0)	0.1203
Mortality (180 Days)			
65+	114 (12.9)	638 (29.9)	<0.0001
65-69	9 (5.7)	14 (8.7)	0.2911
70-79	36 (9.7)	110 (21.1)	<0.0001
80-89	57 (17.0)	315 (26.0)	<0.0001
90+	12 (66.7)	199 (81.2)	0.2330
Mortality (360 Days)			
65+	152 (17.2)	763 (35.7)	<0.0001
65-69	16 (10.2)	22 (13.7)	0.1750
70-79	57 (15.4)	126 (24.2)	0.0144
80-89	66 (19.6)	405 (33.5)	<0.0001
90+	13 (72.2)	210 (85.7)	0.1948
Mortality (720 Days)			
65+	184 (20.9)	908 (42.5)	<0.0001
65-69	22 (14.0)	30 (18.6)	0.1400
70-79	70 (18.9)	154 (29.6)	0.0004
80-89	79 (23.5)	511 (42.2)	<0.0001
90+	13 (72.2)	213 (86.9)	0.1639
Readmission (30 Days)			
65+	179 (20.3)	356 (16.7)	0.0054
65-69	24 (15.3)	21 (13.0)	0.2393
70-79	78 (21.1)	86 (16.5)	0.0473
80-89	73 (21.7)	223 (18.4)	0.1158
90+	4 (22.2)	26 (10.6)	0.2481

PAPER 8 continued



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

PAPER 9

Utility of Novel Acute Spinal Cord MRI Protocol at Level-1 Trauma Center

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Introduction: Treatment of acute spinal cord injury is based on accurate detection of neurologic and soft tissue injury. Initiating an early operative intervention for acute spinal cord injury is predicated on clinical evaluation and diagnostic imaging. The diagnostic modality with highest sensitivity to detect spinal cord/neurologic, soft tissue, ligamentous, disc, and occult injuries is magnetic resonance imaging. Standard MRI imaging protocols may have longer acquisition times and may be performed on a non-urgent basis in the setting of spinal cord injury potentially delaying treatment and chance of neurologic sensorimotor recovery. We aim to demonstrate in this study the utility and effectiveness of a dedicated acute spinal cord MRI protocol.

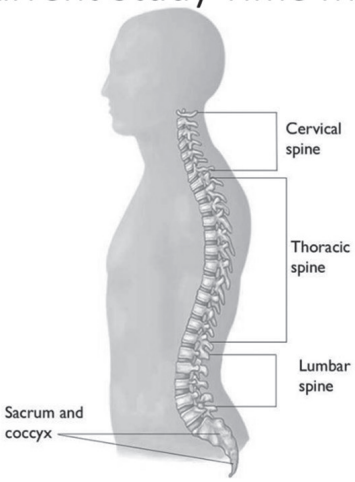
Materials and Methods: At our level-1 trauma center we implemented a dedicated, priority 24-hour available MRI protocol with sagittal T1, Stir, T2 and axial T1, T2, post axial T1 fat-suppression, fat-suppression series of the cervical, thoracic and lumbar spine. This MRI protocol was limited to use by orthopedic, spine surgery, neurosurgery spine and emergency department providers for evaluation of spinal cord injury patients. We compared this novel protocol with the standard cervical, thoracic and lumbar spine MRI protocols used for patients presenting with spinal cord injury. Statical analysis was performed with t-test to compare the standard and novel protocols.

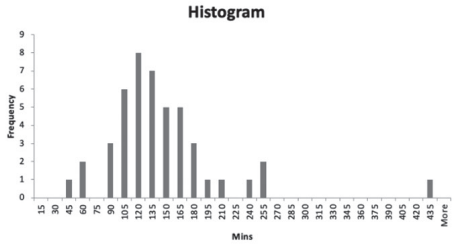
Results: The baseline standard MRI protocol dates reviewed ranged from 7/1/2021-10/27/2021 (354 total MRI scans). The novel acute spinal cord injury protocol ranged from 11/1/2021-4/19/2022 (28 total MRI scans). The median acquisition time for standard cervical, thoracic and lumbar spine MRI was 126.5 (Q1-Q3: 104 - 154) minutes. During the standard MRI review, 40% of MRI studies were found to be combination of cervical, thoracic and/or lumbar spine studies. The novel acute spinal cord injury MRI protocol timing was median 50.0 (Q1-Q3: 26.2 - 74.3) minutes (p=<0.05). MRI protocol Scan time from 68.6 mins (standard) to 24.9 mins (novel spinal cord injury) demonstrating 63.7% reduction in time, not accounting for positioning and time to check scan. During this period an average time savings per patient of 76.5 minutes was achieved. At our institution, this approximates to diagnostic MRI cost saving of $2,335.80 per patient.

Conclusion: The dedicated acute spinal cord MRI protocol demonstrated shorter acquisition time and less cost per patient compared to previous standard MRI protocols at our level-1 trauma center. This novel MRI approach is able to reduce time between diagnosis and surgical decision making for acute spinal cord injury patients.

PAPER 9 continued

Current Study Time Metrics

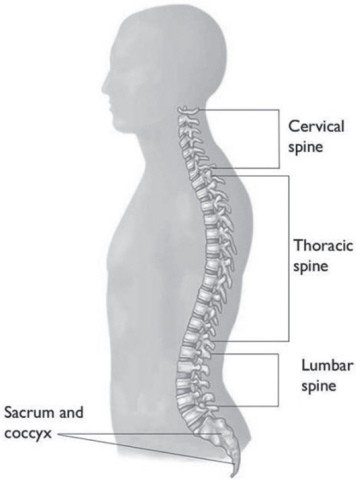




Median 126.5 (Q1-Q3: 104 – 154) minutes

40% (143/354) spine MRIs were combo spines.

Post Intervention



Median 126.5 (Q1-Q3: 104 – 154) minutes

Median 50.0 (Q1-Q3: 26.2 – 74.3) minutes

Since Nov, 2021 – used 28 times

Time savings
76.5 minutes per patient → $2,335.8 per patient
2,142 total minutes → $65,402.40 over 6 months

Considering at our institute $916 per 30 minute block

PAPER 10

Anticoagulation Therapy in Cervical Spine Fractures: Insights from a Large Healthcare Database Analysis

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Introduction: The type of chemical thromboembolic event (TEE) prophylaxis to administer following cervical spine fracture is a matter of contention. The risk of TEE must be weighed against the risk of bleeding complications from the therapy itself. Patients with cervical fractures may be at greater risk of devastating bleeding complications such as epidural hematoma, particularly after surgical decompression. The goal of this database study was to provide an accurate estimate to serve as a reference in the literature and specifically evaluate (1) comorbidity burden, (2) rate of thromboembolic events, (3) rate of anemia and transfusion events, and (4) evaluate utilization rates of various forms of pharmacologic prophylaxis following cervical spine fracture.

Materials and Methods: A retrospective review of the Humana insurance database from 2007 to 2016 was performed to identify patients who sustained a fracture of the cervical spine and prescribed anticoagulation therapy. Patients were subdivided by the type of agent prescribed: aspirin/anti platelet therapy, warfarin, heparin/low molecular weight heparin (LMWH), or factor Xa inhibitors. Each cohort was longitudinally tracked for 6 months following surgery for occurrence of deep venous thrombosis (DVT), pulmonary embolism (PE), stroke, anemia, or occurrence of blood transfusion. Chi-squared test was used to determine significance.

Results: 5,871 patients were included. Demographics of each cohort were statistically similar. Patients receiving warfarin had a greater CCI compared to the other cohorts (4.1; $p < 0.05$). Patients on aspirin/anti-platelet therapy were the least likely to develop any TEE (2.1%; $p < 0.05$). There was no statistically significant difference found between cohorts in regard to the incidence of stroke, transfusion rate, or anemia.

Conclusion: Aspirin and anti-platelet anticoagulation therapy after cervical fracture had the least number of thromboembolic events when used within 6 months compared to other common forms of anticoagulation, without any statistically significant difference in bleeding risk.

PAPER 11

Which Radiographic Parameter Can Aid in Deciding Optimal Allograft Height Used for Anterior Cervical Discectomy and Fusion?

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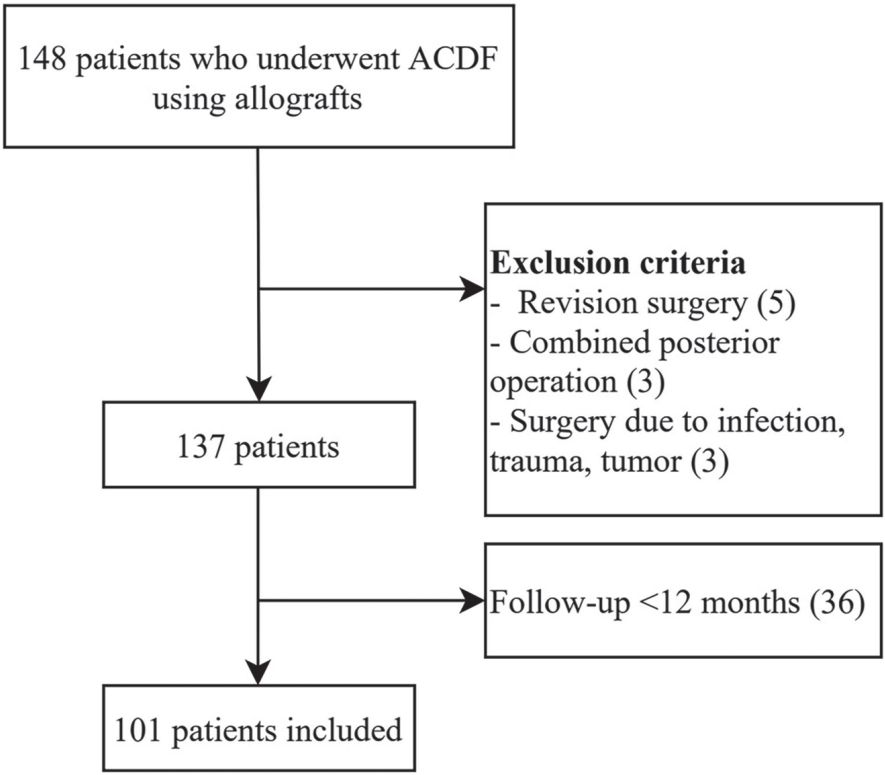
Introduction: Allograft height selection for anterior cervical discectomy and fusion (ACDF) depends on intraoperative assessment supported by trials; however, there is currently no radiographic reference parameter that could aid in allograft height selection for improved outcomes. If preoperative radiographic parameter is correlated to optimal allograft height that can result in high fusion rate and less subsidence, it would be an objective guide for allograft height selection. Furthermore, surgeons would also understand how much distraction should be made during the operation. Therefore, the present study was conducted to identify preoperative radiographic parameters that can guide optimal allograft height selection for ACDF.

Materials and Methods: A total of 148 patients who underwent ACDF using allografts and were followed-up for more than 1 year were retrospectively reviewed. Fusion rates, subsidence, segmental lordosis, and foraminal height were assessed. Segments were divided into two groups according to whether the inserted allograft height was within 1 mm from the following three reference radiographic parameters: (1) uncinate process height, (2) adjacent disc height, and (3) preoperative disc height +2 mm.

Results: This study included 101 patients with 163 segments. Segments with an allograft-uncinate height difference of ≤1 mm had a significantly higher fusion rate at 1-year follow-up compared to segments with allograft-uncinate height difference of >1 mm (85/107 [79.4%] vs. 35/56 [62.5%]; p=0.025). Subsidence, segmental lordosis, and foraminal height did not significantly differ between the groups when segments were divided according to uncinate height. In addition, using preoperative disc height +2 mm or adjacent segment height as a reference for allograft height selection was not significant in terms of fusion and subsidence. Multivariate logistic regression analysis demonstrated that allograft-uncinate height difference of ≤1 mm and allograft failure were factors associated with fusion.

Conclusion: The uncinate process height can guide optimal allograft height selection for ACDF. Using an allograft with an allograft-uncinate height difference of ≤1 mm resulted in a higher fusion rate. Distracting the disc height according to uncinate height would restore physiological mechanical loading of the segment, since uncinate height would represent normal undegenerated segmental height of the individual. However, adjacent segment height and preoperative disc height could not indicate physiologic state of the segment since these parameters would change with aging and degeneration process. Hence, no significant results were demonstrated when adjacent segment height or preoperative disc height were used as a reference value in the present study. Therefore, the uncinate process height should be checked preoperatively and used in conjunction with intraoperative assessment when selecting allograft height.

PAPER 11 continued



PAPER 11 continued

Table. Comparison between segments with allograft height ≤1 mm from uncinate height and segments with allograft height >1 mm from uncinate height

		>1 mm from uncinate height (n = 56)	≤1 mm from uncinate height (n = 107)	P value
Allograft height (mm)		6.3 ± 0.7	5.9 ± 0.7	0.002*
Number of operated levels of the construct which segment is included		1.8 ± 0.7	2.0 ± 0.7	0.237
Uncoforaminotomy	None	13 (23.2%)	20 (18.7%)	0.961
	Unilateral	14 (25.0%)	29 (27.1%)	
	Bilateral	29 (51.8%)	58 (54.2%)	
PLL resection	No	37 (66.1%)	83 (77.6%)	0.141
	yes	18 (32.1%)	24 (22.4%)	
Fusion	ISM	31 (55.4%)	80 (74.8%)	0.014*
	CT	35 (62.5%)	85 (79.4%)	0.025*
Subsidence	Amount (mm)	1.0 ± 1.2	1.0 ± 1.2	0.999
	>2 mm	13 (23.2%)	21 (19.6%)	0.542
Allograft failure		27 (48.2%)	37 (34.6%)	0.095
Segmental lordosis (°)	Preoperative	1.5 ± 4.8	0.8 ± 4.9	0.355
	Postop 2 days	5.4 ± 4.3	4.9 ± 4.6	0.459
	Postop 1 year	3.9 ± 4.1	3.0 ± 4.4	0.229
Foraminal height (mm)	Preoperative	9.2 ± 1.0	9.2 ± 1.0	0.790
	Postop 2 days	10.2 ± 1.0	10.0± 1.4	0.348
	Postop 1 year	9.4 ± 1.2	9.3 ± 1.4	0.666

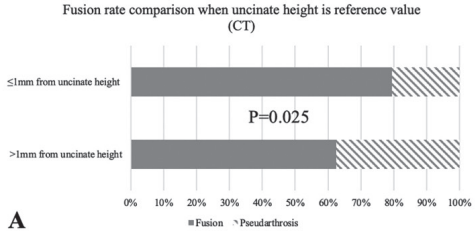
n, sample size; ISM, interspinous motion; CT, computed tomography; PLL, posterior longitudinal ligament

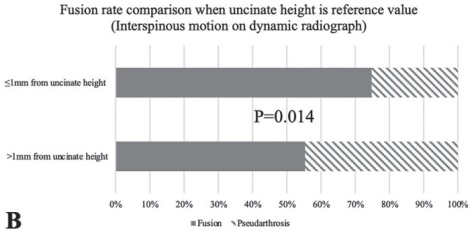
Categorical variables were analyzed using a chi-square test

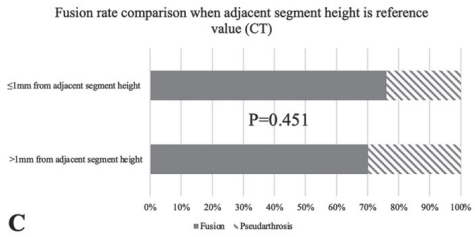
Continuous variables were analyzed using student's t-test

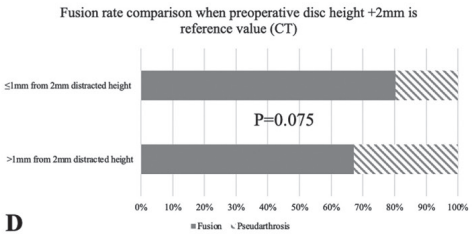
*P<0.05

PAPER 11 continued









Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

PAPER 12

Nerve Transfers in Spinal Cord Injury: Analysis of Factors Influencing Motor Recovery

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Introduction: Cervical spinal cord injury (SCI) can cause devastating loss of upper extremity function and independence.[1] Nerve transfers are a promising approach to reanimate upper limbs in patients with cervical SCI (i.e., tetraplegia). Despite the increasing adoption of this technique, clinical outcomes remain heterogeneous.[2] There is a significant void in the literature describing the factors that influence motor recovery following nerve transfers in tetraplegia.[3] The aim of this study was to evaluate the association of preoperative factors with motor outcomes following nerve transfers in cervical SCI.

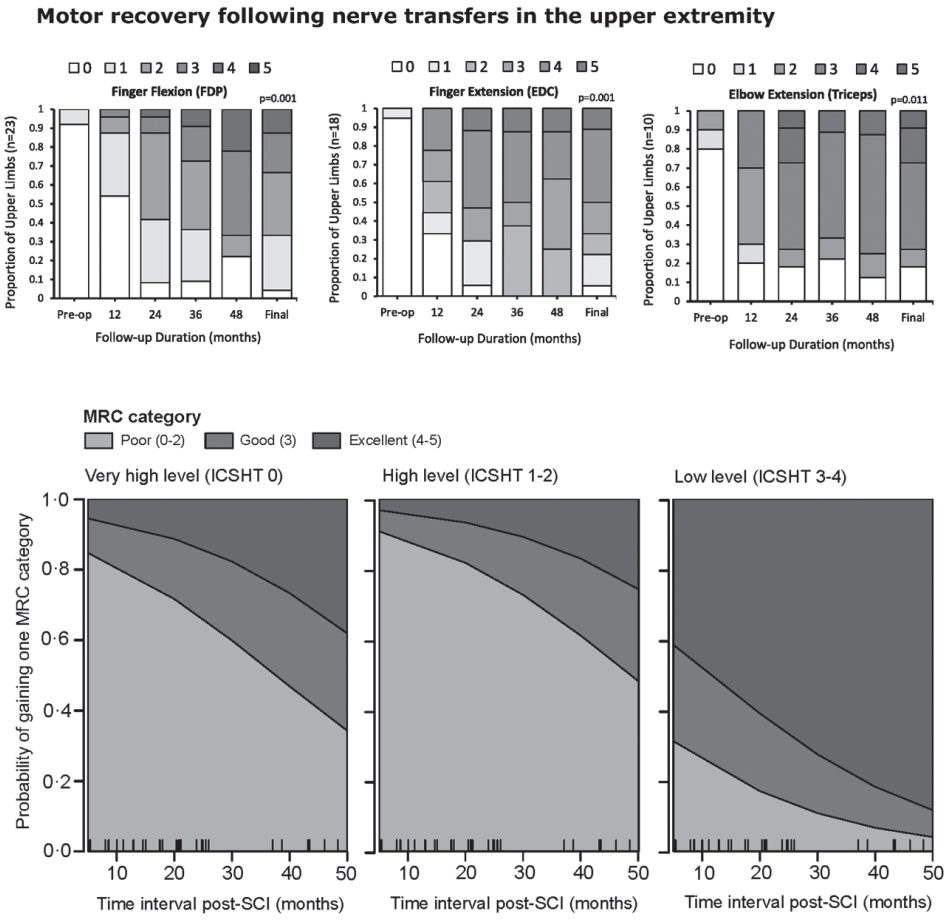
Materials and Methods: This was a post-hoc analysis of a prospective cohort study of cervical SCI patients who underwent nerve transfers and followed-up until 48-months. Patients were >=18 years of age with cervical SCI (American Spinal Injury Association [ASIA] grade A-C).[4] Preoperative variables known to impact nerve transfer outcomes included age, time-interval between SCI and nerve transfer, ASIA impairment grade, neurological level of injury, international classification of the surgery of the hand in tetraplegia (ICSHT)[5] which indicates preserved upper extremity motor function based on intact muscles, and recipient nerve electrodiagnosis. The primary outcome was motor recovery assessed in medical research council (MRC) grades. Univariate analyses assessed the relationship of preoperative variables with motor recovery. A multivariable proportional odds logistic regression was then used to identify independent significant predictors. Motor outcomes were categorized as an ordinal measure with three categories: poor recovery (MRC grades 0-2); good recovery (MRC grade 3); and excellent recovery (MRC grade 4-5). The ICSHT groups were categorized into very high-level injury (ICSHT 0; absent residual function); high-level injury (ICSHT 1-2; only intact biceps and brachioradialis); and low-level injury (ICSHT 3-4; intact wrist extension and pronation).

Results: 21 cervical SCI patients were included who underwent 57 nerve transfers on 33 upper limbs at a median time of 21 (range 6-142) months post-SCI. At final follow-up, all patients significantly improved upper limb motor strength: median gain in triceps MRC was 3 ([IQR] 2·5-4, p=0·011), finger extensors was 4 (2-4, p<0·001), and finger flexors was 2 (1-3, p<0·001) (Figure-1). On univariate analysis, variables that were significantly associated with motor recovery were age, time-interval between SCI and nerve transfer, and the ICSHT groups. On multivariable analysis, the low-level injury (ICSHT 3-4 groups) was significantly associated with superior motor outcomes as compared to higher-level injuries (Odds ratio [OR] 12.2, 95% CI, 2.34–91.4; p=0.005). Each month delay had a 5% increase in the odds of gaining superior motor function (OR 1.05, 95% CI, 1.01–1.11; p=0.03). The probabilities of gaining each category of motor function with time delay and level of injury is shown in Figure 2.

Conclusion: Our analysis demonstrates that the baseline preserved motor function in the upper extremities (i.e., ICSHT grouping) was significantly associated with motor outcomes following nerve transfers in tetraplegia. Nerve transfers in high-level tetraplegia results in modest motor recovery and should be the target of further innovations in reinnervation strategies. Nerve transfers in chronic SCI (12 months) are feasible and comparable motor

PAPER 12 continued

outcomes to earlier reinnervation can be achieved with careful selection of intact recipient nerves.



PAPER 13

Expectations of Clinical Improvement Following Corrective Surgery for Adult Cervical Deformity Based on Functional Disability at Presentation

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Introduction: Surgical intervention has been shown to be an effective treatment modality for Adult cervical deformity (CD), yet patient reported outcomes vary even when patients are optimally realigned. While patients with higher baseline disability have more room for improvement, we propose there may be a threshold beyond which greater disability limits HRQL improvement due to elevated risks and a point of no return. We sought to assess the impact of baseline disability on HRQL outcomes.

Materials and Methods: CD patients with baseline (BL) and 2-year (2Y) were included. The cohort was ranked into quartiles by baseline NDI, from lowest/best score (Q1) to highest/worst score (Q4). Means comparison tests analyzed differences between disability groups. ANCOVA and logistic regressions assessed differences in outcomes of interest while accounting for covariates including BL deformity, HRQLs, surgical details and complications.

Results: 116 patients met inclusion (Age: 60.97±10.45 yrs, BMI: 28.73±7.59kg/m2, CCI: 0.94±1.31). The cohort presented with mean cSVA of 38.54 ± 19.43mm, TS-CL: 37.34 ± 19.73, and mJOA: 13.62 ± 2.71 (Table 1). Surgically, patients had an average of 8.44 ± 3.41 levels fused, with 53.5% of patients undergoing decompression and 48.3% undergoing osteotomy. Mean BL NDI and NRS of the cohort were 48.33 ± 17.99 and 6.74 ± 2.48 respectively. Mean BL NDI by disability group was as follows: Q1: 25.04 ± 8.19, Q2: 41.61 ± 2.77, Q3: 53.31 ± 4.32, and Q4: 69.52 ± 8.35. Improvement in NRS Neck and NRS Back was significantly different between disability groups (both p=.007). Patients in Q2 demonstrated the greatest improvement in NRS Neck at 2Y (-3.93), which was greater than those in Q3 (-1.61, p=.032) and Q4 (-1.41, p=.015). Patients in Q2 demonstrated greater improvement in NRS Back at 2Y (-1.71), compared to those in Q4 (+0.84, p=.010). Rates of reaching MCID in NRS Neck were also significantly different across disability groups (p=.023). Patients in Q2 met MCID at the highest rates (69.9%) of all groups, higher than those in Q4 (30.3%), p=.039. Further, patients in Q2 demonstrated the greatest improvement in EQ5D at 2Y (+0.082), compared to Q1 (+0.073), Q3 (+0.022), and Q4 (+0.014), p=.034. Finally, patients in Q2 demonstrated the greatest improvement in mJOA score from baseline (+1.517), p=.042.

Conclusion: Patients in Q2, with mean baseline NDI of 42, consistently demonstrated the greatest improvement in HRQLs whereas those in Q4, with mean baseline NDI of 70, saw the least improvement. Thus, baseline NDI between 39 and 44 may represent a disability "Sweet Spot," within which operative intervention maximizes patient reported outcomes. Furthermore, delaying intervention until patients are severely disabled, beyond an NDI of 61, limits benefits of surgical correction in cervical deformity patients.

PAPER 14

Sleep Impairment in CSM: Prevalence and Postoperative Outcomes – An Analysis from the QOD

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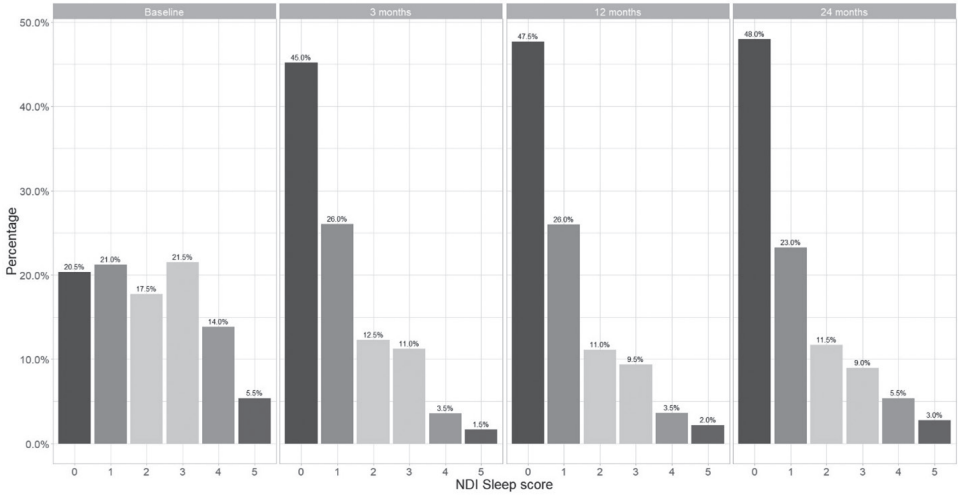
Introduction: Sleep impairment is a common clinical presentation in patients with cervical spondylotic myelopathy (CSM). Yet, there is a limited investigation on the prevalence and prognosis of sleep disturbances in patients with CSM. The aim of this study is to evaluate the prevalence and predictors of improved sleep quality at 24 months postoperatively in patients with CSM by utilizing the Quality Outcomes Database (QOD) registry.

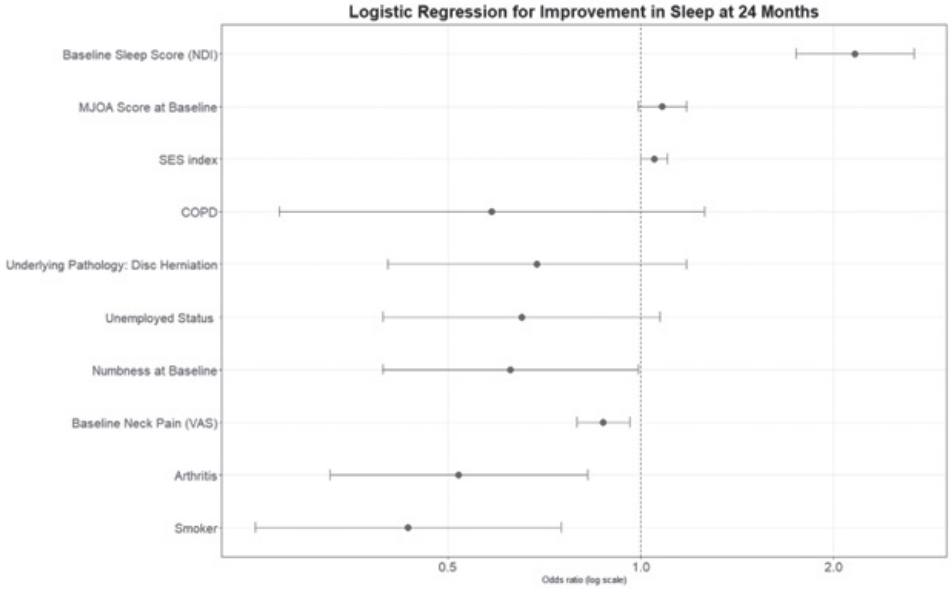
Materials and Methods: The QOD was utilized to identify patients with CSM who had data on sleep quality as assessed via the Neck Disability Index (NDI) at baseline and at 24 months post-operation. A multivariate logistic model was performed to evaluate predictors of improved sleep of patients with CSM. The sleep component of the NDI questionnaire is an ordinal 6-level scale in which 0 represents no trouble sleeping, and 5 represents a complete disturbance in sleep (loss of 5-7 hours) due to clinical symptoms.

Results: A total of 1135 patients with CSM who had baseline sleep scores were included in this analysis. At baseline, 231 (20.4%) patients had no impairment in sleep (NDI sleep score = 0), while 904 (79.6%) patients had some degree of sleep dysfunction. At 3 months postoperatively, among 956 patients with available follow-up, 430 patients (45%) had no impairment. Among 742 patients with baseline improvement and available 24-month follow-up, 540 (72.8%) reported improvement in sleep impairment. In the multivariable analysis, patients who did not improve by 24 months were more like to be smokers at baseline (OR = 0.4; 95% CI 0.3-0.8), have arthritis (OR = 0.5, 95% CI 0.3-0.8), report numbness at baseline (OR = 0.6; 95% CI 0.4-0.99), and report a higher neck pain score (OR = 0.3; 95% CI 0.3-0.4). A higher SES index (OR = 1.04; 95% CI 1.01-1.1) and a higher baseline sleep impairment (OR = 2.2; 95% CI 1.7-2.7) were found predictive of sleep improvement. Patients with improved sleep at 24 months noted higher satisfaction with surgery (88.0 vs. 72.9%, p = 0.01) and were more likely to achieve minimal clinically important differences (MCID) in quality-life adjusted years (QALY) (42.5% vs. 25.7%, p < 0.01). In a multivariable analysis adjusted for a multitude of patient-reported outcomes, improved sleep at 24 months was found to be a significant predictor of achieving QALY MCID at 24 months (OR = 1.05; 95% CI [1.01-1.1; p = 0.01) postoperatively.

Conclusion: A majority of patients presenting with CSM have associated sleep disturbances. The quality of sleep of patients with CSM can be significantly improved postoperatively and maintained at 24 months. Improvement in sleep is associated with a significant improvement in patients' quality of life.

PAPER 14 continued





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PAPER 15

Metabolic Bone Disorders are Predictors for Two-Year Adverse Outcomes in Patients Undergoing 2-3-Level Anterior Cervical Discectomy and Fusion for Cervical Radiculopathy or Myelopathy

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Introduction: Metabolic bone disorders (MBDs) and cervical degenerative pathologies, including cervical radiculopathy and myelopathy (CR, CM), are prevalent in the aging population. However, the impact of MBDs on complications following 2-3-level ACDF (Anterior Cervical Discectomy and Fusion) for CR/CM is not well known.

Materials and Methods: The New York Statewide Planning and Research Cooperative System (SPARCS) was used to identify all patients with cervical myelopathy or radiculopathy who underwent an ACDF of 2-3 vertebrae from 2009-2011 with a minimum 2-year follow up. From this population, patients diagnosed (via International Classification of Diseases [ICD]-9 code) with one or more MBD at baseline (vitamin D deficiency, hyperparathyroidism, osteomalacia, or rickets) were compared to a control cohort without any MHD diagnosis. Any patients with osteoporosis or other systemic (fibrous dysplasia, sickle cell disease, renal osteodystrophy) or endocrine disorders (thyroid hypo- or hyperfunctioning disorders, adrenal insufficiency, adrenal hyperplastic syndromes) affecting bone quality or production were excluded, as were patients with surgical indications of trauma, systemic disease, infection, or cancer/metastatic disease. Cohorts were compared for demographics, hospital-related parameters, and 2-year medical, surgical, and overall complications. Binary multivariate logistic regression was used to identify independent predictors of these 2-year outcomes.

Results: 22,276 patients were identified (MBD, n=214; no-MBD, n=22,062). MBD patients were older (53.0 vs 49.7 years, $p<0.001$), predominantly female (55.1 vs 47.0%, $p=0.03$), more often white (71.8% vs 67.3%, $p=0.038$), and with higher Deyo index (1.0 vs. 0.5, $p<0.001$). MBD patients also experienced longer postoperative hospital length of stay (6.1 vs. 3.2 days) and incurred higher total charges ($49,493 vs. $43,858) (all $p\leq0.048$). Among MBD patients, the predominant portion had vitamin D deficiency (n=194, 90.7%), followed by hyperparathyroidism (n=19, 9.9%). MBD patients had higher rates of individual medical complications, including anemia (6.1% vs. 2.3%), postoperative pneumonia (4.7% vs. 2.1%), hematoma (3.3% vs. 0.7%), infection (2.8% vs. 0.9%), and sepsis (3.7% vs. 0.9%), as well as overall medical complications (23.8% vs. 9.6%) (all, $p\leq0.033$). MBD patients also experienced higher individual surgical complication, including implant-related complications (6.2% vs. 2.0%), wound infection (4.2% vs. 1.2%), and wound disruption (0.9% vs. 0.2%), and overall surgical complications (9.8% vs. 3.2%) (all, $p\leq0.039$). MBD patients incurred higher overall 2-year complications (28.5% vs. 11.3%, $p<0.001$). Regression analysis revealed that a baseline diagnosis of MBD was independently associated with increased risk of 2-year surgical complications (OR=2.10, 95% CI: 1.50-2.94, $p<0.001$) and medical complications (OR=1.84, 95% CI: 1.28-2.65, $p=0.001$).

PAPER 15 continued

Conclusion: MBD as a comorbidity was associated with increased risk of 2-year postoperative complications following 2-3-level ACDF for CR or CM. This data can help guide preoperative risk stratification and optimization by improving screening for such disorders, especially vitamin D deficiency, to potentially curve the postoperative risks associated with MBDs.

PAPER 16

Unemployment and Education Level Are Important Drivers of 90-day Readmission Rates after PCDF.

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Introduction: Social Determinants of Health (SDH) are a critically important yet understudied discipline within spine surgery. SDH elements are factors that influence the health and overall well-being of an individual. Currently, there is no published literature assessing SDH on 90-day readmission following posterior cervical decompression and fusion (PCDF). Novel machine learning (ML) algorithms have the potential to elucidate previously unknown relationships between variables in large, clinical databases. The purpose of this study is to determine the relationships between SDH and 90-day readmission rates following PCDF.

Materials and Methods: Patients that underwent single or multi-level PCDF at a multi-center academic health system between 2002 –2020 were acquired from Northwestern Medicine Electronic Data Warehouse. More than 70 clinical variables including demographics, past medical and surgical history, postoperative complications, 30-day readmission, 90-day readmission, 90-day reoperation, and 1-year reoperation rates were included. Each patient was assessed for 27 different SDH characteristics using the Social Deprivation Index (SDI), which was retrieved from the American Community Survey conducted on county level by the US Census Bureau. The primary outcome for this study was rates of 90-day readmission. Several ML models were run, using custom R scripts and were validated by Area Under the Curve (AUC). The data was split into training/testing (80/20) sets. Validation was performed on withheld test data following optimization. The best performing model was determined by AUC; variable importance was calculated for the best model and ranked by impact on output prediction.

Results: A total of 1,066 patients and 64 variables were included in the final sample. The 30-day and 90-day readmission rates were 12.0% (n=128) and 16.5% (n=176), respectively. The 90-day and 1-year reoperation rate was 4.1% (n=44) and 5.2% (n=56), respectively. Of the 4 models ran, Support Vector Machine performed best with an AUC of 0.600 (Figure 1). An AUC figure for the best performing model is shown in Figure 2. Calculated variable Importance scores showed that even when including all clinical variables, unemployment score and education score were found to be the first and third most important factors in determining 90-day readmission. Of the top 10 important variables, the identification of being Hispanic, percentage of renters and the presence of Managed Care insurance were found to be highly predictive of 90-day readmission (Figure 3).

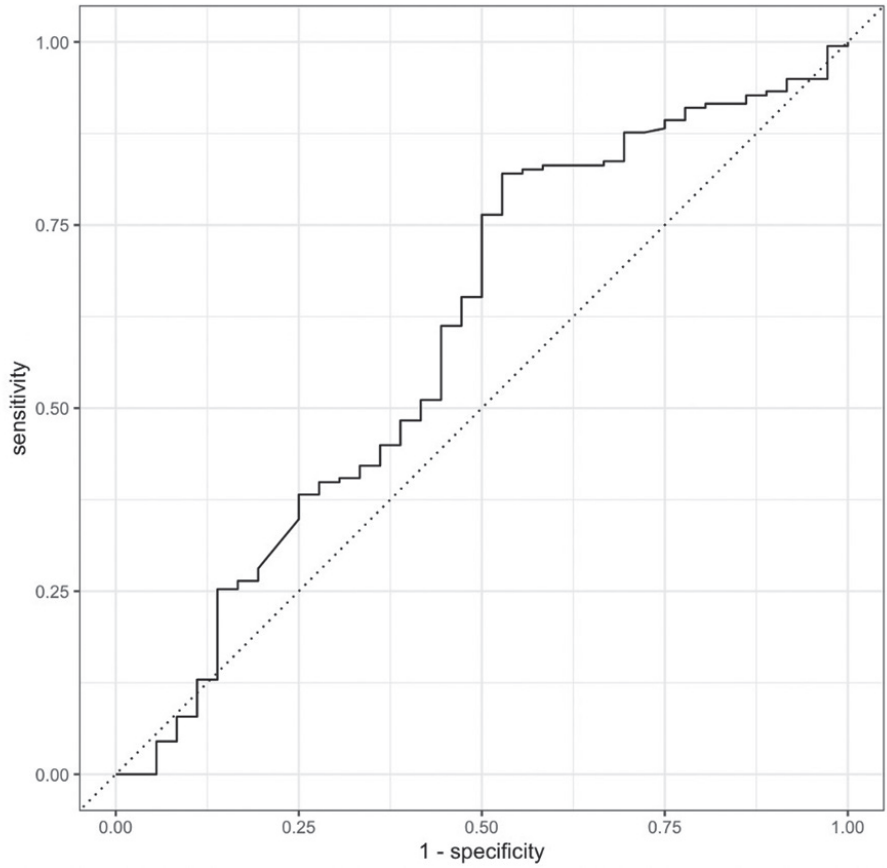
Conclusion: In this study, unemployment score and education score were among the top 3 important clinical and demographic variables that are most predictive of 90-day readmission following PCDF. The results here highlight the importance of considering patients' social determinants of health alongside clinical comorbidities as drivers of health outcomes.

PAPER 16 continued

Model Validation Metrics

Models	AUC (± CI)	Sensitivity	Specificity
Support Vector Machine	**0.600 (0.487, 0.711)**	**0.832**	**0.417**
Boosted Tree (XGboost)	0.518 (0.400, 0.636)	0.657	0.472
Logistic Regression	0.510 (0.386, 0.594)	0.669	0.306
Random Forest	0.496 (0.381, 0.610)	0.758	0.361

Figure 1: List the AUC, sensitivity, and specificity for competing models.



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PAPER 16 continued

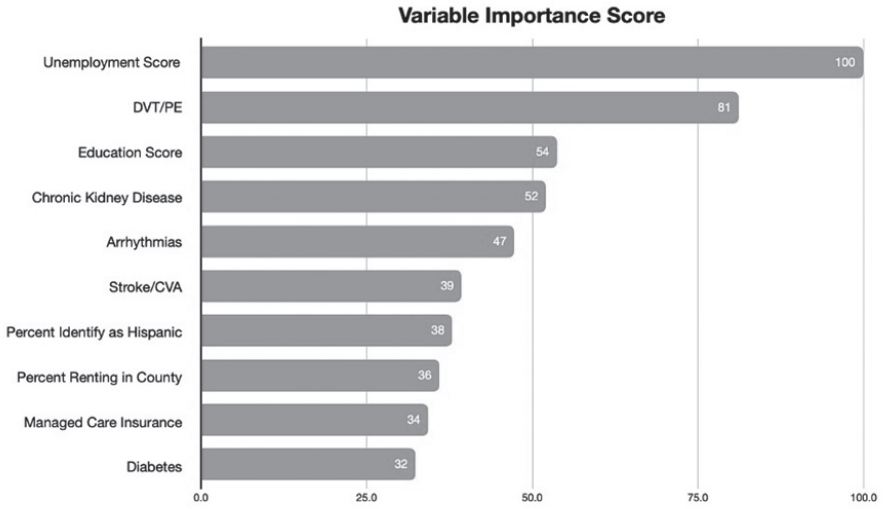

Figure 3: Variable importance score of the top 10 most predictive variables in 90-day readmission.

PAPER 17

Identifying Clinical Predictors of Increased Postoperative Health Utilization after ACDF Using a Machine Learning Approach

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Introduction: Hospital readmissions and overutilization of health services are responsible for a substantial portion of postoperative expenses.[1] By applying machine learning (ML) methods to large datasets, there is an opportunity to identify the driving factors that predispose patients to postoperative readmission and utilization of further diagnostic testing and imaging.[2] The current study aims to create ML models capable of predicting postoperative healthcare utilization in a group of patients who underwent anterior cervical discectomy and fusion (ACDF).

Materials and Methods: The analysis cohort consisted of patients that underwent a single or multilevel anterior cervical fusion between 2002 – 2021. A total of 64 variables including patient demographics, medical history, procedure characteristics, and the most recent pre-operative complete blood count (CBC) and basic metabolic panel (BMP) values within 3 months of surgery were included. Outcomes of interest were 90-day reoperation, 1-year reoperation, 90-day readmission, 90-day Emergency Department (ED) or Urgent Care (UC) visits, and 90-day outpatient resource use, which was defined as the sum of invasive procedures (e.g. cardiac catheterization), non-routine testing (e.g. EMG), and non-routine imaging (CT, X-Ray, MRI). Three algorithms – a random forest (RF), an elastic-net regression (LR), and a gradient boosted tree (GBM) – were constructed. Additionally, a deep learning neural network (NN) with two hidden layers and interspersed dropout layers was constructed. Performance was assessed using the Area Under the Receiver Operating Curve (AUC) statistic or the Mean Absolute Error (MAE) and feature importance scores were computed.

Results: A total of 1064 patients were included with an average age of 55.1 (SD: 12.2), BMI 29.8 (SD: 9.3), and 47.7% males (Table 1). A total of 415 patients (39.0%) underwent single level ACDF compared to 649 patients (61.0%) that underwent multilevel ACDF. Average outpatient resource use was 4.8 (SD: 2.6). Reoperation rates at 90-day and 1-year were 0.94% and 1.5%, respectively. A total of 101 patients (9.5%) were readmitted within 90-days and 199 patients (18.7%) had at least one ED/UC visit. All models outperformed the benchmark model with high AUC scores (Table 2). LR was found to be the best performing model for 90-day reoperation (AUC 0.74 ± 0.04) and 1-year reoperation (AUC 0.73 ± 0.04), with the top two predictors being platelet count and history of hepatic condition for both (Figure 1). RF was the best performing model for outpatient resource sum (MAE 1.82 ± 0.03), 90-day readmission (AUC 0.73 ± 0.01), and ED/UC use (AUC 0.67 ± 0.01), with the top predictors for those being history of hepatic condition, pulmonary condition (other than COPD), endocrine disorders (other than diabetes).

Conclusion: In a cohort of patients undergoing ACDF, RF and LR models were created with high accuracy to identify predictors of increased postoperative health utilization. This approach may allow physicians to individually counsel patients at risk postoperatively for readmission, reoperation or need for other procedures.

PAPER 17 continued

Table 1: Demographics of Overall Sample

Characteristic	ACDF Patients, N = 1,064
Age (Years)	55.1 (12.2)[1]
Body Mass Index (kg/m²)	29.8 (9.3)[1]
Gender	
Male	508 (47.7%)
Female	556 (52.3%)
ACDF Level	
Single-Level	415 (39.0%)
Multi-Level	649 (61.0%)
ASA Score	
1	32 (3.0%)
2	561 (52.7%)
3	450 (42.3%)
4	21 (2.0%)
Outpatient Resource Sum	4.8 (2.6)[1]
90-Day Reoperation	10 (0.94%)
365-Day Reoperation	16 (1.5%)
90-Day Readmission	101 (9.5%)
ED/UC Utilization	199 (18.7%)

[1] Mean (SD); [2] n (%)

Abbreviations: ACDF: Anterior Cervical Discectomy and Fusion; ASA: Ame
Anesthesiologists

Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

PAPER 17 continued

Table 2: Performance of Machine Learning Models

Outcome	Benchmark	Elastic Net	Random Forest	Gradient Boosted Tree	Neural Network
ED/Urgent Care Use AUC (± 95% CI)	0.50 ± 0.00	0.67 ± 0.01	0.67 ± 0.01	0.62 ± 0.02	0.63 ± 0.01
90-Day Readmission AUC (± 95% CI)	0.50 ± 0.00	0.70 ± 0.01	0.73 ± 0.01	0.66 ± 0.01	0.64 ± 0.02
90-Day Reopcration AUC (± 95% CI)	0.50 ± 0.00	0.74 ± 0.04	0.68 ± 0.04	0.56 ± 0.05	0.70 ± 0.05
365-Day Reoperation AUC (± 95% CI)	0.50 ± 0.00	0.73 ± 0.04	0.68 ± 0.04	0.56 ± 0.05	0.64 ± 0.05
Outpatient Resource Sum MAE (± 95% CI)	2.03 ± 0.03	1.85 ± 0.03	1.82 ± 0.03	1.85 ± 0.03	1.85 ± 0.03

Abbreviations: AUC: Area Under Curve; CI: Confidence Interval; ED: Emergency Department

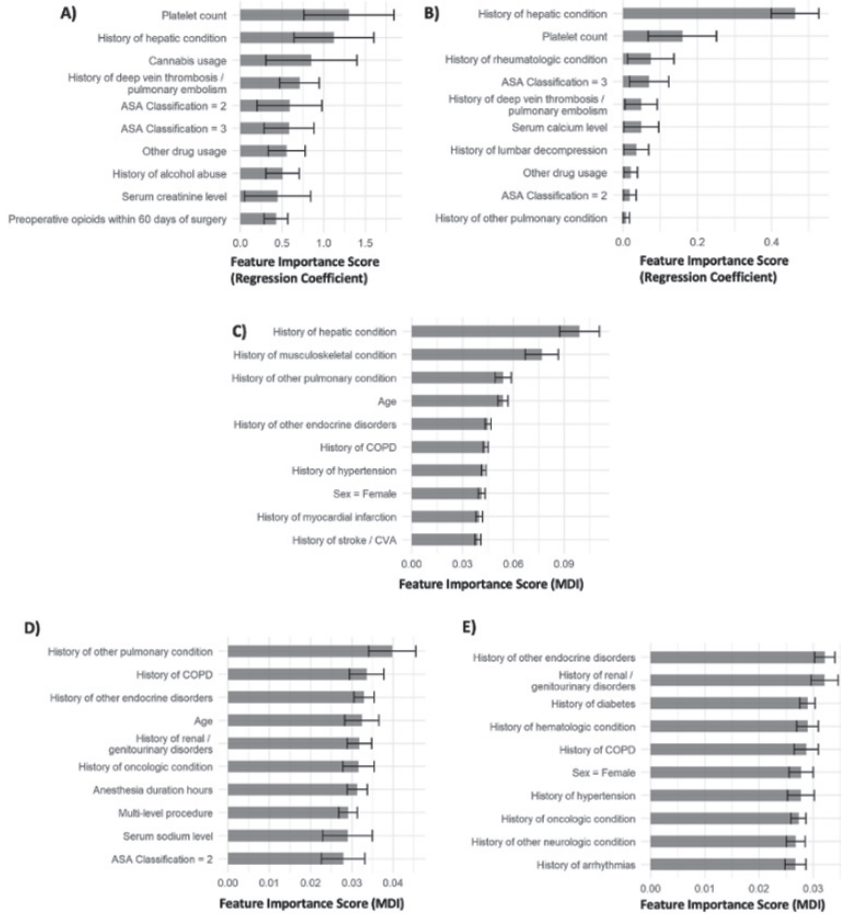

Figure 1. The top 10 features by average importance for the highest performing model in each outcome, with those whose confidence intervals overlapped with 0 being excluded. **(a)** Elastic Net for 90-day reoperations, **(b)** Elastic Net for 365-day reoperations, **(c)**, Random Forest for outpatient resource sum, **(d)** Random Forest for 90-day readmissions, **(e)** Random Forest for Emergency Department/Urgent Care utilization

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PAPER 18

Does Posterior Longitudinal Ligament Resection During Cervical Artificial Disc Replacement Affect Clinical or Radiographic Outcome?

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Introduction: Cervical artificial disc replacement (ADR) has been widely used to restore or maintain segmental motion while achieving neural decompression. It is expected to decrease adjacent segment degeneration (ASD) and patient discomfort caused by fusion. According to the shape and location of the compressive pathology, posterior longitudinal ligament (PLL) could be resected or preserved during ADR procedure. However, unlike fusion operation, outcomes of ADR might be affected by PLL resection since segmental motion is preserved with ADR and PLL checks flexion motion of the segment. Previous biomechanical study has suggested that PLL resection during ADR could partly increase range of motion (ROM). Nevertheless, the effect of PLL removal in ADR in clinical setting remains unclear. Therefore, the present study was conducted to evaluate how PLL resection affect clinical or radiographic outcome in ADR. We hypothesized that segmental flexion capacity and segmental ROM would increase since PLL limits flexion motion.

Materials and Methods: Patients who underwent ADR for the treatment of cervical myelopathy or radiculopathy and were followed-up for ≥24 months were retrospectively reviewed. C2-C7 lordosis, C2-C7 SVA, C2-C7 cervical ROM, C2-C7 flexion capacity, C2-C7 extension capacity, segmental ROM, segmental flexion capacity, segmental extension capacity, ASD, and heterotopic ossification (HO) were assessed. Patient reported outcome measures including neck pain visual analogue scale (VAS), arm pain VAS, and neck disability index (NDI) were recorded. Results were compared between the PLL preservation group and the PLL resection group.

Results: Among 52 patients included, 23 patients (44.2%) were included in the PLL preservation group while 29 patients (55.7%) were included in the PLL resection group. There was no significant intergroup difference in baseline patient characteristics between the two groups (Table 1). Furthermore, global cervical motion and segmental motion also was not significantly different between the PLL preservation group and PLL resection group. Incidence of HO or ASD at 2-years postoperative follow-up did not significantly differ between the two groups ($p=1.000$, and 0.974, respectively) (Table 2). Neck pain VAS ($p<0.001$, <0.001, respectively), arm pain VAS ($p<0.001$, <0.001, respectively), and NDI ($p<0.001$, <0.001, respectively) all significantly improved after the operation in both groups while there was no significant intergroup difference at all time points (Table 3). PLL resection was not associated with ROM decrease in logistic regression analysis (95% confidence interval, 0.547-5.342; odds ratio, 1.709; $p=0.356$).

Conclusion: The present study demonstrates that segmental ROM or clinical outcome is not affected by PLL resection. Although previous biomechanical study has demonstrated that segmental ROM, especially the flexion capacity increases when PLL is resected during ADR, this finding did not apply to clinical situations. Not only PLL but also other factors such as prosthesis design, anatomy of facet joints, and paraspinal muscles would stabilize the motion segment, and resection of PLL does not seem to have significant effect on ROM or patient symptoms. Therefore, whether to resect PLL during ADR should be decided solely based on

PAPER 18 continued

whether it is needed for adequate decompression, since PLL resection itself does not adversely nor favorably affect the surgical outcome.

Table1. Patient characteristics

	PLL preservation	PLL resection	p value
Age	50.3 ± 10.3	50.6 ± 10.3	0.944
Sex			
Male	13 (56.5%)	14 (48.3%)	0.588
Female	10 (43.5%)	15 (51.7%)	
DM	2 (8.7%)	2 (6.9%)	1.000
HTN	2 (8.7%)	4 (13.8%)	0.682
Smoking status	7 (30.4%)	10 (34.5%)	1.000
BMI (kg/m^2)	24.0 ± 2.5	23.4 ± 4.7	0.554
F/U period (m)	64.9 ± 38.1	58.7 ± 51.0	0.629
Complications			
Dural tear	0 (0.0%)	0 (0.0%)	n/a
Reoperation	0 (0.0%)	0 (0.0%)	n/a
Neurologic deterioration	0 (0.0%)	0 (0.0%)	n/a

PLL, posterior longitudinal ligament; DM, diabetes mellitus; HTN, hypertension; BMI, body mass index; m, months

Continuous variables were analyzed using a student's t-test

Categorical variables were analyze using a chi-square test

PAPER 18 continued

Table 2. Radiographic results

		PLL preservation	PLL resection	p value
Preoperative	C2C7 ROM	45.8 ± 13.1	51.0 ± 12.6	0.155
	C2C7 flexion capacity	30.4 ± 17.2	36.3 ± 10.5	0.137
	C2C7 extension capacity	15.4 ± 11.2	14.8 ± 8.4	0.805
	C2C7 lordosis	11.7 ± 9.0	10.9 ± 10.4	0.751
	C2C7 SVA	18.9 ± 11.4	16.3 ± 7.5	0.312
	Segmental ROM	7.9 ± 4.4	8.3 ± 3.4	0.684
	Segmental flexion capacity	5.9 ± 3.1	6.7 ± 3.6	0.435
	Segmental extension capacity	2.0 ± 3.3	1.7 ± 2.8	0.724
Postop 3m	C2C7 ROM	44.8 ± 12.6	49.6 ± 11.6	0.160
	C2C7 flexion capacity	31.4 ± 11.1	35.8 ± 10.3	0.144
	C2C7 extension capacity	13.4 ± 9.7	13.8 ± 7.7	0.868
	C2C7 lordosis	13.9 ± 10.7	14.0 ± 8.6	0.974
	C2C7 SVA	17.0 ± 9.0	14.8 ± 9.6	0.398
	Segmental ROM	8.0 ± 4.0	9.5 ± 3.8	0.155
	Segmental flexion capacity	7.0 ± 4.3	8.6 ± 5.8	0.283
	Segmental extension capacity	0.9 ± 1.8	0.9 ± 5.4	0.989
Postop 2y	C2C7 ROM	48.0 ± 14.6	50.8 ± 12.5	0.454
	C2C7 flexion capacity	32.8 ± 12.4	35.7 ± 9.4	0.352
	C2C7 extension capacity	15.1 ± 8.7	15.1 ± 7.2	0.997
	C2C7 lordosis	13.5 ± 8.8	13.3 ± 7.4	0.925
	C2C7 SVA	15.9 ± 9.2	15.6 ± 7.5	0.893
	Segmental ROM	8.3 ± 5.4	9.8 ± 4.9	0.277
	Segmental flexion capacity	7.0 ± 5.2	9.2 ± 6.2	0.169
	Segmental extension capacity	1.3 ± 2.8	0.6 ± 6.6	0.643
	Heterotopic ossification	12 (52.2%)	15 (51.7%)	0.974
	Adjacent segmental disease	3 (13.0%)	4 (13.8%)	1.000
	Segmental ROM decrease	10 (43.5%)	9 (31.0%)	0.397

PLL, posterior longitudinal ligament; m, months; y, years; ROM, range of motion; SVA, sagittal vertical axis

Continuous variables were analyzed using a student's t-test

Categorical variables were analyze using a chi-square test

Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

PAPER 18 continued

Table 3. Patient reported outcome measures

		PLL preservation	PLL resection	p value
Preoperative	Neck pain VAS	3.6 ± 2.9	4.5 ± 3.1	0.489
	Arm pain VAS	5.4 ± 2.6	5.4 ± 2.7	0.872
	NDI	29.2 ± 16.0	36.3 ± 26.4	0.840
Postop 2y	Neck pain VAS	2.1 ± 2.4	1.8 ± 1.9	0.296
	Arm pain VAS	2.3 ± 2.6	2.2 ± 2.5	0.205
	NDI	12.3 ± 13.1	15..0 ± 16.6	0.290

PLL, posterior longitudinal ligament; VAS, visual analogue scale; NDI, neck disability index; y, years

All analyzes were performed using a Mann-Whitney U test

PAPER 19

Two-Level Anterior Cervical Diskectomy and Fusion versus Anterior Cervical Corpectomy: Does one Treatment Strategy Demonstrate Superiority?

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Introduction: This study evaluates two-level anterior cervical diskectomy and fusion (ACDF) versus single-level anterior cervical corpectomy and fusion (ACCF) in a propensity score matched (PSM) analysis. Prior studies have compared these two procedures matching for several variables; however, investigation including preoperative lab values, which can provide additional stratification of patient risks for post-operative complications, has not been undertaken.

Materials and Methods: The American College of Surgeons National Surgical Quality Improvement (ACS-NSQIP) database was surveyed for all patients who underwent two-level ACDF or single-level ACCF from the years 2011 to 2020. Patients were excluded if surgery was performed for infection, neoplasm, fracture/dislocation, or revision/removal of hardware. Only elective cases with selected pre-operative laboratory values were included.

As patients were not randomized to treatment arms, propensity score matching was employed to minimize treatment selection bias when estimating causal treatment effects. A multivariable logistic regression was used to delineate factors significantly associated with a specific treatment group. Individual propensity scores per covariate were calculated in a logistic regression model. "Case" (ACDF) and "control" (Corpectomy) patients were paired 1:1 on these propensity scores via exact matching based on factors that were found to be significantly associated with the decision to perform ACDF versus corpectomy including self-identified race, age, comorbid diabetes, smoking status, functional status, and ASA class. Additionally, pre-operative hematocrit and albumin were matched.

Standardized differences are estimated before and after matching to evaluate the balance of covariates; small absolute values (~0.2) indicate balance between treatment groups. The PSM matched cohort was evaluated using 2-sided t-tests with Welch's correction. Analyses of binary variables with Fisher mid-P value. Following PS matching, the incidence of a non-binary event was evaluated using the McNemar test.

Results: Compared to patients who underwent two-level ACDF, patients who underwent single-level ACCF experienced a similarly low complication profile in the subsequent 30-day post-operative period. Superficial and deep infections were not found to be statistically different between unmatched and matched cohorts. Wound disruption and post-operative pneumonia were higher in the ACCF group when unmatched, but these were not factors after PSM. Additionally, post-operative deep vein thrombosis (DVT) and sepsis were higher in the unmatched ACCF group, but the relationship was not significant after PSM.

Patients who underwent ACCF were more likely to have a longer hospital length of stay 2.74 days versus 1.83 days ($p<0.0001$) and longer length of surgery with 169 minutes compared to 136 minutes ($p<0.0001$) when matched. Matched single-level ACCF patients also had a higher 30-day reoperation rate of 2.99% compared to 1.72% ($p=0.009$). Unmatched ACCF patients had a higher 30-day readmission rate, but this relationship did not exist after PSM.

PAPER 19 continued

Conclusion: This large database analysis shows that, when matched, patients who undergo single-level ACCF are at increased risk of reoperation within 30 days but not increased risk of infection, pneumonia, pulmonary embolism/DVT or sepsis compared to two-level ACDF. Patients can be counseled that single-level ACCF and two-level ACDF have comparable outcomes when patients are matched to comorbidities when considering hematocrit and albumin as part of the pre-operative assessment.

PAPER 20

Clinical significance of C2 slope after multilevel cervical spine fusion surgery

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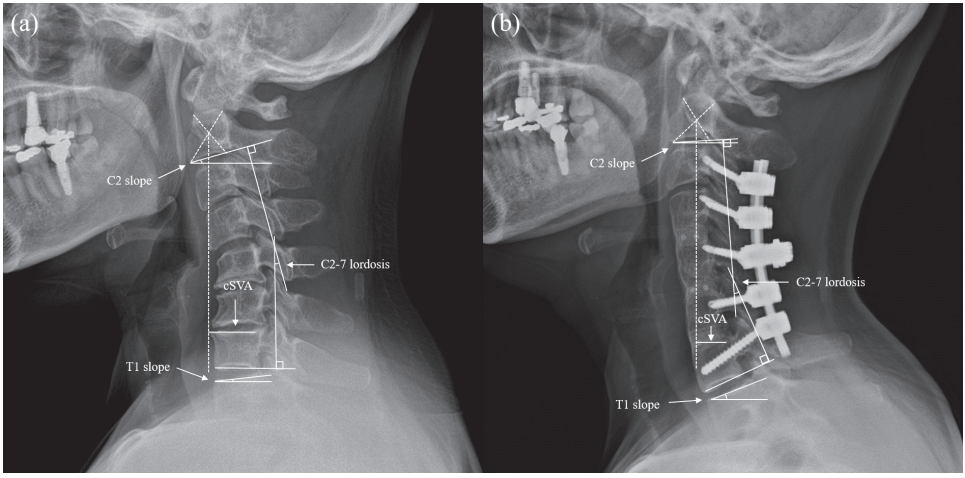
Introduction: It is well-known that cervical sagittal malalignment may cause neck disability. The C2 slope is one of the parameters that can determine cervical sagittal alignment. However, its clinical significance is relatively unexplored. Therefore, the purpose of this study was to evaluate the clinical significance of C2 slope after multilevel cervical spine fusion surgery.

Materials and Methods: A total of 111 patients who underwent multilevel cervical spine fusion were included in this study. C2 slope (C2S), cervical sagittal vertical axis (cSVA), C2-7 lordosis, and T1 slope (T1S) were measured in standing lateral cervical spine radiographs preoperatively and 2 years after the surgery. Clinical outcome measures were neck pain and arm pain Visual Analog Scale (VAS), neck disability index (NDI), Japanese Orthopedic Association (JOA) score, and patient-reported subjective improvement rate in percentage (IR). Statistical analysis was performed using paired samples t-test and Pearson's correlation, and Receiver operating characteristic (ROC) curve to determine the cut-off values of C2S.

Results: C2S demonstrated a significant correlation with the cSVA, C2–7 lordosis, T1S, and T1 slope minus cervical lordosis (T1S-CL). C2S revealed a significant correlation with the Japanese Orthopedic Association (JOA) score, neck pain, and neck disability index (NDI) scores at 2 years after surgery. Change in the C2S correlated with postoperative neck pain and NDI scores. ROC curve demonstrated the cut-off value of C2S as 18.8°, 22.25°, and 25.35° according to a cSVA of 40 mm, severe disability expressed by NDI, and severe myelopathy, respectively.

Conclusion: C2 slope can be an additional cervical sagittal alignment parameter that can be a useful prognostic factor after multilevel cervical spine fusion surgery.



PAPER 20 continued

Table 1. Correlation between radiographic parameters preoperatively and at 2-year follow up

Pre-op		C2S	T1S	cSVA	C2–7 lordosis	T1S-CL
C2S	R	1	0.118	0.534*	-0.711*	0.977*
	P value		0.219	<0.001	<0.001	<0.001
T1S	R		1	0.216*	0.593*	0.114
	P value			0.023	<0.001	0.232
cSVA	R			1	-0.240*	0.478*
	P value				0.011	<0.001
C2–7 lordosis	R				1	-0.732*
	P value					<0.001
2-year follow up		C2S	T1S	cSVA	C2–7 lordosis	T1S-CL
C2S	R	1	0.350*	0.404*	-0.582*	0.951*
	P value		<0.001	<0.001	<0.001	<0.001
T1S	R		1	0.470*	0.511*	0.380*
	P value			<0.001	<0.001	<0.001
cSVA	R			1	0.082	0.349*
	P value				0.394	<0.001
C2–7 lordosis	R				1	-0.600*
	P value					<0.001

Abbreviations: C2S, C2 slope; T1S, T1 slope; cSVA, C2 –C7 sagittal vertical axis; T1S -CL, T1 slope minus cervical lordosis

* indicates significance

PAPER 20 continued

Table 2. Correlation of radiographic parameters and clinical outcome measures preoperatively and at 2-year follow up

Pre-op	C2S		T1S		cSVA		C2–7 lordosis		T1S-CL	
	R	P value	R	P value	R	P value	R	P value	R	P value
Neck pain VAS (n=111)	0.054	0.575	-0.137	0.151	-0.040	0.680	-0.133	0.163	0.049	0.613
Arm pain VAS (n=111)	-0.071	0.462	-0.065	0.497	-0.100	0.296	0.041	0.880	-0.073	0.446
JOA (n=111)	0.008	0.930	-0.219*	0.021	-0.181	0.057	-0.169	0.077	0.023	0.814
NDI (n=111)	0.024	0.799	0.048	0.620	-0.081	0.396	0.020	0.837	0.016	0.868
2-year follow up	C2S		T1S		cSVA		C2–7 lordosis		T1S-CL	
	R	P value	R	P value	R	P value	R	P value	R	P value
IR (n=105)	-0.171	0.082	-0.042	0.669	-0.127	0.195	0.122	0.216	-0.170	0.083
Neck pain VAS (n=107)	0.232*	0.016	0.222*	0.022	0.117	0.230	-0.034	0.726	0.244*	0.011
Arm pain VAS (n=106)	0.101	0.302	0.131	0.181	0.132	0.178	0.006	0.949	0.119	0.226
JOA (n=102)	-0.306*	0.002	-0.213*	0.032	-0.367*	<0.001	0.020	0.840	-0.220*	0.026
NDI (n=102)	0.325*	0.001	0.145	0.147	0.250*	0.011	-0.128	0.199	0.273*	0.006
EQ5D Index (n=65)	-0.057	0.650	-0.056	0.655	-0.239	0.055	0.000	0.999	-0.044	0.725
EQ5D VAS (n=65)	-0.127	0.315	0.043	0.731	-0.183	0.146	0.150	0.234	-0.119	0.346

Abbreviations: C2S, C2 slope; T1S, T1 slope; cSVA, C2–C7 sagittal vertical axis; T1S-CL, T1 slope minus cervical lordosis; IR, subjective improvement rate; VAS, Visual Analogue Scale; JOA, Japanese Orthopedic Association score; NDI, neck disability index; EQ5D, EuroQol-5 Dimension

* indicates significance

PAPER 21

Accuracy of cervical pedicle screw insertion using the freehand technique: The deviation rate for C7 is unexpectedly high

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Introduction: The Cervical Pedicle Screw (CPS) is the most potent anchor in cervical posterior fusion surgery, but it risks severe complications due to deviation.[1] In this study, we examined the rate of CPS deviation and its complications in our institute.

Materials and Methods: We included 466 CPSs inserted from C2 to C7 in 148 patients who underwent posterior cervical fusion from 2010 to 2019 in our institute. Patient ages ranged from 13-84 years old, 97 male and 51 female. The diseases included degenerative diseases in 50 patients, ossification of a posterior longitudinal ligament in 38, spinal tumors in 20, a trauma in 17, rheumatoid arthritis in 9, athetotic cerebral palsy in 9, congenital malformations in 3, and pyogenic spondylitis in 2. All CPS were inserted using the freehand technique with preoperative CT measurements and intraoperative fluoroscopy. The CPS position was evaluated on 3-dimension multi-sectional reconstructed images of postoperative CT using the classification of Yukawa.[2] The CPS position was classified into three grades; Grade 0: correct position, Grade 1: deviation by less than half screw diameter, Grade 2: deviation by more than half screw diameter.

Results: CPS was 158 in the C2 group, 123 in the C3-6 group, and 185 in the C7 group, and extraosseous deviation was observed in 66 screws (14.4%) overall, with 44 (9.5%) Grade 1 and 22 (4.7%) Grade 2 deviations. (Table 1) The Grade 2 deviation rates were 1.3% in the C2 group, 6.5% in the C3-6 group, and 6.5% in the C7 group, with significantly higher rates in the C3-6 and C7 groups compared to the C2 group. ($p = 0.020$) Complications from CPS included one vertebral artery injury in the C3-6 group and one nerve root injury in the C7 group. (Figure 1, 2) Grade 2 deviations of CPS were 11 medial and 11 lateral, with mean deviation distances of 4.7 (±0.8) mm and 3.8 (±1.4) mm, respectively, and all medial deviations were asymptomatic.

Conclusion: CPS deviation is more common in the middle cervical spine, where the pedicle diameter is narrower, and Grade 2 deviation is associated with the risk of neurovascular injury. Our study suggested that the safe range for medial deviation is at least 4 mm. In our study, the deviation rate tended to be low in the C2 group and high in the C3-6 and C7 groups. This was thought to be because the entry point of the C3-7 CPS was lateral, and the angle of entry was steep, so it was easily pushed by the paraspinal muscles and deviated from the pedicle. The bony landmarks at the C7 CPS entry point are difficult to recognize, and the shoulder obscures the C7 on lateral fluoroscopy. Although the C7 CPS is considered safe with a low risk of vertebral artery injury, the risk of deviation is unexpectedly high with the freehand technique. The C7 CPS is often the caudal end of the posterior cervical fusion, which requires strict fixation in the exact position and careful insertion.

PAPER 21 continued

Table 1: Accuracy of CPS positioning and the incidence of deviations by vertebral level.

Spinal level	C2		C3-6		C7		Total	
	No. of PS	Ratio (%)	No. of PS	Ratio (%)	No. of PS	Ratio (%)	No. of PS	Ratio (%)
CPS	158		123		185		466	
Grade 0	146	92.4	99	80.5	155	83.8	400	85.8
Grade 1	10	6.3	16	13.0	18	9.7	44	9.5
Grade 2	2	1.3	8	6.5	12	6.5	22	4.7
-(Medial)	2		6		3		11	
-(Lateral)	0		2		9		11	
Grade 1 + 2	12	7.6	24	19.5	30	16.2	66	14.2

CPS, cervical pedicle screw.

PAPER 21 continued

Figure 1: An axial CT image at C4 detected lateral deviation of Grade 2 on left CPS. (A). Postoperative CT angiography revealed occlusion of the left vertebral artery, but no symptoms were observed. (B)

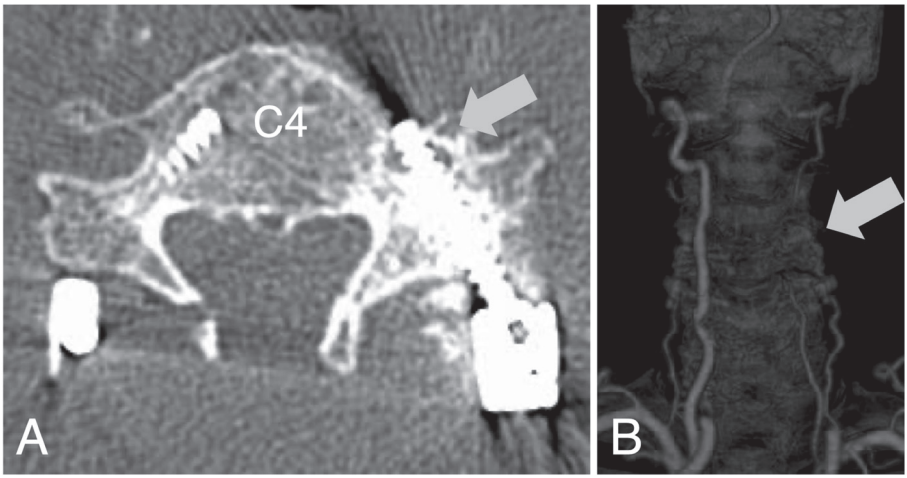
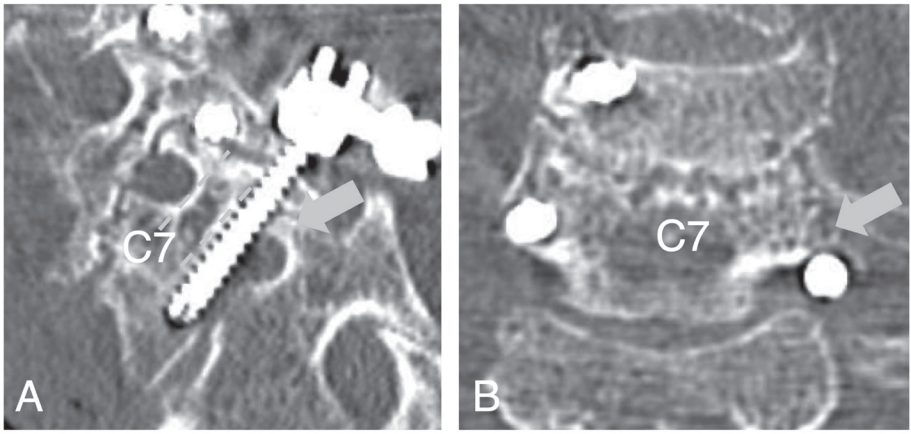


Figure 2: Parasagittal CT image (A) and coronal CT image (B) at C7 detected lateral deviation of Grade 2 on left CPS. Mild postoperative numbness of the left finger was noted but improved over time.



PAPER 22

Are All Cervical Cages Created Equal? A Comprehensive Analysis of a Decade of Adverse Event Reports in the US

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The Taylor Collaboration[1]

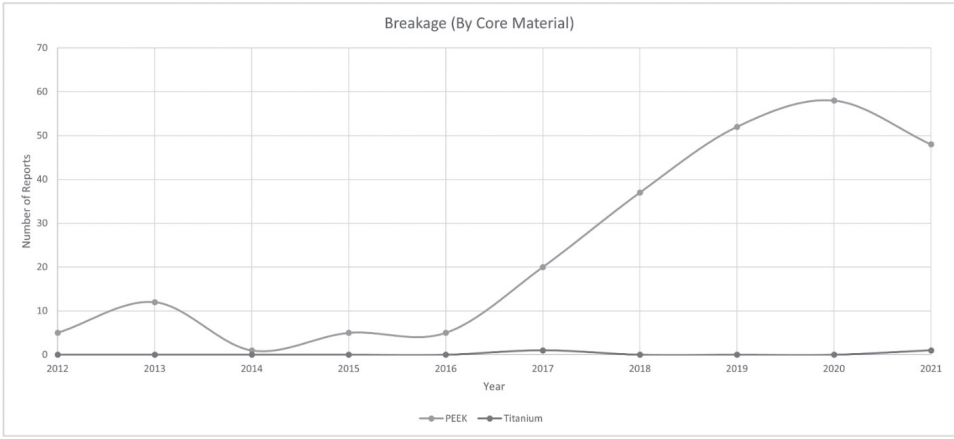
Introduction: The choice of implant materials for interbody fusion devices is crucial in the context of optimizing procedure efficiency and patient recovery. Recently, new manufacturing methods and materials have been introduced to the market, but no prior publications have analyzed failure reports associated with material choice and specific manufacturers. Therefore, the purpose of this study is to comprehensively analyze failure rates of interbody device materials and their manufacturers in order to determine the most optimal material configurations.

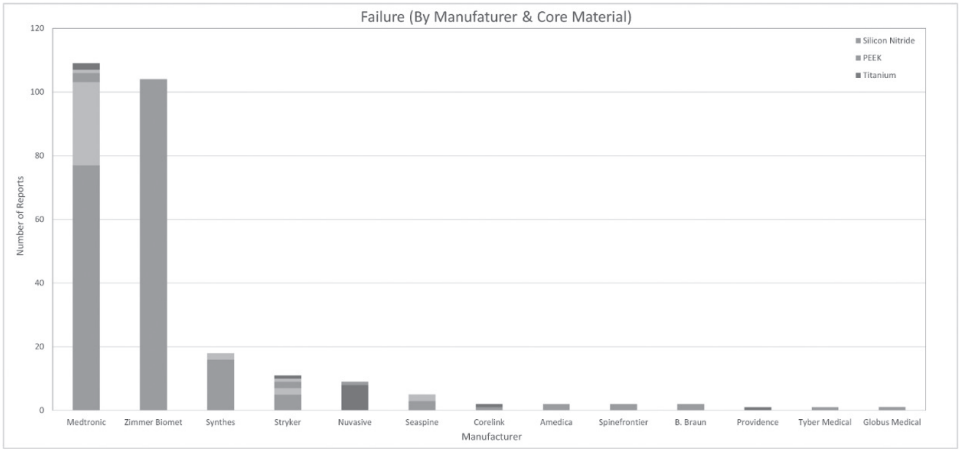
Materials and Methods: Adverse event reports for cervical interbody fusion devices were exported from the MAUDE FDA database. The product codes allowed the indexing of a comprehensive list of reports from 2012 to 2021. The entries were filtered, only leaving reports of interbody fusion device failure. Each report was manually analyzed and assigned the corresponding manufacturing material which was determined from 510(k) premarket notifications of the products. The materials were separated into three categories, depending on the core material of the device: PEEK, Titanium, and Silicon Nitride. Additionally, the entries were categorized into two groups depending on the type of failure: breakage and migration. Next, a market analysis of all the listed public manufacturers was conducted and a 'failure to yearly revenue index' was calculated by dividing the number of reports of the respective manufacturer by their approximative revenue from spinal implants in the US (in billions) along the years. Outlier analysis was performed in order to create a yearly threshold calculated by adding the median revenue of the year to one mean absolute deviation. Values above this threshold were defined as much higher than the normal index.

Results: A total of 802 adverse event reports were filtered, yielding 267 reports that satisfied the requirements. When compared to Titanium, PEEK was found to be the material with the most breakage reports as shown in figure 1, totaling 243 reports. Out of all failure reports, two manufacturers were observed to have a noticeably high number, as shown in figure 2. The most failing manufacturer accounted for approximately 40.8% of the total reports and the second accounted for approximately 39.0%. Other manufacturers accounted for 20.2% of all reports. Five out of eight public manufacturers showed a failure to revenue index above the threshold in at least one of the years as shown in figure 3. Out of the five manufacturers, the second most failing manufacturer has been found to have the highest failure to revenue index.

Conclusion: There have been a number of interbody device failures reported to the FDA over the past decade. The true number of failures is unknown but is likely much higher. PEEK cages were reported to fail more often than Titanium cages. There were more failures of cages from some manufacturers indicating the possible contribution of the cage manufacturing process and architecture towards failure. More research is needed into the contribution of the cage manufacturing process, structure, shape, and topography towards its intra-operative failure. More uniform reporting of device failures and broader adoption of spine registries would probably facilitate this goal.

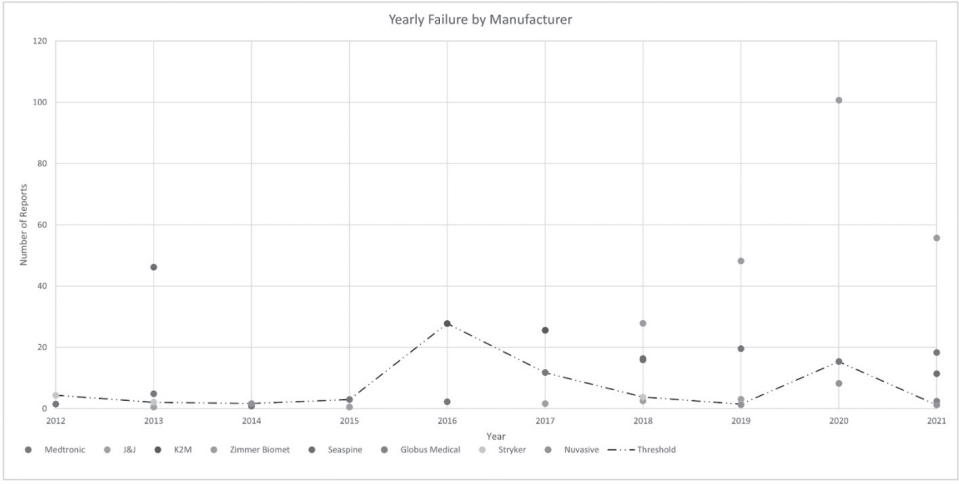
PAPER 22 continued





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

PAPER 22 continued



PAPER 23

Spinal Cord Shift may not be a Cause of C5 Palsy After Cervical Laminoplasty: Protective Effect of Medial Gutter

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Introduction: Postoperative significant spinal cord shift is one of the most commonly supposed causes of C5 palsy after cervical laminoplasty. However, at our institute, the C5 palsy rate after cervical laminoplasty with the medial gutter is extremely low, regardless of the extent of the postoperative spinal cord shift. This study aimed to verify the relationship between the spinal cord shift and C5 palsy.

Materials and Methods: We retrospectively reviewed clinical and radiological outcomes of patients who underwent cervical laminoplasty between 2015 and 2017 in our institute, and compared them to the outcomes of patients in reference papers. In our institute, we performed all cervical laminoplasty using the open-door technique with bilateral bony gutters of 3mm medial location to the medial border of lateral mass to preserve the facet joints as much as possible. On the other hand, lateral gutters were made next to the medial facet joints in the patients of the reference papers. Clinically, C5 palsy occurrence and Japanese Orthopedic Association (JOA) scores before and after surgery were reviewed. Radiologically, the extent of the postoperative spinal cord shift before and after the surgery were measured using computed tomography (fig 1). One-sample T-test was mainly used for statistical analysis.

Results: A total of 190 patients who underwent cervical laminoplasty in our institute were enrolled in the medial gutter group (MG group), and 26 patients in reference papers were assigned to the control group. The preoperative baseline characteristics and the JOA scores did not show a significant difference between the two groups (table 1). The mean postoperative spinal cord shift was significantly larger in the MG group than in the control group (1.54 vs. 1.1mm, $p<0.001$). Despite this finding in the spinal cord shift, either the occurrence of C5 palsy or the postoperative JOA scores was not significantly different between the two groups (table 2).

Conclusion: A larger extent of spinal cord shift after cervical laminoplasty did not necessarily increase the incidence of C5 palsy. Moreover, medial gutters may serve as a protective effect against the C5 palsy.

PAPER 23 continued

Table 1. Baseline Characteristics

	MG group	Control group	p-value
Age (range)	58.53 (26-84)	60 (38-95)	0.095
Sex (M : F)	128 : 62	20 : 6	0.376
BMI (kg/m^2, ± SD)	25.25 ± 3.01	NaN	NaN
Diabetes Mellitus (%)	38 (20.0%)	NaN	NaN
Smoking (%)	34 (17.9%)	NaN	NaN
Diagnosis (CSM : OPLL)	118 : 72	NaN	NaN
Side (Rt : Lt)	105:85	NaN	NaN

MG, medial gutter; M, male; F, female; BMI, body mass index; SD, standard deviation; CSM, cervical spondylotic myelopathy; OPLL, ossification of posterior longitudinal ligament; Rt, right; Lt, left

Table 2. Surgical Outcomes

	MG group	Control group	p-value
C5 palsy occurence	0	0	
Preop JOA	11.3	11.7	0.024
JOA recovery rate after 2yr (%)	70.60%	66.70%	0.275
Postop spinal cord shift (mm, ± SD)	1.54 ± 0.81	1.1 ± 0.5	p<0.001

MG, medial gutter; JOA, Japanese Orthopaedic Association; Preop, preoperative; Postop, postoperative; SD, standard deviation

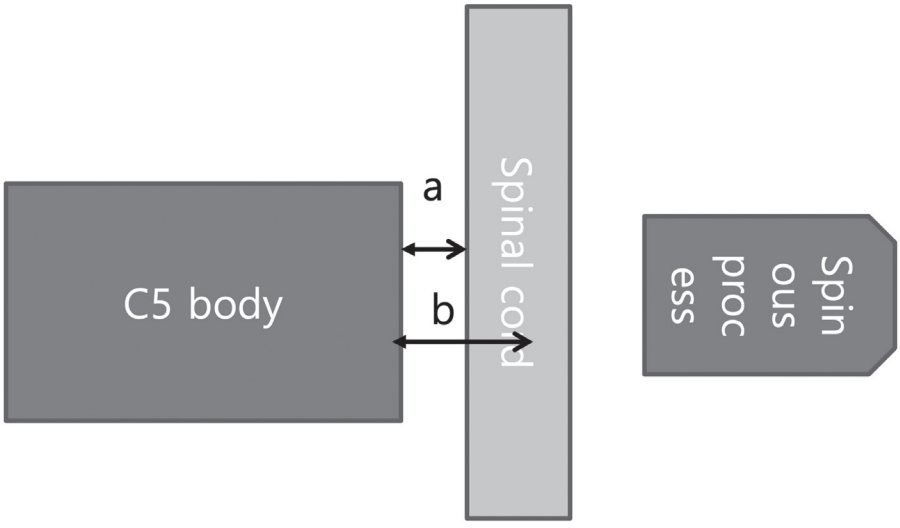

Figure 1. The Method of Spinal Cord Shift Measurement

PAPER 24

Epidural Steroid Injection and Infection Risk Following Posterior Cervical Surgery

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Introduction: Epidural steroid injection (ESI) is a helpful tool in alleviating pain and possibly preventing the need for spinal surgery. However, a recent small scale study found that ESI within 3 months prior to cervical fusion was associated with an increased risk of postoperative infection. The purpose of this study was to characterize infection risk of preoperative ESI with an expanded set of indications while matching for a full list of comorbidities in patients undergoing posterior cervical fusion.

Materials and Methods: Patients from 2010-2020 with cervical myelopathy, spondylosis, and radiculopathy who underwent posterior cervical procedure including laminectomy, laminoforaminotomy, fusion, or laminoplasty were queried from the PearlDiver database. Patients who underwent revision or fusion above C2 or who had a diagnosis of neoplasm, trauma, or pre-existing infection were excluded. Patients were then divided based on whether they received an ESI within 30 days prior to the procedure. The two groups were subsequently matched based on age, gender, and preoperative comorbidities. A chi-square test was used to calculate the risk of developing a postoperative wound infection within 90 days of surgery.

Results: Based on our inclusion and exclusion criteria, 82,907 patients were identified, including 991 who received a preoperative ESI and 81,916 who did not. Matching resulted in 975 in the injected group and 1,929 in the control group. There was no significant difference in postoperative infection rate in those who received an ESI within 30 days preoperatively and those who did not (3.28% verus 3.78%, OR=0.86, 95% CI: 0.57-1.32, p=0.494).

Conclusion: The present study found no association between preoperative ESI within 30 days prior to surgery and postoperative infection in patients undergoing posterior cervical fusion.

PAPER 25

Optimal timing of referral for nerve transfer surgery for postoperative C5 palsy

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Introduction: C5 palsy can occur following surgery for cervical spine pathology. The prognosis of C5 palsy is generally favorable and most patients recover useful function. However, some patients fail to recover useful strength. Nerve transfers are a potential effective treatment of postoperative severe C5 palsy. This study aimed to further delineate the natural history of recovery from postoperative C5 palsy, determine whether lack of recovery at specific time points predicts poor recovery prognosis, and thereby determine a reasonable time point for referral to a complex peripheral nerve specialist.

Materials and Methods: We conducted a retrospective review of 72 patients who underwent surgery for cervical spondylosis and stenosis complicated by C5 palsy. Medical Research Council (MRC) motor strength grades were recorded preoperatively, immediately postoperatively, at discharge, and 2 weeks, 3 months, 6 months, and 12 months postoperatively. Univariate and multivariate logistic regression models were used to identify demographic and clinical risk factors associated with recovery of useful strength after severe C5 palsy.

Results: Mean age of patients was 62.5 years, and 36.1% of patients were female. Thirty patients (41.7%) experienced severe C5 palsy with less than antigravity strength (MRC grade 2 or less) at discharge. Twenty-one (70%) of these patients recovered useful strength (MRC grade 3 or greater) at 12 months postoperatively, and 9 patients (30%) failed to recover useful strength at 12 months. Of those patients with persistent severe C5 palsy at 3 months postoperatively, 50% recovered useful strength at 12 months. Of those patients with persistent severe C5 palsy at 6 months postoperatively, 25% recovered useful strength at 12 months. No patient with MRC grade 0 or 1 strength at 6 months postoperatively recovered useful strength. History of diabetes was associated with occurrence of severe C5 palsy. On multivariate analysis, female gender was associated with recovery of useful strength.

Conclusion: Most patients with severe C5 palsy recover useful strength in their C5 myotome within 12 months of onset. However, at 3 months postoperatively, patients with persistent severe C5 palsy had only a 50% chance of recovering useful strength by 12 months. Lack of recovery of useful strength at 3 months postoperatively is a reasonable time point for referral to a complex peripheral nerve center to establish care and to determine candidacy for nerve transfer surgery if severe C5 palsy persists.

PAPER 25 continued

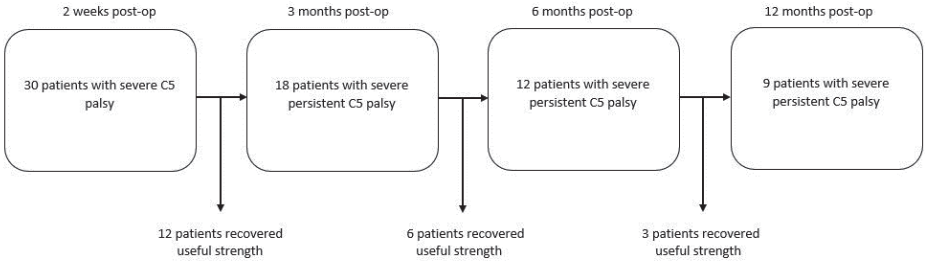
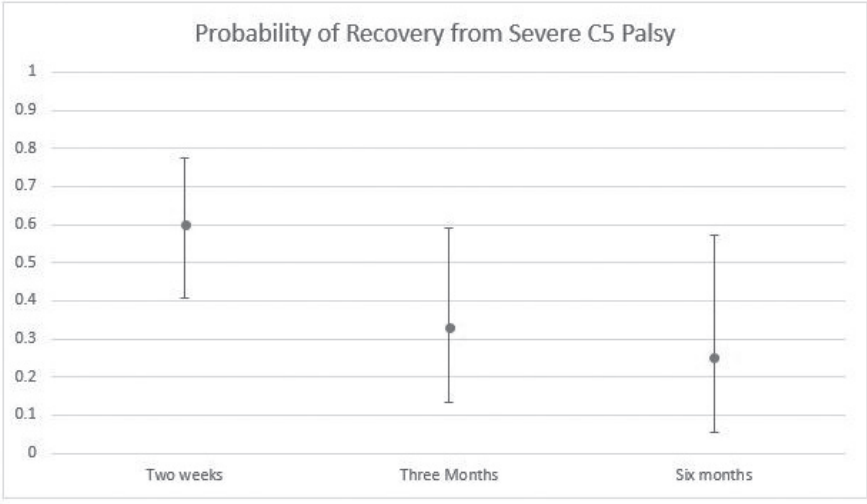


Figure 2 – chart demonstrating the probability of recovery to useful strength at different time points following severe post-operative C5 palsy.



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

PAPER 26

Risk Factors, Incidence and Mortality of Patients of Vertebral Artery Injury in Patients Undergoing Anterior Cervical Corpectomy: A Retrospective Large National Data Base Study

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Introduction: Anterior cervical decompression by removal of vertebral body, known as corpectomy, is a commonly used surgical technique for treating cervical spondylotic myelopathy or radiculopathy. Injury to the vertebral artery (VAI) during anterior corpectomy is a well-recognized complication of surgery with a reported incidence ranging from 0.07% [1] to 2.2% [2]. Given that the aberrancy in vertebral artery course, concerns for VAI are more significant with full or partial corpectomies compared to routine discectomies.

VAI can be of significant consequence as it can result in stroke or death if hemodynamic instability is severe [3-5]. Although there are reports of these complications associated with VAI, much of the literature consists primarily of small case series [1-6]. Because of the rarity of the complication the true incidence of VAI remains unclear, and the demographic of patients and long-term mortality and morbidity is not well described in the literature. This present study aims to quantify the incidence of VAI and identify risk factors and related complications using a large commercial database.

Materials and Methods: This study was a retrospective cross-sectional review of anterior cervical corpectomy procedures during the years 2010 to 2017 and their corresponding rates of VAI using the PearlDiver Inc database [7]. The PearlDiver database includes 91 million anonymized and longitudinal HIPAA-compliant medical record claims data from all payers except Kaiser and Tricare throughout the United States.

Inclusion criteria consisted of any patient who underwent a corpectomy procedure, identified using the CPT code, 63081, while VAI were identified using their corresponding ICD-10 and ICD-9 diagnosis codes (Table 1). Patient data, including age, gender, ICD-10 diagnosis codes, CPT codes, obesity status, tobacco use status, osteoporosis status, diabetes status, both Charlson and Elixhauser comorbidity Index (ECI) scores, and one year mortality rates were collected. The risk were calculated compared with those patients who did not have VAI.

Results: 26,126 patients were identified to have undergone cervical corpectomy. Vertebral artery injuries occurred in 78 patients at an incidence of 0.3%. Multivariate analysis of risk factors showed that younger age and male sex were associate with higher rate of injury ($t=-11.5$; $p<0.0001$ and $t=3.8$; $p=0.0001$, respectively).

Same admission death or VAI were rare. However, in follow up period, 11(14%) VAI patients had a cerebral infarction compared with 1705(7%) for non-VAI patients (OR=2.13; 95% CI=[1.18 – 3.85; p=0.0179]). 1-year mortality rates were also higher in patients who suffered a VAI (14%) compared to those who did not suffer a VAI (4%; OR=3.85; CI=[2.04 – 7.14]; $p<0.0001$).

Conclusion: VAI is rare injury that occurs in 0.3% of all cervical corpectomy cases. Post-operatively, patients with VAI are at increased risk for cerebral vascular impairment and death [1,3], however few of these complication and mortality occurred during the hospitalization for index surgery. Therefore consequence of VAI injury may not be known for months following

PAPER 26 continued

the injury and safely getting patients through the initial hospitalization is not enough. This study suggests that further investigations into long term health risk of VAI is needed.

Table 2. Factors associated with rates of vertebral artery injury.

	WITH VAI n = 78	NO VAI n = 26048	P-VALUE	OR	LOWER LIMIT	UPPER LIMIT
Age (±SD)	41.1 (17.4)	56.8 (11.8)	> 0.0001			
ECI	2.8 (2.7)	3.5 (3.1)	0.01720			
MALE	52 (67%)	12505 (48%)				
FEMALE	26 (33%)	13543 (52%)	0.00147	2.17	3.45	1.35
OBESE	25 (32%)	8882 (34%)				
NOT OBESE	53 (68%)	17166 (66%)	0.79390	1.1	0.68	1.77
TOBACCO USE	7 (9%)	2592 (10%)				
NO TOBACCO USE	71 (71%)	23456 (90%)	0.92170	1.12	0.52	2.44
DIABETES	16 (21%)	9740 (37%)				
NO DIABETES	62 (79%)	16308 (63%)	0.00308	0.43	0.75	0.25
CEREBRAL INFARCTION	11 (14%)	1705 (7%)				
NO CEREBRAL INFARCTION	67 (86%)	24343 (93%)	0.01384	2.13	3.85	1.18
SUBARACHNOID HEMORRHAGE	2 (3%)	63 (0%)				
NO SUBARACHNOID HEMORRHAGE	76 (97%)	25985 100%)	0.00295	6.67	25.00	1.61

Table 3. Non-propensity matched and propensity matched vertebral artery injury 1-year mortality rates.

ALL CORPECTOMIES	WITH VAI n = 78	NO VAI n = 26048	P-VALUE	OR	LOWER LIMIT	UPPER LIMIT
DECEASED (1-YEAR)	11	1056				
NOT DECEASED (1-YEAR)	67	24992	> 0.0001	3.85	7.14	2.04
PROPENSITY MATCHED	**WITH VAI n = 78**	**NO VAI n = 78**	**P-VALUE**	**OR**	**LOWER LIMIT**	**UPPER LIMIT**
DECEASED (1-YEAR)	11	2				
NOT DECEASED (1-YEAR)	67	76	0.02	6.24	1.33	29.16

PAPER 27

Surgical Complications and Insufficient Canal Widening of the Vertebral Body Sliding Osteotomy for the Treatment of Cervical Myelopathy

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Introduction: Vertebral body sliding osteotomy (VBSO) is a surgical technique that involves anterior translation of the vertebral body with compressive lesions such as ossification of the posterior longitudinal ligament (OPLL), disc, or spurs. Fewer complications, improved lordosis restoration, and faster bone union with VBSO than corpectomy have been reported. However, data on the surgical complications of VBSO are lacking. Furthermore, VBSO achieves cord decompression through canal widening (Figure 1) instead of complete removal of compressive lesions; thus, understanding the incidence and risk factors associated with incomplete canal widening is important. We therefore conducted this study to describe the incidence of VBSO-associated surgical complications, and evaluate the incidence and risk factors of insufficient canal widening.

Materials and Methods: Patients who underwent VBSO to treat cervical myelopathy and were followed up for more than 2 years were retrospectively reviewed. C2-C7 cervical lordosis, C2-C7 sagittal vertical axis, and canal occupying ratio (COR) were measured. Patient-reported outcome measures including neck pain visual analog scale, neck disability index, Japanese Orthopedic Association (JOA) scores, and surgical complications were recorded. Patients with preoperative COR <50% and COR ≥50% were compared. Logistic regression analysis was performed to identify factors associated with incomplete canal widening (postoperative COR >20%).

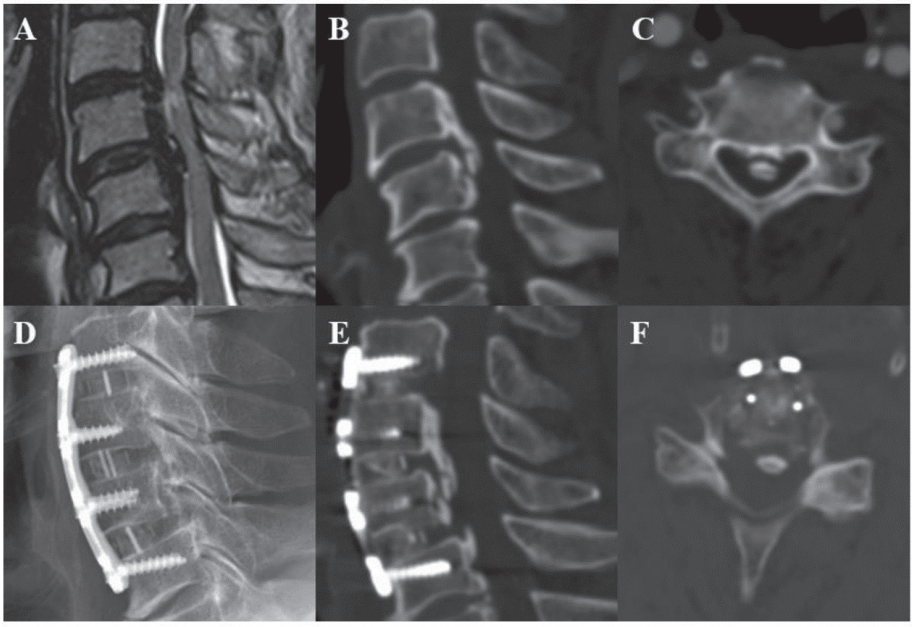
Results: Among the 109 patients, 60 (55.0%) were included in the COR <50% group, and 49 patients (45.0%) in the COR ≥50% group (Table 1). The most frequent complication was mild dysphagia (7.3%). Dural tears were observed in two patients (1.8%); one occurred during posterior longitudinal ligament resection and the other during foraminotomy. Two patients (1.8%) underwent reoperation due to radiculopathy from adjacent segment disease. Other complications are summarized in Table 2. Insufficient canal narrowing occurred in 21 patients (19.3%; postoperative COR, 24.8 ± 3.8%). Logistic regression analysis demonstrated that high preoperative COR was the only factor associated with insufficient narrowing (95% CI: 1.008–1.122; odds ratio, 1.063; p=0.024). The amount of canal widening was significantly greater in the COR ≥50% group (p<0.001); however, postoperative COR did not demonstrate a significant difference between the two groups (p=0.169). The JOA recovery rate was significantly higher in the COR ≥50% group compared with the COR <50% group (p=0.005) (Table 1).

Conclusion: Although VBSO aims to decrease the complication rate of corpectomy, it was not free of dural tears. Special care would be required during ligament resection around OPLL masses. Insufficient canal widening occurred in 19.3% of patients, and high preoperative COR was the only risk factor for insufficient canal widening. However, greater canal widening occurred in the COR ≥50% group, leading to a higher JOA recovery rate; thus, high COR would not be a contraindication for VBSO. In conclusion, dural tears may still occur despite VBSO minimizing the need for OPLL lesion manipulation, so caution is warranted. Although high preoperative COR is a risk factor for insufficient canal widening, favorable clinical outcomes can

PAPER 27 continued

be expected in patients with a COR ≥50%.

Figure 1. A representative case of a patient who underwent vertebral body sliding osteotomy. A 71-year-old man with ossification of the posterior longitudinal ligament (OPLL)



(A, B, C) Preoperative MRI and CT images of the patient, showing a canal occupying ratio of 69%. (D, E, F) Postoperative radiograph and CT images of the patient, showing a significant decrease in canal occupying ratio to 9%. Cervical Japanese Orthopaedic Association (C-JOA) score recovery rate of the patient was 100%, from a C-JOA score of 11 (preoperative) to 17 (postoperative).

PAPER 27 continued

Table 1. Patient characteristics, radiographic and clinical results

		Preop COR <50%	Preop COR ≥50%	p value
Patient characteristics	Age	59.0 ± 8.9	60.6 ± 13.5	0.714
	Sex			
	Male	41 (68.3%)	32 (65.3%)	0.738
	Female	19 (31.7%)	17 (34.7%)	
	BMI	24.9 ± 3.2	25.4 ± 3.3	0.550
	Smoking status	17 (28.3%)	10 (20.4%)	0.340
	OPLL	51 (85.0%)	44 (89.8%)	0.457
	CSM	9 (15.0%)	5 (10.2%)	
	Number of operated segments	2.7 ± 0.5	2.9 ± 0.3	0.015*
	F/U period	46.9 ± 23.3	43.4 ± 23.5	0.546
Preoperative	Preop radiographic measurement			
	C2-C7 lordosis	7.2 ± 6.2	10.0 ± 7.1	0.093
	C2-C7 SVA	19.1 ± 21.4	21.4 ± 12.7	0.448
	Canal occupying ratio	38.4 ± 9.0	60.7 ± 8.0	<0.001*
	Preop patient-reported outcomes			
	Neck pain VAS	2.3 ± 2.6	3.6 ± 2.4	0.178
	NDI	12.7 ± 7.7	14.7 ± 8.3	0.497
	JOA score	13.8 ± 1.9	13.3 ± 2.2	0.512
Postoperative	Postop radiographic measurement			
	C2-C7 lordosis	12.3 ± 5.7	16.5 ± 11.3	0.171
	C2-C7 SVA	18.6 ± 8.4	19.1 ± 11.7	0.885
	Canal occupying ratio	6.3 ± 10.2	9.7 ± 9.8	0.169
	Canal widening	32.2 ± 11.3	50.9 ± 10.5	<0.001*
	Insufficient widening	9 (15.0%)	12 (24.5%)	0.211
	Postop patient-reported outcomes			
	Neck pain VAS	2.4 ± 2.4	1.7 ± 2.1	0.410
	NDI	8.1 ± 5.9	6.8 ± 7.2	0.592
	JOA score	14.8 ± 1.5	15.9 ± 1.4	0.076
	JOA recovery rate (%)	23.6 ± 32.2	68.0 ± 36.4	0.005*

COR, canal occupying ratio; preop, preoperative; BMI, body mass index; OPLL, ossification of the posterior longitudinal ligament; CSM, cervical spondylotic myelopathy; SVA, sagittal vertical axis; VAS, visual analogue scale; NDI, neck disability index; JOA, Japanese Orthopedic Association; postop, postoperative.

Categorical variables were analyzed using the chi-square test or Fisher's exact test.

Continuous variables were analyzed using Student's *t*-test

* p-value < 0.05

PAPER 27 continued

Table 2. Surgical complications

	Incidence	%
Dural tear	2	1.8
Neurological deterioration	0	0.0
Infection	0	0.0
Reoperation	2	1.8
Graft dislodgement	0	0.0
Dysphagia	8	7.3
C5 palsy	5	4.6

PAPER 28

Low Preoperative Serum Calcium Levels Predict Perioperative Medical Complications and Healthcare Utilization in Patients Undergoing ACDF

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Introduction: Calcium and Vitamin D are essential for bone homeostasis; however, many patients undergoing spine surgery may be at risk for deficiency. Vitamin D deficiency has been associated with worsened patient-reported outcomes and higher risk of pseudarthrosis, while the literature regarding preoperative serum calcium levels and spine surgery outcomes is sparse.[1,2] The present study intends to analyze the effects of preoperative serum calcium and vitamin D levels on medical complications and postoperative health resource utilization in patients undergoing anterior cervical discectomy and fusion (ACDF). A secondary aim is to identify discriminative lab values to preoperatively identify high-risk patients.

Materials and Methods: Patients ≥18 years who underwent ACDF from 2002 - 2021 at a multi-site academic center were included. Basic demographic data, medical and surgical history, as well as the latest preoperative serum vitamin D and serum calcium values within 3 months of surgery were included. Primary endpoints were major medical complications within 90 days (acute myocardial infarction, cardiac arrest, deep vein thrombosis, pulmonary embolism, respiratory distress, pneumonia, sepsis, and stroke), minor medical complications within 90 days (anemia, delirium, dysphagia, nausea, vomiting, and urinary retention), 90-day readmissions, 90- and 365-day reoperation, and emergency department (ED)/urgent care (UC) utilization rates. Univariate analyses were performed using independent, two-tailed Welch's t-tests. Outcomes significant on univariate analysis were evaluated using multivariate binomial logistic regression. Significant outcomes on multivariate analysis were further analyzed using Receiver Operating Characteristic (ROC) curves. Youden's Index was used to identify optimal cutoffs. ROC curves were assessed using Area under the ROC Curve (AUC) measurements and Mann-Whitney U tests.

Results: A total of 1,810 patients with serum calcium levels and 453 individuals with vitamin D measurements were included (Table 1). Univariate analysis found significantly lower levels of serum calcium in patients with readmissions within 90 days ($p<0.001$), major medical complications ($p<0.001$), ED/UC use ($p<0.001$), 90-day reoperations ($p=0.012$), and 365-day reoperations ($p=0.031$) (Table 2). Vitamin D levels were not significantly associated with any outcome. In multivariable analysis, each unit increase in calcium levels (mg/dL) corresponded to lower odds of 90-day readmission (OR: 0.511; CI: 0.359 - 0.728, $p<0.001$), major medical complications (OR: 0.466; CI: 0.329-0.660, $p<0.001$), 90-day reoperation (OR: 0.483; CI: 0.239-0.978, $p=0.043$), and ED/UC utilization (OR: 0.664; CI: 0.490-0.900, $p=0.008$). ROC curve analysis revealed serum calcium cutoffs of ≤9.0 mg/dL predictive of major medical complications (39% sensitivity, 76% specificity, AUC: 0.61 ± 0.05, $p<0.001$), ≤9.4 mg/dL predictive of 90-day readmissions (67% sensitivity, 53% specificity, AUC: 0.62 ± 0.05, $p<0.001$), ≤9.0 mg/dL predictive of 90-day reoperations (50% sensitivity, 81% specificity, AUC: 0.66 ± 0.10, $p=0.002$), ≤9.4 mg/dL predictive of emergency department/urgent care use (59% sensitivity, 53% specificity, AUC:

PAPER 28 continued

0.57 ± 0.04, p<0.001) (Figure 3).

Conclusion: Lower serum calcium levels were associated with worsened outcomes following ACDF surgery in this study. Further studies need to be done to explore the role of hypocalcemia and outcomes after cervical fusion.

Table 1: ACDF Sample Demographics

Characteristic	Calcium, *N = 1810*	Vitamin D, *N = 453*
Age	55.5 (12.1)**	57.9 (12.2)**
BMI	29.9 (8.4)**	30.1 (6.5)**
Gender:		
Male	888 (49.1%)	202 (44.6%)
Female	922 (50.9%)	251 (55.4%)
Fusion Type:		
Single Level	713 (39.4%)	154 (34.0%)
Multi Level	1097 (60.6%)	299 (66.0%)
Serum Value	9.4 mg/dL (0.5)**	36.3 mg/dL (19.1)**
ASA Class:		
Class 1	59 (3.3%)	6 (1.3%)
Class 2	988 (54.6%)	215 (47.5%)
Class 3	739 (40.8%)	225 (49.7%)
Class 4	24 (1.3%)	7 (1.5%)

Values shown as N (%).
** denotes Mean (Standard Deviation)

PAPER 28 continued

Table 2: ACDF Univariate and Multivariate Results - Calcium and Vitamin D

Outcome Variable	Calcium			Vitamin D		
	Univariate	Multivariate		Univariate	Multivariate	
	P-value	Adjusted OR (95% CI)	P-value	P-value	Adjusted OR (95% CI)	P-value
ED/UC Visit	0.001*	0.664 (0.490, 0.900)	0.008*	0.101	–	–
Major Medical Complication	<0.001*	0.466 (0.329, 0.660)	<0.001*	0.168	–	–
Minor Medical Complication	0.126	–	–	0.547	–	–
Reoperation:						
within 90 days	0.012*	0.483 (0.239, 0.978)	0.043*	0.192	–	–
within 1 year	0.031*	0.558 (0.308, 1.010)	0.054	0.158	–	–
Readmission within 90 days	<0.001*	0.511 (0.359, 0.728)	<0.001*	0.611	–	–

* denotes statistical significance as defined by p<0.05.
Abbreviations: Emergency Department (ED), Urgent Care (UC)

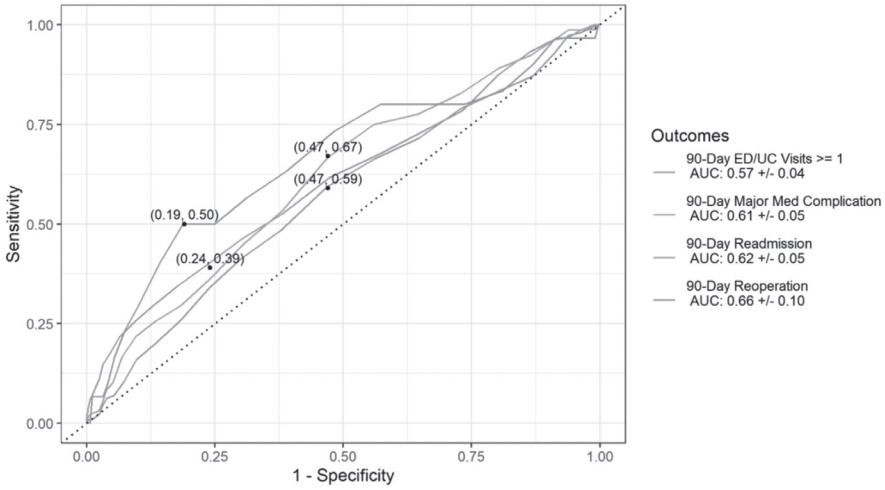

Figure 3. Receiver Operating Characteristic Curves for Predicting Medical Complications and Postoperative Healthcare Utilization Using Preoperative Calcium Levels. The AUC for 90-day ED/UC visits was 0.57, and the optimal cutoff value was 9.4 mg/dL. The AUC for 90-day major medical complications was 0.61 with an optimal cutoff value of 9.0 mg/dL. The AUC for 90-day readmission was 0.62 with an optimal cutoff value of 9.4. The AUC for 90-day reoperations was 0.66 and the optimal cutoff value was 9.0 mg/dL.

Abbreviations: AUC: Area Under the ROC Curve; ED: Emergency Department; UC: Urgent Care

PAPER 29

Is Complete Correction of Cervical Sagittal Malalignment Necessary During 4-Level Anterior Cervical Discectomy and Fusion Surgery in Patients With Kyphosis?

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Introduction: We investigated whether complete correction of cervical sagittal malalignment is necessary during 4-level anterior cervical discectomy and fusion (ACDF) in patients with kyphosis.

Materials and Methods: This retrospective study included 84 patients who underwent 4-level ACDF surgery at a university hospital between January 2010 and December 2015. Based on the degree of cervical lordosis correction, patients were categorized into the following groups: mild (0-10), moderate (10-20), and complete correction (>20). The clinical outcomes, radiological parameters, and functional outcomes were analyzed.

Results: We observed no significant intergroup differences in the baseline characteristics. The cervical sagittal vertical axis (CSVA) correction loss at the final follow-up was lesser in the mild- and moderate- than in the complete-correction group. The spinocranial angle (SCA) and T1 slope (T1 S) were significantly higher in the moderate- and complete-correction groups than in the mild-correction group, 3 days postoperatively. The cervical proximal junctional kyphosis (CPJK), adjacent segment degeneration (ASD), and ASD following CPJK rates were higher in the complete-correction group. We observed no significant intergroup differences in postoperative complications; however, 5 patients showed internal fixation failure in the completecorrection group; 4 of these patients required reoperation. No significant intergroup difference was observed in the Japanese Orthopedic Association and neck disability index scores at any time point.

Conclusion: A mild-to-moderate correction of cervical lordosis is superior to complete correction in patients with kyphosis who undergo 4-level ACDF because this approach is associated with lesser axial stress and CSVA correction loss.

PAPER 29 continued

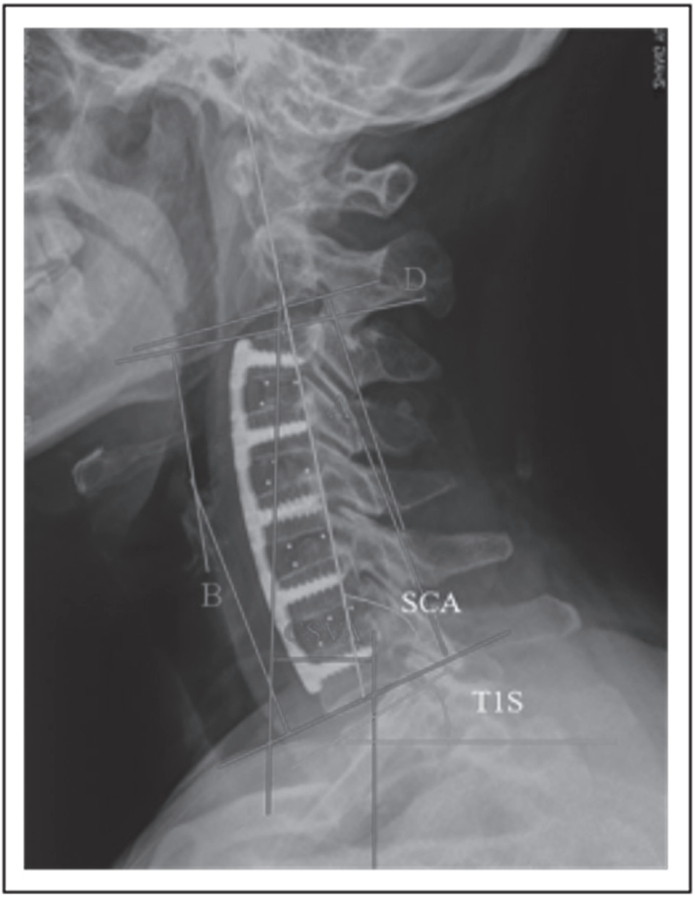

Figure 1. Lateral radiograph of the cervical spine showing measurements of the C2-7 Cobb angle (Angle A), Cobb angle of the fused segments (Angle B), proximal junctional sagittal Cobb angle (Angle D) and the CSVA, SCA and T1S. CSVA, cervical (C2-7) sagittal vertical axis; SCA, spinocranial angle; T1S, T1 slope.

PAPER 29 continued

Table 1. Baseline Characteristics of Study Population.

Variables	Mild	Moderate	Complete	*P* value
Number of patients	28	24	32	NA
Age	64.60 ± 9.88	65.80 ± 12.16	66.12 ± 9.41	.926
Sex (Male/female)	13/15	10/14	17/15	.540
BMI	25.13 ± 4.39	24.17 ± 3.85	25.72 ± 4.31	.596
Hospital Stay (days)	5.33 ± 0.81	5.20 ± 0.86	5.27 ± 0.88	.913
Duration of follow-up (months)	65.13 ± 10.78	64.5 ± 9.58	63.7 ± 7.67	.761

Abbreviations: NA, not applicable; BMI, body mass index.

Table 2. Comparison of Radiographic Parameters Between the 3 Groups.*

Variables	Mild	Moderate	Complete
Preoperative angle A (°)	−5.90 ± 3.10	−5.41 ± 3.88	−5.75 ± 4.68
Preoperative angle B (°)	−4.59 ± 3.67	−5.48 ± 3.19	−4.86 ± 4.63
Postoperative angle B (°)	3.72 ± 1.15	10.76 ± 2.92*	17.18 ± 2.10*#
Angle C (°)	8.30 ± 1.22	16.07 ± 2.42*	22.04 ± 2.04*#
Preoperative CSVA (mm)	25.22 ± 6.67	24.64 ± 4.98	26.34 ± 7.42
CSVA at 3 days postoperatively (mm)	15.36 ± 2.44	14.98 ± 3.26	15.96 ± 3.38
Loss correction of CSVA (mm)	1.99 ± 2.03	1.88 ± 2.94	8.44 ± 5.78*#
Preoperative SCA (°)	93.60 ± 8.34	94.08 ± 9.33	93.49 ± 9.29
SCA at 3 days postoperatively	85.26 ± 7.37	80.58 ± 6.34*	76.59 ± 6.67*#
Preoperative T1S (°)	−13.16 ± 6.30	−13.65 ± 7.94	−12.92 ± 5.52
T1S at 3 days postoperatively	−24.22 ± 3.14	−26.89 ± 4.26*	−30.02 ± 3.08*#

* The angle A (C2-7 Cobb angle) was defined as the angle between the perpendicular lines to the lines parallel to the inferior endplates of C2 and C7 vertebral bodies; The angle B (Cobb angle of the fused segment) refers to the angle formed by the lines parallel to the upper plane and the lower plane of the fused segment; Angle C = (postoperative–preoperative) angle B; CSVA (C2-C7 sagittal vertical axis) refers to the distance from the posterior, superior corner of C7 to the plumbline from the centroid of C2; SCA is defined between the C7 slope and the straight line joining the middle of C7 endplate and the middle of the sella turcica. T1S is defined between a horizontal line and the line parallel to the superior endplate of T1.
** $P < .05$ versus mild correction group.
# $P < .05$ compared with moderate correction group; Negative sign indicates kyphosis in the values.

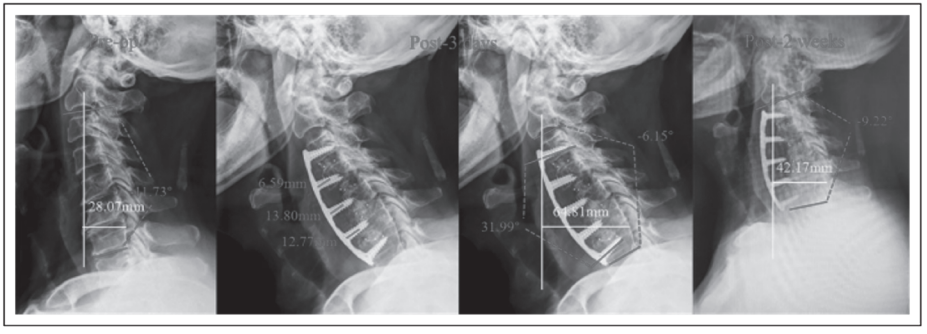

Figure 4. Image showing internal fixation failure secondary to complete correction of cervical lordosis in a representative case of a 65-year-old man without osteoporosis. Cervical lordosis correction is approximately 40°. Screw loosening gradually worsened over the first 2 weeks postoperatively, and the cervical spine curvature gradually returned from a lordotic to kyphotic pattern. Preoperative findings: Cobb angle −11.73°, CSVA 28.07 mm; 3 days postoperatively: Cobb angle −6.15°, CSVA 64.81 mm; 2 weeks postoperatively: Cobb angle −9.22°, CSVA 42.17 mm. CSVA indicates, cervical sagittal vertical axis.

PAPER 30

Identifying the Impact of Body Mass Index on Surgical and Patient Outcomes for Cervical Spine Surgery

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Introduction: The impact of body mass index (BMI) on cervical spine surgery is unknown, with controversial outcomes for patients high and low BMI. We aim to investigate the effects of body mass index (BMI) on postsurgical cervical spine surgery outcomes and identify a potential substratification of obesity with worse outcomes.

Materials and Methods: The cervical spine Quality Outcomes Database (QOD) was queried for a total of 10,381 patients who underwent single-stage cervical spine surgery with known baseline outcomes meeting inclusion criteria. Patients were substratified into six groups including underweight, (BMI less than 18), normal (BMI 20-25), overweight (BMI 25-30), class I Obesity (BMI 30-35), class II Obesity (BMI 35-40), and class III Obesity (BMI > 40). Surgical outcomes, complications, hospitalization outcomes, and patient reported outcomes for each cohort included mJOA, NRS-AP, NRS-NP, NDI, and EQ-5D were assessed. We performed univariate and multivariate analysis for 3- and 12-month follow-up after surgical intervention.

Results: Obese patients (class I, II, III) requiring spine surgery were statistically younger than nonobese patients and had higher rates of diabetes compared to normal BMI patients. Class III obese patients had longer hospitalizations ($p = 0.02$), greater blood loss and longer surgical timing ($p < 0.001$). Surgical length was found to be longer for overweight and all classes of obese patients ($p < 0.01$). Class III obese patients had higher odds of postoperative complications. Underweight patients had a higher rate of readmission at 3 months. Baseline PROs for patients with class II and III obesity were significantly worse than normal BMI patients ($p < 0.05$). Patients with class II and III obesity had lower odds at achieving optimal mJOA at 3-months (OR = 0.8 (0.67 - 0.94), $p < 0.01$, OR = 0.68 (0.56 - 0.82), $p < 0.001$, respectively) and 12-months (OR = 0.82 (0.68 - 0.98), $p = 0.03$, OR = 0.79 (0.64 - 0.98), $p = 0.03$, respectively). At 3-month follow-up, class III obese patients had lower odds of achieving MCID (OR = 0.75 (0.60 - 0.93), $p = 0.01$).

Conclusion: This study investigates the relationship between substratified BMI and postoperative outcomes of cervical spine surgery. Class II and III obese patients have substantially greater risk factors and poor outcomes postoperatively. Additionally, low BMI also presents unique challenges for patients. Further research is needed for comprehensive analysis on outcomes of cervical spine surgery after correcting BMI.

PAPER 30 continued

Table 2. Comparison of Baseline Clinical Factors by BMI Class

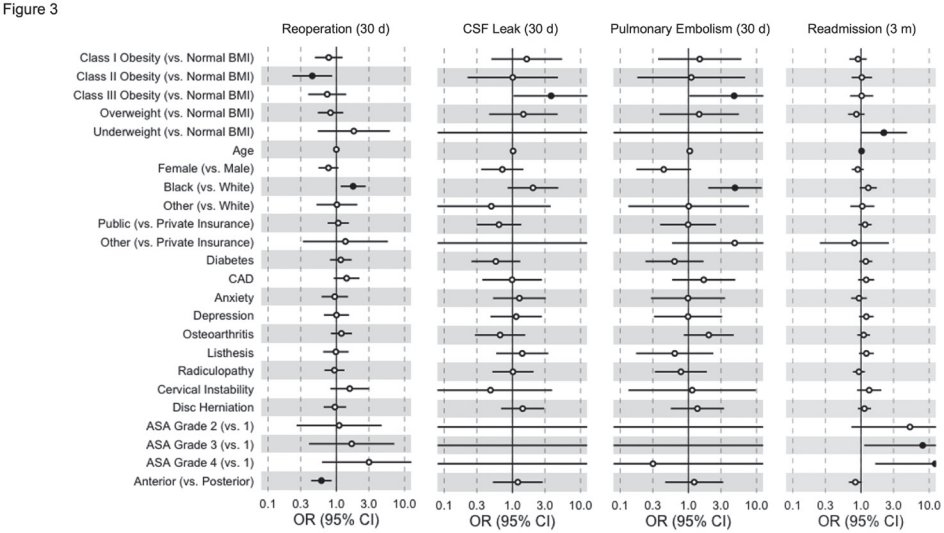
	Normal BMI	Class I Obesity	Class II Obesity	Class III Obesity	Overweight	Underweight	p
N	**2059**	**2562**	**1329**	**885**	**3456**	**88**	
Comorbidities							
Diabetes	252 (12.2)	740 (28.9)	443 (33.4)	339 (38.3)	655 (19.0)	7 (8.0)	<0.001
CAD	169 (8.2)	307 (12.0)	136 (10.3)	109 (12.3)	428 (12.4)	6 (6.8)	<0.001
PVD	43 (2.4)	75 (3.3)	35 (3.0)	21 (2.6)	90 (2.9)	2 (2.6)	0.643
Anxiety	436 (21.2)	583 (22.8)	341 (25.7)	240 (27.1)	703 (20.4)	23 (26.1)	<0.001
Depression	471 (22.9)	676 (26.4)	410 (30.9)	291 (32.9)	784 (22.7)	23 (26.1)	<0.001
Osteoarthritis	378 (21.0)	564 (24.9)	351 (29.8)	250 (31.5)	684 (22.5)	23 (30.3)	<0.001
Chronic Renal Disease	70 (3.9)	99 (4.3)	65 (5.5)	41 (5.1)	135 (4.4)	2 (2.6)	0.296
Pain Location							<0.001
Neck Pain	733 (35.6)	872 (34.0)	415 (31.2)	278 (31.4)	1164 (33.7)	32 (36.4)	
Arm Pain	353 (17.2)	441 (17.2)	233 (17.5)	178 (20.1)	630 (18.2)	12 (13.6)	
Neck = Arm Pain	678 (33.0)	930 (36.3)	531 (40.0)	351 (39.7)	1189 (34.4)	37 (42.0)	
No Pain	293 (14.2)	318 (12.4)	150 (11.3)	78 (8.8)	471 (13.6)	7 (8.0)	
Motor Deficit	1131 (55.0)	1411 (55.1)	749 (56.4)	500 (56.6)	1914 (55.4)	52 (59.1)	0.892
Ambulation							<0.001
Independent	1728 (83.9)	2091 (81.6)	1060 (79.8)	639 (72.2)	2897 (83.8)	73 (83.0)	
With Assist Device	302 (14.7)	427 (16.7)	237 (17.8)	227 (25.6)	506 (14.6)	13 (14.8)	
Non-ambulatory	29 (1.4)	43 (1.7)	32 (2.4)	19 (2.1)	53 (1.5)	2 (2.3)	
Listhesis	419 (22.0)	398 (16.8)	176 (14.6)	125 (15.1)	640 (20.4)	20 (24.7)	<0.001
Radiculopathy	744 (36.1)	992 (38.7)	527 (39.7)	359 (40.6)	1358 (39.3)	24 (27.3)	0.025
Myelopathy	1984 (96.4)	2465 (96.3)	1281 (96.4)	857 (96.8)	3327 (96.3)	86 (97.7)	0.948
Neck Pain	64 (3.1)	56 (2.2)	18 (1.4)	24 (2.7)	94 (2.7)	1 (1.1)	0.024
Surgical Diagnosis							
Herniated Disc	589 (28.6)	818 (31.9)	450 (33.9)	317 (35.8)	1050 (30.4)	24 (27.3)	0.001
Foraminal Stenosis	928 (45.1)	1153 (45.0)	623 (46.9)	390 (44.1)	1563 (45.3)	38 (43.2)	0.818
Central Stenosis	1483 (72.1)	1837 (71.7)	970 (73.0)	642 (72.5)	2495 (72.3)	63 (71.6)	0.972
Cervical Instability	120 (5.8)	110 (4.3)	44 (3.3)	38 (4.3)	146 (4.2)	6 (6.8)	0.011
Pseudoarthrosis	21 (1.0)	21 (0.8)	8 (0.6)	9 (1.0)	35 (1.0)	0 (0.0)	0.662
Adjacent Segment Disease	96 (4.7)	142 (5.5)	80 (6.0)	55 (6.2)	199 (5.8)	7 (8.0)	0.346

Table 1. Comparison of Patient Demographics by BMI Class

	Normal BMI	Class I Obesity	Class II Obesity	Class III Obesity	Overweight	Underweight	p
N	**2059**	**2562**	**1329**	**885**	**3456**	**88**	
Age (mean (SD))	60.86 (12.30)	59.94 (11.05)	58.18 (11.06)	55.66 (10.65)	61.16 (11.63)	60.38 (11.55)	<0.001
Female (%)	1110 (53.9)	1134 (44.3)	709 (53.3)	556 (62.8)	1336 (38.7)	56 (63.6)	<0.001
Smoker (%)	604 (29.5)	487 (19.1)	214 (16.2)	139 (15.8)	716 (20.9)	43 (48.9)	<0.001
Race							<0.001
White	1729 (84.2)	2081 (81.3)	1060 (79.9)	700 (79.1)	2900 (84.0)	78 (88.6)	
Black	191 (9.3)	317 (12.4)	189 (14.3)	134 (15.1)	355 (10.3)	7 (8.0)	
Other	134 (6.5)	161 (6.3)	77 (5.8)	51 (5.8)	198 (5.7)	3 (3.4)	
Education Level							<0.001
Less than high school	133 (6.7)	165 (6.7)	66 (5.1)	50 (5.9)	216 (6.5)	7 (8.5)	
High school Diploma or GED	856 (43.1)	1149 (46.7)	620 (48.2)	422 (49.8)	1435 (43.2)	43 (52.4)	
2-year College Degree	322 (16.2)	452 (18.4)	249 (19.4)	162 (19.1)	555 (16.7)	12 (14.6)	
4-year College Degree	371 (18.7)	419 (17.0)	228 (17.7)	135 (15.9)	643 (19.4)	14 (17.1)	
Post-college	304 (15.3)	274 (11.1)	123 (9.6)	79 (9.3)	470 (14.2)	6 (7.3)	
Employement							0.002
Employed and Currently Working	682 (33.3)	944 (36.9)	471 (35.5)	317 (35.9)	1267 (36.7)	24 (27.3)	
Employed and on leave	143 (7.0)	212 (8.3)	123 (9.3)	86 (9.7)	242 (7.0)	9 (10.2)	
Unemployed	1221 (59.5)	1399 (54.7)	732 (55.1)	475 (53.8)	1939 (56.2)	55 (62.5)	
Attending School	5 (0.2)	3 (0.1)	2 (0.2)	5 (0.6)	5 (0.1)	0 (0.0)	
Insurance							<0.001
Private	931 (45.2)	1300 (50.7)	688 (51.8)	494 (55.8)	1756 (50.8)	36 (40.9)	
Public	1100 (53.4)	1233 (48.1)	617 (46.5)	374 (42.3)	1672 (48.4)	50 (56.8)	
Uninsured	28 (1.4)	29 (1.1)	23 (1.7)	17 (1.9)	27 (0.8)	2 (2.3)	

PAPER 30 continued

Figure 3



PAPER 31

Adverse Clinical Outcomes After Anterior Cervical Discectomy and Fusion Correlate Better with Degree of Facet Distraction Measured Using Computed Tomography Than Using Radiography

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Introduction: Anterior cervical discectomy and fusion (ACDF) is the gold standard treatment for patients with radicular pain and myelopathy. However, ACDF itself has the potential risk of inducing facet-mediated pain through over-distraction. Notably, the relationship between the clinical outcome and facet distraction after ACDF remains unclear. The reason may be that measurement using radiography is not in the true lateral position or is inappropriate for measuring facet distraction, which is a significantly small unit. Therefore, this study aimed to measure facet distraction using computed tomography (CT) and compare the results with clinical outcomes.

Materials and Methods: Overall, 144 patients who underwent single-level ACDF were included in this study. Each patient underwent upright, lateral cervical spine radiography preoperatively and immediately to 2 years after surgery. CT was performed 3 days and 1 year after surgery. The inter-facet distance of the operated segment was measured at each time point, and the change values from the preoperative distance were obtained. Patient-reported outcome measures including the neck and arm pain visual analogue scale (VAS) scores, neck disability index (NDI), and short form health survey (SF-36) scores were obtained preoperatively and 3 and 6 weeks and 3 and 6 months postoperative and at the 1- and 2-year follow-up visits. Receiver operating characteristic (ROC) curves were generated to derive the critical facet distraction amount contributing to adverse clinical outcomes.

Results: The neck pain VAS score showed a tendency to decrease during the follow-up period, and the neck pain VAS score at 3 weeks postoperatively (4.81 ± 2.11) was most severe. There was a significant positive correlation between facet distraction measured using CT 3 days postoperatively and neck pain VAS score 3 weeks postoperatively (Table 1, Spearman's correlation coefficient: 0.703, $P<0.001$). Facet distraction measured using radiography showed less correlation with neck pain VAS score at all time points than CT. An ROC curve analysis showed that the cut-off value of facet distraction was 1.8 mm for neck pain VAS score ≥ 4 (area under the curve = 0.901, sensitivity = 87%, specificity = 81%) (Fig. 1). Based on the cut-off value of facet distraction of 1.8 mm, the patients were divided into Group C (Control group; facet distraction <1.8 mm, n = 69) and Group O (Over-distraction group; facet distraction ≥1.8 mm, n = 75). Group O showed significant worse clinical outcomes than Group C, including neck and arm pain VAS scores at all time points until the final 2-year follow-up (Table 2).

Conclusion: Our results showed that facet distraction measured using CT rather than radiography correlated better with neck pain, and over-distraction contributed to adverse long-term outcomes, including neck and arm pain after ACDF. Since the inter-facet distance is measured in millimeters and it is difficult to obtain radiographs true lateral to the corresponding level, it is better to evaluate the degree of over-distraction using CT. Additionally, an over-distraction ≥ 1.8 mm may cause radiculopathy of adjacent segments along with facet mediated axial pain; therefore, care should be taken to plan the cage height,

PAPER 31 continued

avoiding over-distraction during ACDF.

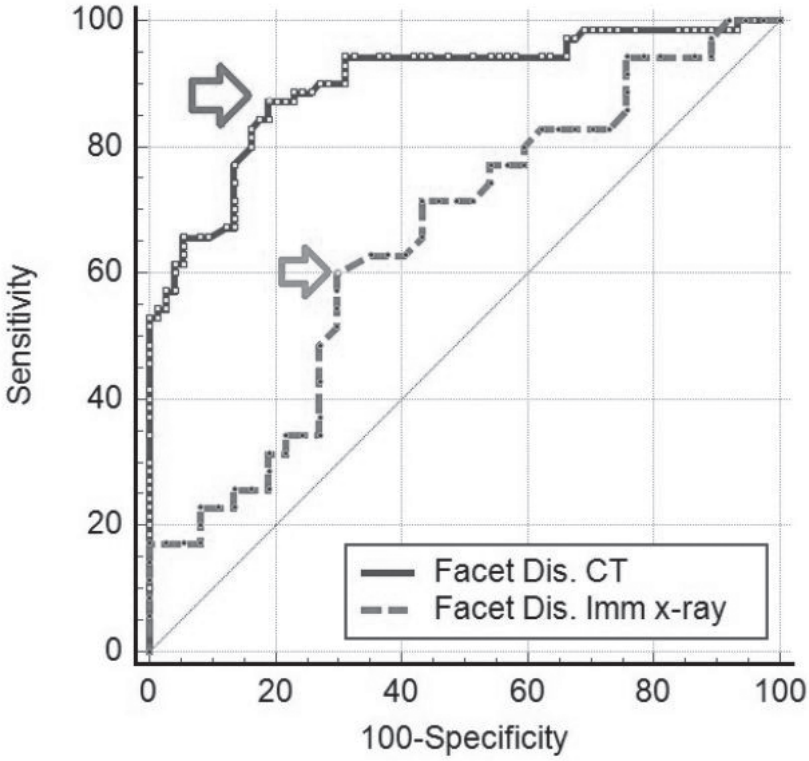

Figure 1. Receiver operating characteristic curve analysis for the cut-off value of facet distraction measured using radiography and computed tomography after anterior cervical discectomy and fusion for neck pain VAS score of ≥ 4. Cut-off value (red arrow) for facet distraction measured using CT was 1.8mm, AUC was 0.901, and 95% confidence interval was 0.840 to 0.944. The sensitivity and specificity were 87.14 and 81.08 respectively. Cut-off value (blue arrow) for facet distraction measured using immediately after surgery using radiography was 2.56mm, AUC was 0.654, and 95% confidence interval was 0.570 to 0.731. The sensitivity and specificity were 60.00 and 70.27 respectively.

Dis., distraction; ROC, receiver operation characteristic; VAS, visual analog scale; Imm, immediately after surgery; CT, computed tomography; AUC, area under curve.

PAPER 31 continued

		VASn 3w	VASn 6w	VASn 3m	VASn 6m	VASn 1y	VASn 2y
Facet Dis. 3d CT	Correlation coefficient	0.703	0.586	0.507	0.442	0.322	0.201
	P-value	<0.001	<0.001	<0.001	<0.001	<0.001	.010

		VASn 3w	VASn 6w	VASn 3m	VASn 6m	VASn 1y	VASn 2y
Facet Dis. Imm. x-ray	Correlation coefficient	0.275	0.307	0.237	0.151	.172	0.195
	P-value	<0.001	<0.001	.003	.023	.054	.029

		VASn 3w	VASn 6w	VASn 3m	VASn 6m	VASn 1y	VASn 2y
Facet Dis. 3m x-ray	Correlation coefficient	0.225	0.341	.145	.131	.024	.230
	P-value	.004	<0.001	.112	.120	.464	.161

		VASn 3w	VASn 6w	VASn 3m	VASn 6m	VASn 1y	VASn 2y
Facet Dis. 6m x-ray	Correlation coefficient	0.257	0.418	.125	.131	.120	0.152
	P-value	.001	<0.001	.094	.087	.197	.031

Table 1. Results of correlation between neck pain visual analogue scale score and facet distraction measured using CT and radiography after ACDF.

Dis., distraction; Imm, immediately after surgery; d, days after surgery; w, weeks after surgery; m, months after surgery; y, year after surgery; VASn, visual analog scale score of neck; CT, computed tomography; ACDF, anterior cervical discectomy and fusion.

Correlation Coefficient Rank: Green **– high, Purple – moderate, Blue – low, Yellow – little**

PAPER 31 continued

Demographic Characteristics	Group C	Group O	p-value	Post-operative clinical outcomes	Group C	Group O	p-value
Case	69	75		**VASn 3w**	2.41±1.14	5.03±2.01	<.001
Facet Dis. CT	1.20±0.320	2.61±0.621	<.001	**VASn 6w**	1.29±1.28	3.40±2.01	<.001
Age	51.23±12.25	53.93±11.64	.210	**VASn 3m**	2.49±2.07	4.69±2.42	<.001
Gender			.235	**VASn 6m**	1.84±1.49	3.08±1.54	<.001
male	36	48		**VASn 1y**	1.00±1.49	2.15±1.59	<.001
female	33	27		**VASn 2y**	0.62±0.78	1.01±0.85	.005
Smoking			.617	**VASa 3w**	3.29±1.93	4.23±1.91	.002
non smoker	33	40		**VASa 6w**	2.78±1.58	3.52±1.83	.011
smoker	36	35		**VASa 3m**	2.61±1.80	4.11±2.43	<.001
Diagnosis			.795	**VASa 6m**	2.14±2.11	2.96±2.33	.036
radiculopathy	33	33		**VASa 1y**	1.61±1.59	3.37±2.10	<.001
myelopathy	17	17		**VASa 2y**	0.91±0.80	1.48±0.87	<.001
myelo-radiculopathy	19	25		**NDI 3m**	19.25±15.51	20.88±12.31	.305
				NDI 6m	14.99±13.58	17.97±14.06	.191
Pre VASn	4.39±2.00	4.71±2.22	.441	**NDI 1y**	12.49±13.83	16.93±12.70	.010
Pre VASa	4.25±2.80	5.11±2.66	.055	**SF-36 3m**	63.11±19.42	63.01±18.30	.946
Pre NDI	30.32±20.65	30.13±17.42	.823	**SF-36 6m**	64.56±19.24	65.72±19.70	.611
Pre SF-36	45.93±20.78	49.66±17.13	.293	**SF-36 1y**	72.61±19.24	68.87±20.42	.291

Table 2. Comparison of demographics and clinical outcomes between Groups O and C.

Dis., distraction; CT, computed tomography; Pre, preoperatively; w, weeks after surgery; m, months after surgery; y, year after surgery; VASn, visual analog scale score of neck; VASa, visual analog scale score of arm; NDI, neck instability index; SF-36, 36-Item Short Form Survey.

* Chi-squared test, Mann- whitney U test

PAPER 32

Analysis of the Implications of Cervical Spine Alignment on Lumbopelvic Alignment

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Introduction: To date, normal patterns of alignment in the cervical spine have not been conclusively defined. Previous studies have attempted to correlate cervical spine alignment with the remainder of the spine and pelvis. Results however, were inconsistent and limited by small sample size. Knowledge of normal alignment is essential in evaluation and preoperative planning for deformity correction. This study aims to establish normative values and correlate these with established patterns of lumbopelvic alignment. We hypothesize alignment of the cervical spine can predict lumbopelvic morphotype.

Materials and Methods: Healthy volunteers (N = 497) between 20-40 years of age with no pre-existing spine pathology were recruited. Baseline demographics, Oswestry Disability Index, and Neck Disability Index were collected. Whole body 2D EOS imaging was obtained for all participants. Using a semi-automated image analysis software (KEOPS, by SMAIO), standard measures of alignment of the pelvis, lumbar, thoracic, and cervical spine were obtained. Roussouly morphotype (RM) was identified for each participant. Principal components (PC) of cervical vertebral body centroids were input into a support vector machine algorithm to predict RM.

Results: Average age of participants was 28.4±5.2 years. Fifty six percent of participants were female, average BMI was 24.9±4.2. Number of participants of each RM were: Type 1 = 26, Type 2 = 126, Type 3 = 221, Type 4 = 124.

When PC explaining 90% of variability were used, RM was appropriately predicted as follows: Between Type 1, 2, 3 and 4 = 50%, Type 2, 3, 4 = 53%, Type 2, 3 = 69%, Type 2, 4 = 47%, Type 3, 4 = 69%. Including nearly all PC (99.99% of the variance), classification rates improved: Between Type 1, 2, 3 and 4 = 68%, Type 2, 3, 4 = 88%, Type 2, 3 = 89%, Type 2, 4 = 99%, Type 3, 4 = 99%.

Conclusion: This study demonstrates that a predictable relationship between cervical and lumbopelvic alignment exists; this relationship is sensitive to subtle features of cervical spine shape, captured by higher order PCs. It provides a robust normative database for cervical spine alignment and will provide insight into normal patterns of lumbopelvic compensation with "abnormal" cervical spine alignment. Future work will aim to classify patterns of cervical spine alignment, and identify features specifically captured by each principal component, particularly the higher components.

PAPER 33

Surgical Threshold Measurements for Cervical Spinal Stenosis: Post-Myelogram Computed Tomography versus Magnetic Resonance Imaging

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Introduction: Quantifying the severity of cervical spinal stenosis and cervical spinal cord compression is a key step in the surgical planning for the treatment of cervical degenerative myelopathy and related conditions. Magnetic resonance imaging (MRI) and computed tomography myelography (CTM) are common diagnostic tests used for preoperative assessment. The purpose of this study was to determine if the two imaging modalities result in the same quantification regarding the severity of the stenosis and cord compression.

Materials and Methods: Fifty patients with cervical spinal cord compression symptoms underwent MRI and CT myelogram within a 6 month timeframe as part of their preoperative assessment. Each cervical spine segment (C3-C7) was quantitatively measured for anterior-posterior (AP) diameter of the canal and AP diameter of the spinal cord on MRI axial, CTM axial, MRI sagittal, and CTM sagittal images. The compression ratio was calculated by dividing the AP cord diameter by the AP canal diameter. Published thresholds for surgically relevant stenosis (<7 mm AP canal diameter) and (>0.8 compression ratio) were used to stratify the per level data.

Results: The mean age of the cohort was 59.6 years with 30 males and 20 females. Using the <7mm threshold for surgery, there was 87% agreement for MRI and CTM on sagittal images and 95% agreement on axial images. More levels met criteria for surgery on MRI compared to CTM with 15% on Sagittal MRI, 6% on Axial MRI, 5% on Sagittal CTM, and 3% on Axial CTM. Using the >0.8 threshold, there was 83% agreement for MRI and CTM on sagittal images and 86% agreement on the axial images. More levels met criteria for surgery on MRI compared to CTM with 17% on Sagittal MRI, 16% on Axial MRI, 3% on Sagittal CTM, and 3% on Axial CTM.

Conclusion: The results of this study shows that while MRI and CTM have relatively good agreement (83-95%) with regard to surgical threshold measurements of cervical spinal stenosis and cord compression, MRI may overestimate the severity in approximately 12% of levels. Axial MRI images had the highest level of agreement (95%) when compared to CTM.

PAPER 34

Evaluation of axonal injury with filtered diffusion weighted magnetic resonance imaging in cervical spondylotic myelopathy

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Introduction: In cervical spondylotic myelopathy (CSM), axonal injury is believed to be the main correlate with functional outcome. Although diffusion tensor imaging (DTI) is sensitive to microscopic pathologies, its utility has been limited in CSM in setting of substantial edema or myelomalacia. The purpose of this study was to assess the spinal cord diffusion measures in patients with CSM using a new filtered diffusion weighted imaging (fDWI) technique that aims to reduce the confounding effects of edema and extracellular water on the measured diffusion values.

Materials and Methods: Twenty-one patients with CSM underwent pre-surgical fDWI and DTI scans on 3T MRI system. DTI was obtained with 25 directions at a b-value of 800 s/mm^2. fDWI employed spinal cord-optimized diffusion weighting along 26 directions with a "filter" b-value of 2000 s/mm^2 and "probe" max b-value of 1000 s/mm^2. Parallel diffusivity metrics obtained from DTI and fDWI were compared to one another and with metrics derived from T_2-weighted MRI including relative signal changes and lesion size.

Results: The parallel apparent diffusion coefficient ($fADC_{||}$) acquired from fDWI at the level of maximum compression (-15.16±12.07%) decreased relative to most cranial slice and had a larger change than axial diffusivity (AD) acquired by DTI (-3.18±14.41%, figure 1). A linear regression identified a significant relationship between AD and T2 metrics (r^2=0.453, p=0.05) whereas $fADC_{||}$ was not significantly related to T2 metrics (r^2=0.069, p=0.70). AD was significantly increased at spinal cord slices with T2 intensities (t(81)=1.65, p=0.05, figure 2) compared to slices without T2 abnormalities, whereas $fADC_{||}$ was not significantly different between spinal cord slices with or without T2 abnormalities (figure 3).

Conclusion: The results demonstrate that filter diffusion encoding reduces the coupling between T2 spinal cord changes and diffusion measurements that are presumed to reflect extracellular water and can considerably affects DTI metrics. Future studies evaluating the relationships with functional status and outcomes in a larger cohort of CSM patients would be beneficial.

PAPER 34 continued

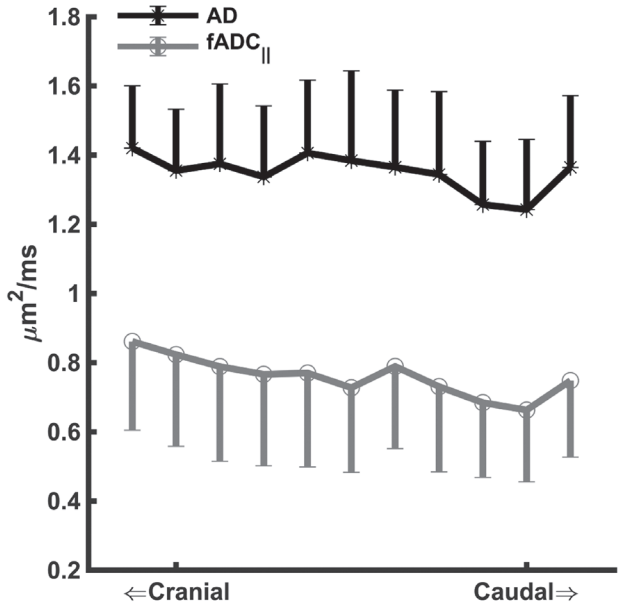

Figure 2. Mean fADC$_{||}$ and AD values at each slice for all CSM participants (n = 21). There is a large, unidirectional decrease in fADC$_{||}$ towards the epicenter of the spinal cord compression compared to multidirectional changes and a lesser decrease in AD values. (* significant compared to most cranial slice, $p < 0.05$).

PAPER 34 continued

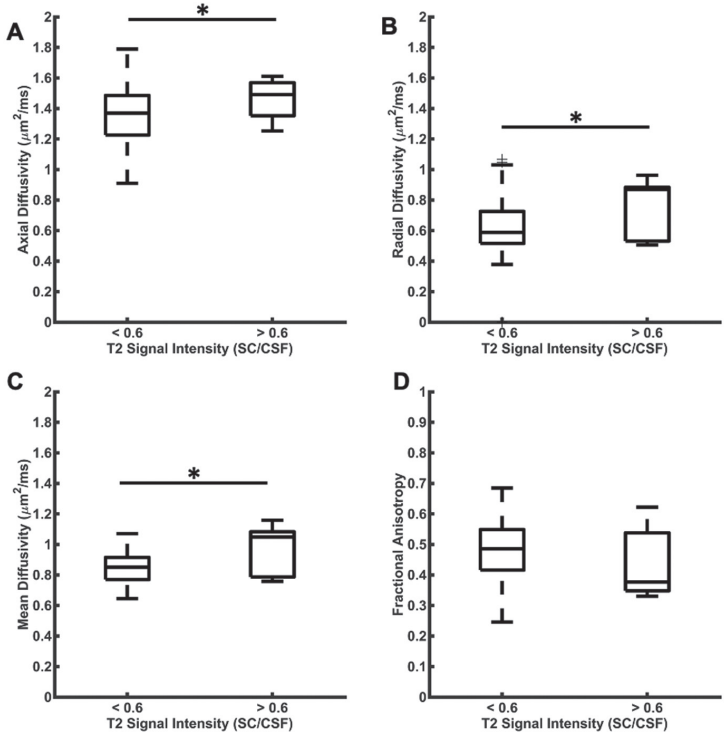

Figure 4. Box plots of diffusion tensor imaging metrics at vertebral levels with T2 intensity (normalized to mean CSF) greater than 0.6 or less than 0.6. T2 intensity for each vertebral level was normalized to mean CSF and the diffusivity metrics were compared. A) AD, (B) RD, and (C) MD significantly increased when T2 signal intensity was greater than 0.6 compared to less than 0.6 (*p<0.05). D) FA decreased though not to a significant degree.

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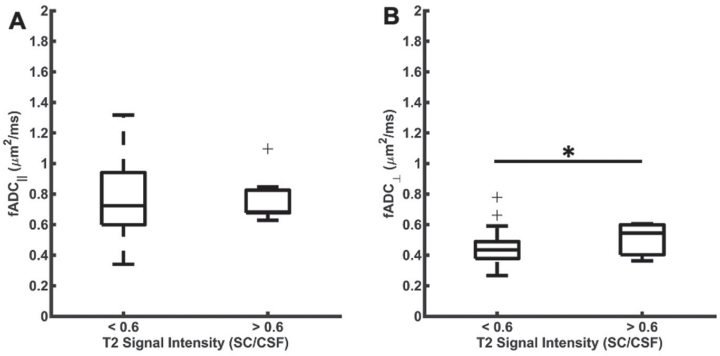

Figure 5. Box plots of fDWI imaging metrics at vertebral levels with T2 intensity (normalized to mean CSF) greater than 0.6 or less than 0.6. T2 intensity for each vertebral level was normalized to mean CSF and the diffusivity metrics were compared. A) $fADC_{||}$ showed no significant increase while B) $fADC_{\perp}$ significantly increased when T2 signal intensity was greater than 0.6 compared to less than 0.6 (*p<0.05).

PAPER 35

Hounsfield unit measurement method and related factors that most appropriately reflect bone mineral density on cervical spine computed tomography

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St. Vincent Hospital[1]

Introduction: Computed tomography (CT) of the spine is a fast and noninvasive imaging test frequently used for diagnostic purposes and useful for pre-operative planning as well as for post-operative evaluation when needed. In this context, if BMD can be estimated from previously performed spine CT, some advantages can be achieved; 1) reduced need for compulsory DXA evaluation and 2) reduced superimposition effects caused by DXA. Our study's purpose was to determine the most reliable Hounsfield units (HU) measurement method to reflect bone mineral density (BMD) on cervical spine computed tomography (CT) and to identify any factors that influence these results.

Materials and Methods: We retrospectively analyzed 439 consecutive patients with mild head and neck injuries. We included only patients ≥18 years old who underwent both cervical spine CT and DXA within one year of each another from 2010–2019 at a single institution.

The HU value from the C2–C7 vertebrae (3073 cervical segment) was determined by measuring the vertebral trabecular portion of each mid-sagittal, mid-coronal, and mid-axial CT image; we used a circle-type region of interest (ROI; ≥35 mm^2). All cortical regions (endplate and anterior-posterior wall of the vertebral body) were avoided during HU attenuation measurement. In drawing the ROIs, we were careful to exclude the posterior part (vascular) of the vertebral body. Mid-sagittal images were used with a reference scout axial image; the middle area of another two images (mid-coronal and mid-axial) were selected using the reference scout sagittal image (Fig.1).

Correlation patterns were analyzed between HU value and corresponding dual-energy X-ray absorptiometry (DXA) in the lumbar vertebra (T-score) and femoral neck (T-score). A sub-group analysis was performed according to patient age, sex, and degree of spinal degeneration.

Results: The mean value of HU at each vertebral segment ranged from 40 to 700 and the correlation coefficient was 0.51–0.65 based on two DXA results (spine and femur). All correlation coefficient values were statistically significant (P<0.001).The mean T-scores for these BMD categories were 0.5 ± 1.2 for the normal group, -1.6 ± 0.4 for osteopenia, and -3.1 ± 0.6 for osteoporosis. Females had a lower T-score than males in each of the three BMD groups (normal/osteopenia/osteoporosis) (Table 1).

Table 2 shows the correlation coefficient (r) of HU measured at each cervical vertebra (from C2–C7) with DXA at the spine and femur. The mean value of HU at each vertebral segment ranged from 40 to 700 and the correlation coefficient was 0.51–0.65 based on two DXA results (spine and femur). All correlation coefficient values were statistically significant (P<0.001). When we classified patients through our degeneration grading method, the following results were obtained: normal group (n=111), mild-degeneration group (n=286), severe-degeneration group (n=42). The correlation values in these three degeneration groups were as follows: the C2-normal group showed the highest value (r=0.71), and the C2-severe degeneration group had the lowest value (r=0.64).The C3-middle age group showed the

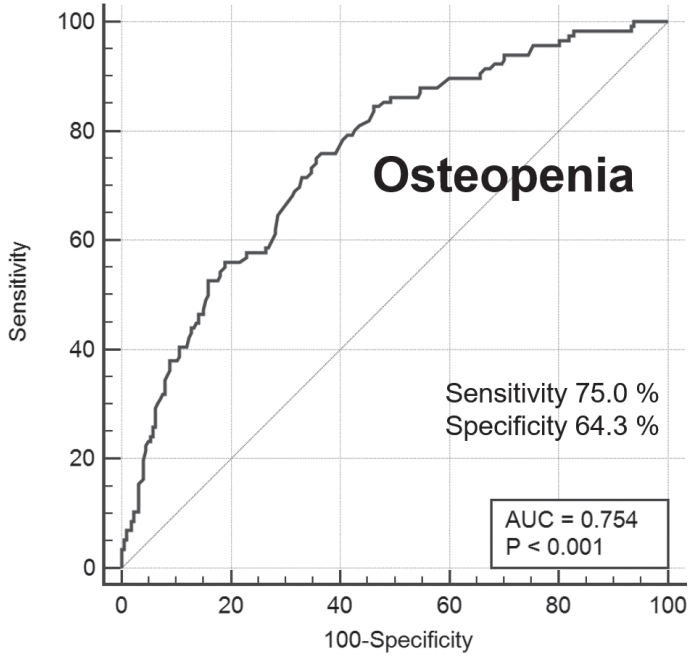
PAPER 35 continued

highest correlation coefficient (r=0.71), while the C2-young age group showed the lowest correlation coefficient (r=0.53) in this study. When the correlation coefficients were compared between males and females, they were relatively higher in females in C2 (0.67 vs. 0.63) and C3 (0.70 vs. 0.63) segments (Table 3).Mean C3 HU values for osteopenia, and osteoporosis were 284.0 ± 63.3 (95% confidence interval, 272.4 - 295.7) and 231.5 ± 52.8 (95% confidence interval, 213.9 - 249.1), respectively (Table 4). The ROC curve demonstrated that the HU method has a sensitivity of 89.2% and specificity of 88.7 % with an AUC of 0.929 to diagnose osteoporosis. The ROC curve also demonstrated that the HU measurement method (axial plane) has a sensitivity of 75.0% and specificity of 64.3 % with an AUC of 0.754 to diagnose osteopenia (Fig. 2).The following formula was calculated through simple linear regression analysis; T-score = 0.01 × (HU) – 4.55.

Conclusion: A simple linear regression analysis revealed the following formula: T-score = 0.01× (HU) – 4.55. The mean HU value for osteopenia, and osteoporosis were 284.0 ± 63.3 and 231.5 ± 52.8, respectively. The ROC curve indicated that the HU method has a sensitivity of 89.2% and specificity of 88.7 % to diagnose osteoporosis. The HU measurement showed a high correlation value (range: r=0.64–0.70) with spine DXA score regardless of degree of degeneration or patient age or sex.

Cervical spine CT can be another useful modality to indirectly predict osteopenia and osteoporosis. The upper cervical vertebrae (C2 and C3) had higher correlation values with DXA than the lower cervical vertebrae, and spine DXA showed a slightly better correlation than the femur DXA. Although this measurement may be slightly affected by measurement plane, age, sex, and spine degeneration, any type of HU measurement (cervical spine CT) may have reliable information for estimating bone mineral density indirectly.

PAPER 35 continued



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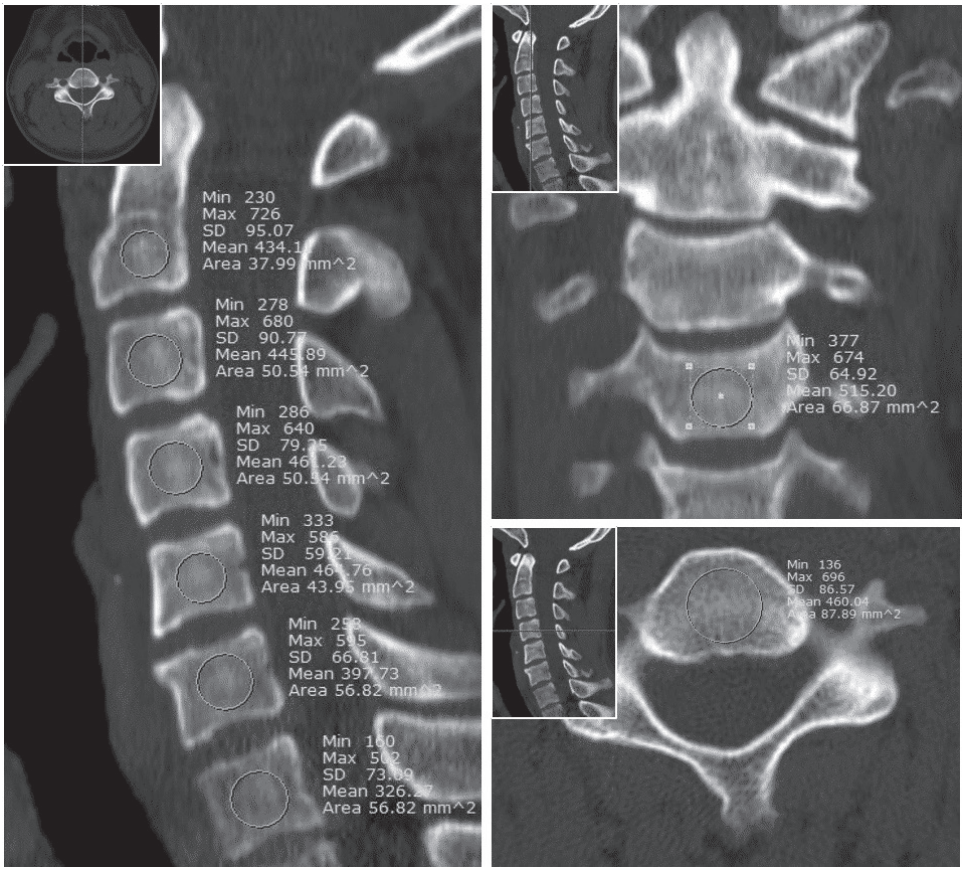

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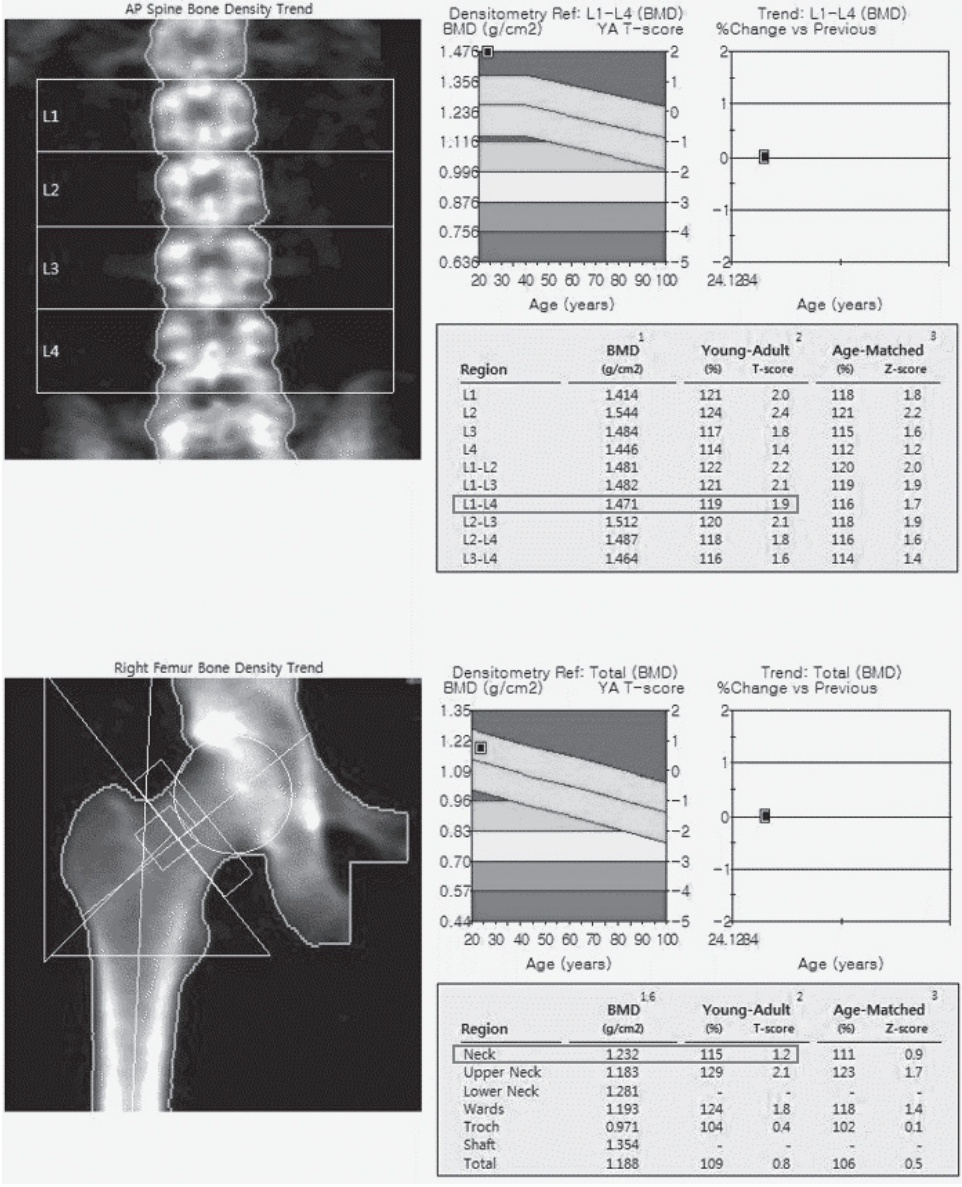

Region	BMD [1] (g/cm2)	Young-Adult [2] (%)	Young-Adult [2] T-score	Age-Matched [3] (%)	Age-Matched [3] Z-score
L1	1.414	121	2.0	118	1.8
L2	1.544	124	2.4	121	2.2
L3	1.484	117	1.8	115	1.6
L4	1.446	114	1.4	112	1.2
L1-L2	1.481	122	2.2	120	2.0
L1-L3	1.482	121	2.1	119	1.9
L1-L4	1.471	119	1.9	116	1.7
L2-L3	1.512	120	2.1	118	1.9
L2-L4	1.487	118	1.8	116	1.6
L3-L4	1.464	116	1.6	114	1.4

Region	BMD [1,6] (g/cm2)	Young-Adult [2] (%)	Young-Adult [2] T-score	Age-Matched [3] (%)	Age-Matched [3] Z-score
Neck	1.232	115	1.2	111	0.9
Upper Neck	1.183	129	2.1	123	1.7
Lower Neck	1.281	-	-	-	-
Wards	1.193	124	1.8	118	1.4
Troch	0.971	104	0.4	102	0.1
Shaft	1.354	-	-	-	-
Total	1.188	109	0.8	106	0.5

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

PAPER 36

Analysis of parameters that can predict the cervical sagittal vertical axis in cervical fusion surgery

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St. Vincent Hospital[1]

Introduction: The sagittal vertical axis of the cervical spine (i.e., the distance between the C2 plumb line and superior posterior corner of the C7 body [C2-7–SVA]) may be the most important parameter closely related to health-related quality of life in cervical spine surgery. However, it is highly likely that the absolute value of C2-7–SVA cannot be guaranteed with certainty on all follow-up cervical radiographs.(Figure 1) Moreover, there have been quite a number of cases in which the C2-7–SVA value varies across follow-up cervical radiographs in the clinical field.Ideally, all simple radiographs should be measured with high uniformity and accuracy, but fluctuations in measured radiographic values can occur due to various situations, such as (1) the non-uniformity of measurement by radiologist technicians; (2) unpredictable factors, such as the patient's unconscious posture changes; and (3) diversity in measurement guidelines among different medical institutions. Empirically, the radiographic cranio-vertebral angle (CVA) offers important information on cervical neck posture (unintentional forehead posture), and the mandible angle (MA) was considered a good possible radiologic factor in a recent horizontal gaze analysis. Under the assumption that measurement errors can occur at any time during follow-up radiography, we tried to examine whether the sagittal parameters change meaningfully and to look for the factors most closely related to the C2-7–SVA value, including the CVA and MA. In addition, we sought to determine how much measurement error may arise on each follow-up radiograph.

Materials and Methods: We enrolled 200 patients who underwent two-level anterior cervical discectomy and fusion (ACDF) (n = 100) or posterior cervical fusion (PCF) (n = 100) between January 2012 and December 2018. All patients were >18 years of age with a condition of degenerative pathologic origin.The CVA, the MA (the angle between the inferior edge of the mandibular body and the horizontal line), the occipital slope (Os), the C2 slope (C2s), the C7 slope (C7s), and the C2-7–SVA were measured on the two randomly selected follow-up radiographs taken after surgery. The slope angle was determined using a horizontal line and a specific reference line set at each cervical spine level, i.e., the Os (between the McGregor line and horizontal line), C2s (between the lower endplate of the C2 body and the horizontal line), and C7s (between the lower endplate of the C7 body and the horizontal line). The C2-7 angle (C2-7A) was calculated by subtracting C7s from C2s.The changes in sagittal parameters (Δ) between the two radiographs were also calculated. We divided all patients into two different groups (large |ΔC2-7–SVA| vs small |ΔC2-7–SVA|, 8 mm; reference value) and compared other parameters between surgical approaches.

Results: The absolute difference values of sagittal parameters (i.e., the difference between the second and first measurements) were as follows: 6.4˚ (|ΔMA|), 5.5 ˚ (|ΔOs|), 6.0˚ (|ΔC2s|), 5.8˚ (|ΔC7s|), 6.1˚ (|ΔC2-7A|), 7.2˚ (|ΔC2-7–SVA|), and 4.3˚ (|ΔC2-7–SVA|) in ACDF patients. In contrast, those among PCF patients were as follows: 6.9˚ (|MA|), 7.6 ˚ (|ΔOs|), 6.0˚ (|ΔC2s|), 7.2.8˚ (|ΔC7s|), 7.1˚ (|ΔC2-7A|), 8.6˚ (|ΔC2-7–SVA|), and 5.0˚ (|ΔC2-7–SVA|), respectively. Only the occipital slope showed a statistically significant difference between the anterior and posterior surgery groups

PAPER 36 continued

($P < 0.05$).(Table1)

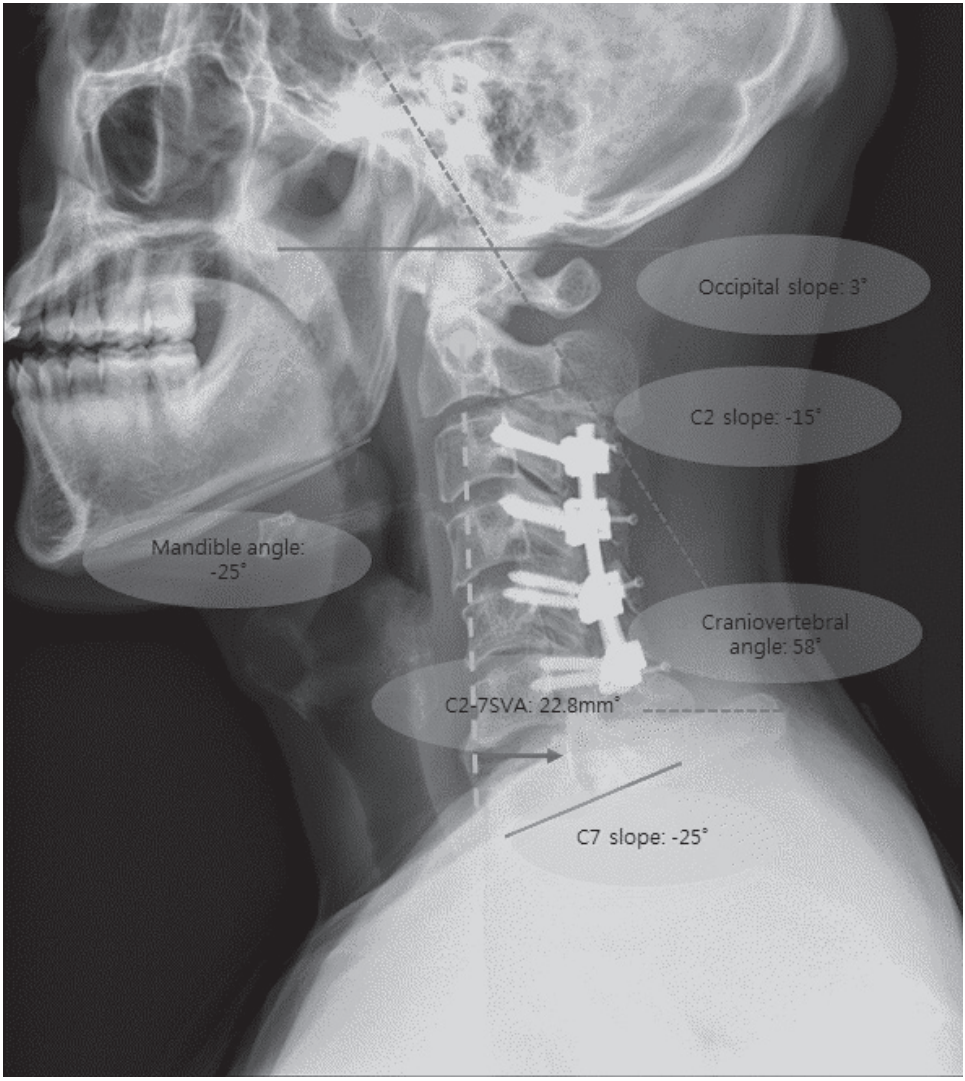
Pearson's correlation analysis showed that statistical significance existed between ΔC2-7–SVA and each of the cervical radiographic parameters (r = |0.40–0.93|, $P < 0.05$), except for ΔC2-7A ($P > 0.05$), in both the anterior and posterior surgery groups (Table 2). Overall, ΔCVA showed the greatest correlation with C2-7–SVA (r = |0.88–0.93|), followed by ΔC2s (r = |0.70–0.86|).

Notably, as the |ΔC2-7–SVA| value increased, the values of other parameters also increased in both surgical approach groups. However, the change in some parameters (C2-7A, MA, and C7s) did not show a statistically significant difference in both approaches or posterior approach

The C2-7A was calculated between C2s and C7s; therefore, it was excluded from the multicollinearity problem. Multivariate regression analysis showed that C2-7–SVA was affected by Os, C2s, C7s, and CVA. The regression equation was Y = 0.587 + 0.126(ΔOs) − 0.577(ΔC2s) − 0.114(ΔC7s) − 0.969(ΔCVA), and the effect size of this study was $R^2 = -0.841$ (adjusted)

Conclusion: Unintentional changes in neck posture are always a possibility, so the C2-7–SVA value is always at risk of unintentional distortion. Sequentially, the above phenomenon may adversely affect the result of sagittal alignment analysis. During cervical fusion surgery, CVA was found to be the most useful and predictable parameter to reflect the C2-7-SVA status compared to other factors (C2s, C7s, or Os). Although MS was also recommended as a good parameter for measuring the horizontal gaze, its correlation with the C2-7–SVA value showed some limitations in our study. If the CVA value differs significantly among follow-up radiographs, stricter criteria should be established to analyze the sagittal alignment.

PAPER 36 continued



Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

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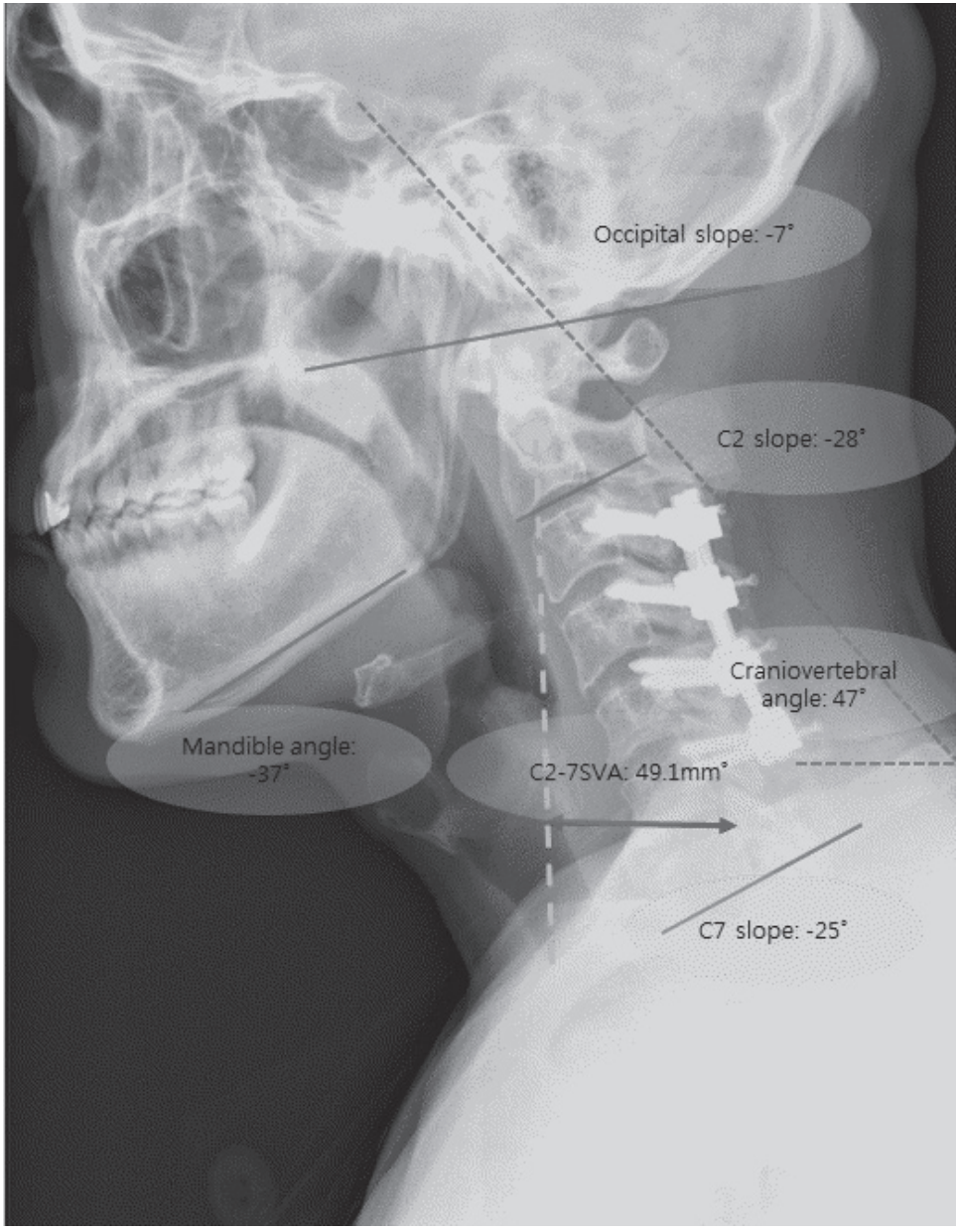

PAPER 36 continued

Table 2. Pearson correlation analysis among various cervical sagittal parameters (posterior cervical fusion / anterior cervical discectomy and fusion)

	ΔMA	ΔOS	ΔC2s	ΔC7s	ΔC2-7A	ΔSVA	ΔCVA
ΔMA	1.	.	.	.	.	.	.
ΔOS	0.36** / *0.91***	1.	.	.	.	.	.
ΔC2s	0.55** / *0.69***	0.47** / *0.69***	1.	.	.	.	.
ΔC7s	0.17 / *0.41***	0.08 / *0.36***	0.33** / *0.36***	1.	.	.	.
ΔC2-7A	0.17 / *0.14*	0.21* / *0.18*	0.29** / *0.43***	-0.80** / *-0.68***	1.	.	.
ΔSVA	-0.58** / *-0.74***	-0.40** / *0.74***	-0.86** / *-0.70***	-0.45** / *-0.57***	-0.09 / *0.01*	1.	.
ΔCVA	0.68** / *0.83***	0.57** / *0.85***	0.85** / *0.76***	0.35** / *0.51***	0.18 / *0.10*	-0.88** / *-0.93***	1.

*** P<0.05, ** P<0.01 MA, mandible angle, Os, occipital slope, C2s, c2slope, C7s, C7slope, C2-7A, C2-7 angle, C2-7-SVA, C2-7-sagittal vertical axis, CVA, cranio-vertebral angle**

PAPER 37

Real-Time Operative Radiation Exposure Levels of Spine Surgeons

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Perelman School of Medicine[1]

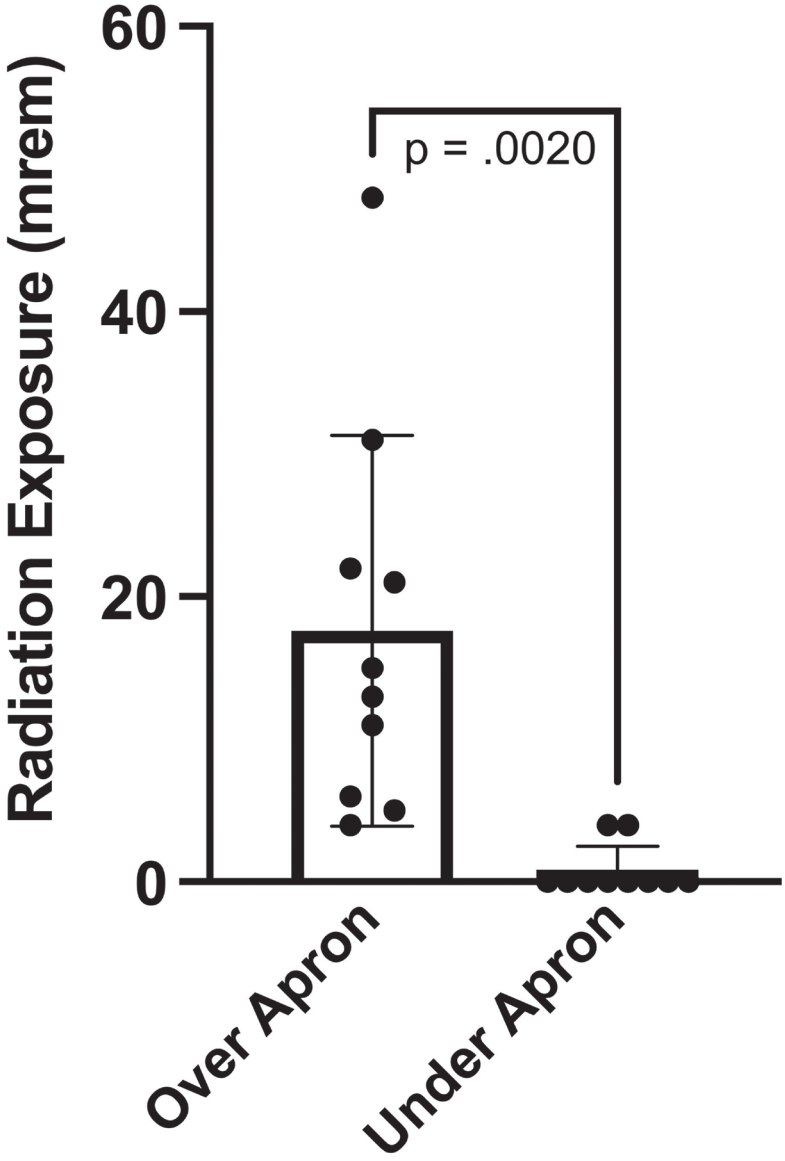
Introduction: C-arm fluoroscopy and O-arm navigation are vital tools in modern spine surgeries, but their repeated usage can endanger spine surgeons. While a surgeon's chest and abdomen are protected by lead aprons, the eyes and extremities generally receive less protection. In this study, we compare the differences in intraoperative radiation exposure across the protected and unprotected regions of the surgeon's body.

Materials and Methods: This prospective cohort study includes 65 consecutive spine surgeries performed by a single spine-focused neurosurgeon over a 9-month period. Radiation exposure to the primary surgeon was measured through dosimeters worn over the lead apron, under the lead apron, on surgical loupes, and as a ring on the dominant hand. Differences were assessed with rigorous statistical testing and radiation exposure per surgical case was extrapolated.

Results: During the study, the measured radiation exposure over the apron, 176 mrem, was significantly greater than that under the apron, 8 mrem (p=.0020), demonstrating shielding's protective effect. The surgeon's dominant hand was exposed to 329 mrem while the eyes were exposed to 152.5 mrem of radiation. Compared to the surgeon's protected abdominal area, the hands (p=.0002) and eyes (p=.0002) received significantly greater exposure. Calculated exposure per case was 2.8 mrem for the eyes and 5.1 mrem for the hands. It was determined that a spine-focused neurosurgeon operating 400 cases annually will incur a radiation exposure of 60,750 mrem to the hands and 33,900 mrem to the eyes over a 30-year career.

Conclusion: Our study found that spine surgeons encounter significantly more radiation exposure to the eyes and the extremities compared to protected body regions. Lifetime exposure exceeds the annual limits set by the International Commission on Radiological Protection for the extremities (50,000 mrem/yr) and the eyes (15,000 mrem/yr), calling for increased awareness about the dangerous levels of radiation exposure that a spine surgeon incurs over one's career.

PAPER 37 continued



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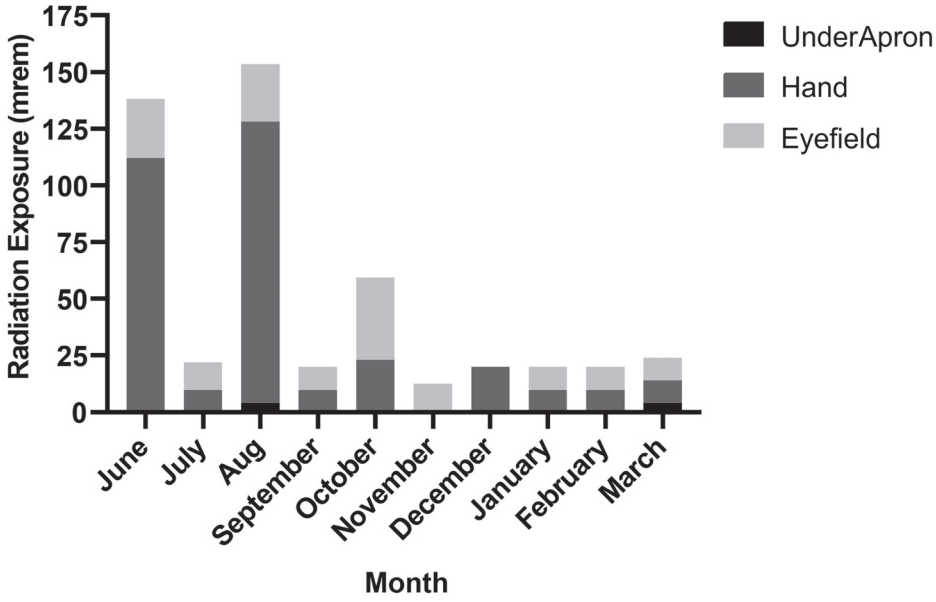

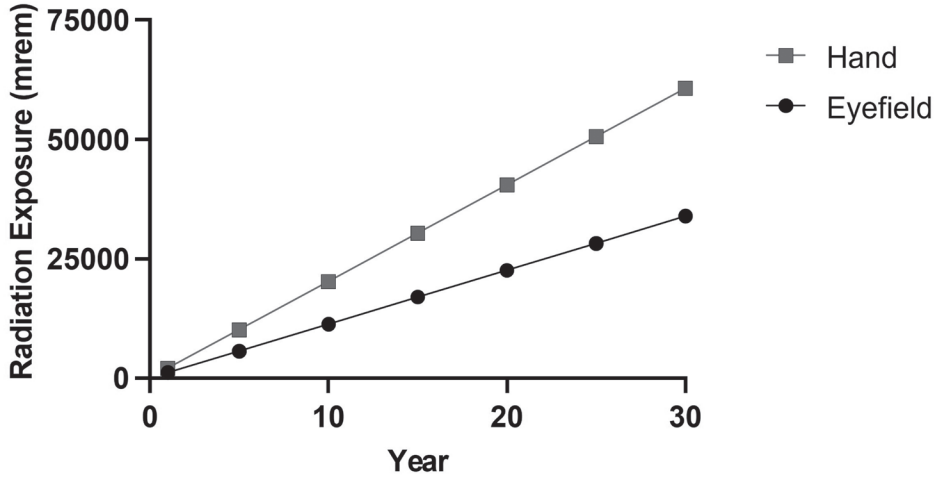

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PAPER 38

Linking patterns of intraoperative neuromonitoring (IONM) alerts to the odds of a new postoperative neurological deficit: Analysis of 27,808 cervical spine procedures from a national multi-institutional database.

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Thomas Jefferson University[1]

Introduction: IONM is utilized during cervical spine surgery because of the potential risk of new nervous system dysfunction associated with the procedure and the patient's diagnosis. That risk is elevated when an IONM alert occurs; however, not all alerts are equal and some alert patterns may portend a greater risk. This analysis characterizes IONM alerts by the patterns of IONM modalities and nerves/muscles involved and provides estimates of the relative odds of a new postoperative deficit according to these patterns, accounting for patient and procedural variables.

Materials and Methods: Retrospective review of a national multi-institutional database of 27,808 cervical extradural spine procedures performed between January 2017 and May 2021. All cases were coded into one of eight alert modality and resolution categories: 1) no alert, 2) spEMG alert, 3) SSEP alert-resolved, 4) SSEP alert-unresolved, 5)MEP alert-resolved, 6) MEP alert-unresolved, 7) combined SSEP & MEP alert-resolved, and 8) combined SSEP & MEP alert-unresolved. Risk of a new-onset neurologic deficit by IONM alert modality, alert resolution and neural structures involved was assessed using mixed-effects logistic regression controlling for demographic and operative factors, with random intercepts to account for clustering in outcomes by surgeon and in-room surgical neurophysiologist. MEP and SSEP alerts were further categorized based on the pattern of nerves/muscles involved:1) C5-6 Nerve Root, 2) C7 Nerve Root 3) C8-T1 Nerve Root, 4) C5-T1 Nerve Root (Arm), 5) Spinal Cord, or 6) Partial Leg. These alert cohorts were further delineated based on the status of the alert at closure: unresolved or resolved.

Results: Odds of a new onset neurological deficit for procedures with unresolved alerts were consistently greater than for procedures without alerts: SSEP & MEP-unresolved OR = 303, 95% Confidence Interval: [175-526], p<0.001; MEP-unresolved OR = 127 [80-202] , p<0.001; SSEP-unresolved OR = 66 [27-159] , p<0.001; with much variation by alert modality and resolution category (Table 1, Model 2). Descriptive analysis showed that patients with a diagnosis of myelopathy or stenosis had a greater frequency of alerts that those with a diagnosis of radiculopathy, and a greater frequency of MEP alerts and spinal cord alerts, but the frequency of spinal nerve root MEP alerts was relatively comparable across diagnostic cohorts (Table 2). Spinal cord and Nerve Root alerts were associated both with a significant elevation in odds of a new onset deficit if unresolved and a significant reduction in odds if resolved, regardless of diagnosis or surgical approach (Figure 1).

Conclusion: Risk elevation following an IONM alert during cervical surgery is dependent on the type and pattern of alert. Successful resolution of alerts is associated with a decrease in odds of a new neurologic deficit. Further research is needed to provide an algorithmic approach to interventions effective in resolving IONM signals when alerts to evolving dysfunction occur

PAPER 38 continued

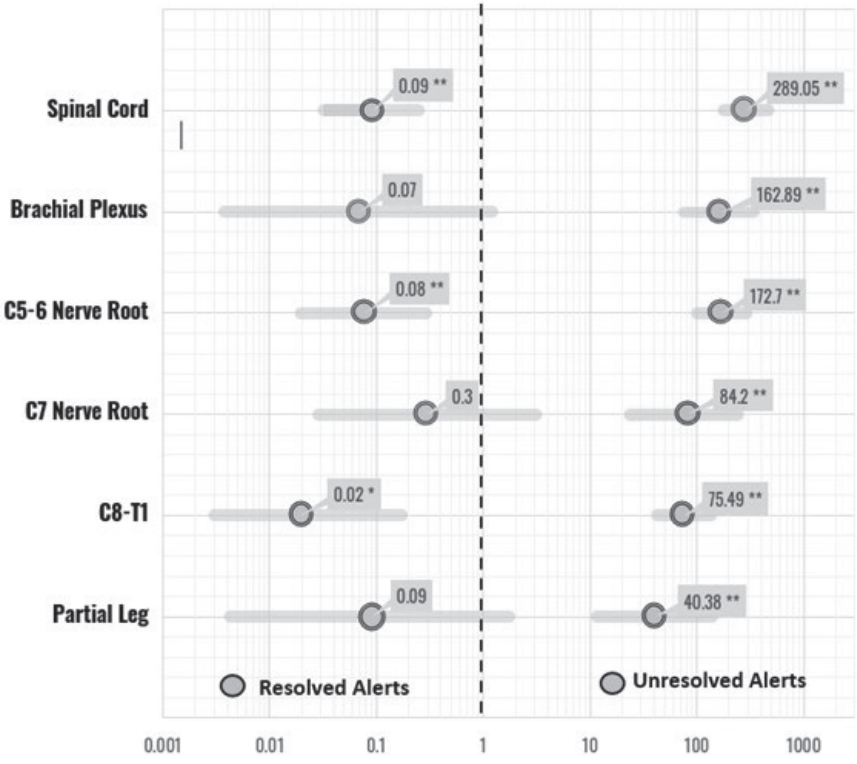
during cervical spine surgery.

Table 1. Model-predicted Odds-Ratios for new neurologic deficit as a function of diagnosis, procedural variables, and modality alert type. Model 1 is without modality alert type, and Model 2 incorporates modality alert type.

	Model 1			Model 2		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
Age	1.01	1.00 – 1.03	**0.045**	1.01	1.00 – 1.02	0.144
One or More MEP Baselines Unmonitorable	1.09	0.79 – 1.50	0.600	0.76	0.54 – 1.08	0.127
Surgical Approach: Anterior/Posterior	2.53	1.51 – 4.24	**<0.001**	1.16	0.66 – 2.03	0.612
Surgical Approach: Posterior	1.82	1.30 – 2.57	**0.001**	1.30	0.91 – 1.87	0.155
Vertebral Levels: Three	1.44	0.91 – 2.26	0.117	1.23	0.76 – 1.98	0.401
Vertebral Levels: Four	2.17	1.39 – 3.39	**0.001**	1.50	0.94 – 2.39	0.093
Vertebral Levels: Five or Six	2.90	1.79 – 4.69	**<0.001**	1.91	1.15 – 3.18	**0.012**
Radiculopathy	0.69	0.47 – 1.01	0.058	0.87	0.59 – 1.30	0.512
Stenosis	0.98	0.70 – 1.38	0.914	1.00	0.69 – 1.45	0.996
Alert Modality & Resolution - spEMG: Alert Present				5.32	2.36 – 11.98	**<0.001**
Alert Modality & Resolution - SSEP: All Alerts Resolved				3.81	0.51 – 28.42	0.192
Alert Modality & Resolution - SSEP: Alerts Unresolved				65.95	27.28 – 159.45	**<0.001**
Alert Modality & Resolution - MEP: All Alerts Resolved				9.17	3.91 – 21.54	**<0.001**
Alert Modality & Resolution - MEP: Alerts Unresolved				126.99	79.99 – 201.60	**<0.001**
Alert Modality & Resolution - SSEP & MEP: All Alerts Resolved				7.60	1.01 – 57.01	**0.049**
Alert Modality & Resolution - SSEP & MEP: Alerts Unresolved				303.65	175.39 – 525.73	**<0.001**
Random Effects						
σ^2	3.29			3.29		
τ_{00}	0.61_{Surgeon}			0.29_{Surgeon}		
	$0.15_{\text{SN\_Primary}}$			$0.11_{\text{SN\_Primary}}$		
ICC	0.19			0.11		
N	$682_{\text{SN\_Primary}}$			$682_{\text{SN\_Primary}}$		
	1351_{Surgeon}			1351_{Surgeon}		
Observations	27808			27808		
Marginal R^2 / Conditional R^2	0.097 / 0.267			0.286 / 0.363		
AIC	2397.317			1565.102		

PAPER 38 continued

Figure 1. Odds Ratio for New Neurologic Deficit by Anatomic Alert Pattern. For unresolved evoked potential alerts and sEMG alerts, the referent was procedures with no alerts. For resolved evoked potential alerts, the referent was unresolved evoked potential alerts of the same anatomic type. **P values <0.001; *P value =0.002



PAPER 39

Diffusion basis spectrum imaging predicts comprehensive clinical outcomes following surgery for cervical spondylotic myelopathy

Justin Zhang, BS, Dinal Jayasekera, MS, Jacob Greenberg, MD, MSCI[1], Saad Javeed, MD[2], Christopher Dibble, MD PhD, Jacob Blum, BS, Peng Sun, PhD, Sheng-Kwei Song, PhD, Wilson Ray, MD
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Introduction: Despite the increasing prevalence of cervical spondylotic myelopathy (CSM), clinicians still lack a firm understanding of its natural history or prognostic factors associated with favorable outcomes. A major shortcoming in improving care for CSM patients is the lack of robust quantitative imaging tools to guide surgical decision making. Advanced diffusion weighted imaging (DWI) techniques, such as diffusion basis spectrum imaging (DBSI), may help address this limitation by providing detailed evaluations of white matter injury in subclinical CSM (Fig. 1). Given these evidence gaps, the purpose of this study was to examine the ability of DBSI measures to predict multiple CSM outcome measures at 2-years follow up and compare its efficacy to a clinically-driven model.

Materials and Methods: Fifty CSM patients were prospectively enrolled at a single tertiary-care institution. After baseline DBSI and clinical assessments, patients underwent cervical decompressive surgery and were followed up to 2-years postoperatively. DBSI metrics included fractional anisotropy (FA), axial (AD) and radial (RD) diffusivity, fiber fraction (FF), extra-fraction (EF), restricted fraction (RF), and non-restricted (NRF) fraction. Neurofunctional status was assessed by the mJOA (MCID: 2 points), myelopathic disability index (MDI; MCID: 3 points), and disabilities of the arm shoulder and hand (DASH; MCID: 10.8 points). Quality-of-life (QoL) was measured by the SF-36 physical (PCS) and mental (MCS) component summary (MCID: 4 points). The neck disability index (NDI) was used to measure self-reported neck pain (MCID: 7.5 points). Long-term patient satisfaction was measured by the NASS satisfaction index. A support vector machine (SVM) classification algorithm was used to predict treatment outcomes. Specifically, three models were built for each outcome measure: clinical, DBSI, and combined (i.e., clinical + DBSI) models. Recursive feature elimination was performed on each training set to identify variables with the highest predictive potential. Leave-one-out (LOO) cross-validation was utilized to test model performance.

Results: Twenty-seven mild (mJOA 15-17), 12 moderate (12-14) and 11 severe (0-11) CSM patients were enrolled. Three patients did not undergo surgery, two patients lacked long-term follow up, and five patients' MRI data were of insufficient quality, and were therefore excluded. Of the remaining 40 patients, 24 (60%) underwent anterior surgery compared to 16 (40%) posterior surgery. The mean (SD) follow-up was 23.2 (5.6, range 6.1-32.8) months. When predicting the mJOA at latest follow-up, the clinically-driven model performed with an accuracy [95% CI] of 61.9 [61.6,62.5], compared to 78.6 [78.4,79.2] in the DBSI model, and 90.5 [90.2, 90.8] in the combined (i.e., clinical + DBSI) model (Fig. 2). The corresponding accuracies, AUCs, precision, recall, and F1-score of each SVM model is provided in Table 1.

Conclusion: When combined with key clinical covariates, DBSI metrics predicted improvement after surgical decompression with high accuracy. These results suggest that DBSI may serve as a non-invasive imaging biomarker for CSM. Though external validation is necessary, these algorithms may be valuable in guiding patient selection and informing preoperative counseling.

PAPER 39 continued

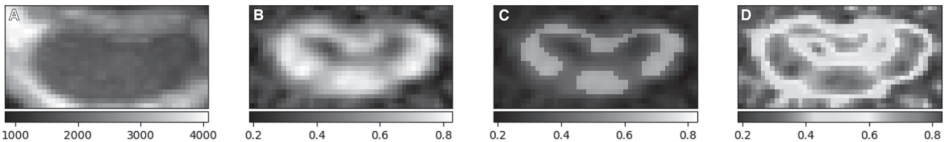
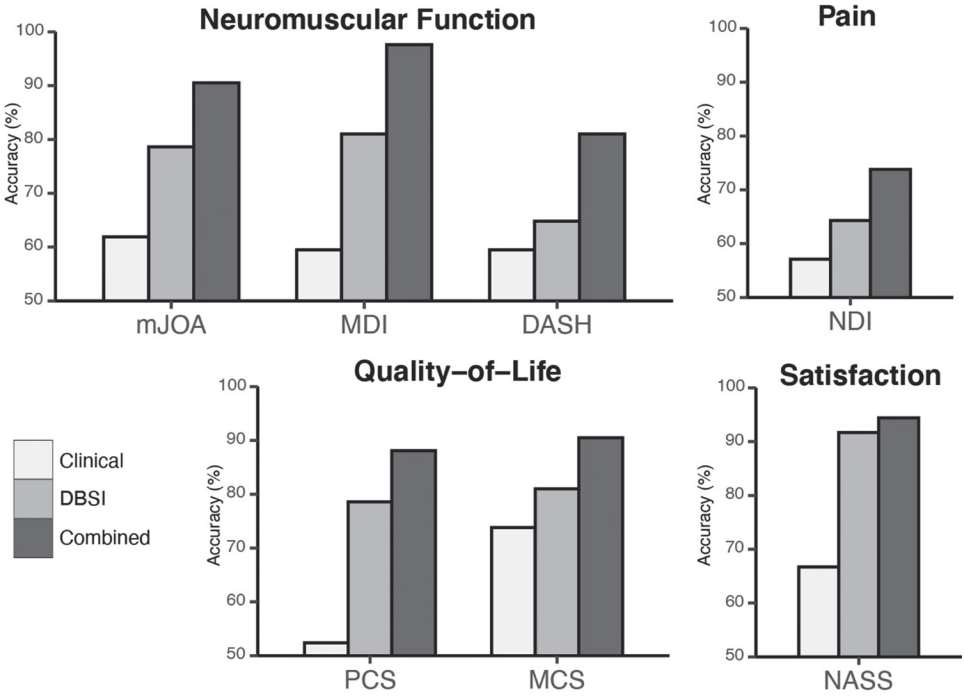


Figure 1. C3 axial spinal cord section. **(A)** Single-slice DWI image (values denote signal intensity), **(B)** Fractional anisotropy (FA) map, **(C)** FA map with superimposed manually drawn region of interest (ROI), **(D)** FA map with color scaling. FA values range from 0 to 1.



Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

PAPER 39 continued

Table 1. Model performance measures of support vector machine classification algorithms on each outcome measure

Metric	Feature set	Accuracy	Precision	Recall	F1-Score	AUC
mJOA	Clinical	61.9 [61.6, 62.5]	42.9 [42.8, 44.4]	42.9 [42.6, 44.3]	42.9 [41.9, 43.3]	59.4 [59.1, 60.4]
	DBSI	78.6 [78.4, 79.2]	69.2 [68.6, 70.2]	64.3 [63.8, 65.4]	66.7 [65.4, 66.7]	75.3 [74.9, 76.0]
	Combined	90.5 [90.2, 90.8]	85.7 [85.1, 86.3]	85.7 [84.7, 85.9]	85.7 [84.6, 85.7]	98.0 [97.8, 98.0]
PCS	Clinical	52.4 [51.9, 52.8]	60.0 [59.5, 60.7]	60.0 [59.7, 61.0]	60.0 [59.2, 60.2]	53.2 [52.9, 54.1]
	DBSI	78.6 [78.1, 78.9]	83.3 [83.1, 84.0]	80.0 [79.2, 80.2]	81.6 [80.9, 81.7]	80.7 [80.1, 81.1]
	Combined	88.1 [87.8, 88.4]	88.5 [87.8, 88.6]	92.0 [91.9, 92.5]	90.2 [89.7, 90.2]	86.4 [86.0, 86.8]
MCS	Clinical	73.8 [73.6, 74.4]	60.0 [60.0, 61.6]	64.3 [63.3, 64.9]	62.1 [60.9, 62.2]	74.5 [74.0, 75.1]
	DBSI	81.0 [80.6, 81.3]	80.9 [80.1, 81.7]	57.1 [55.9, 57.6]	65.7 [65.0, 66.5]	78.1 [78.0, 79.1]
	Combined	90.5 [89.9, 90.5]	85.7 [84.8, 86.0]	85.7 [84.7, 85.9]	85.7 [84.5, 85.7]	89.8 [89.1. 89.9]
NDI	Clinical	57.1 [56.3, 57.2]	50.0 [48.5, 50.1]	44.4 [43.5, 45.1]	45.9 [45.2, 46.5]	48.8 [48.2, 49.4]
	DBSI	64.3 [64.0, 64.9]	66.7 [65.4, 67.5]	33.3 [32.8, 34.2]	44.4 [42.9, 44.4]	54.6 [54.1, 55.3]
	Combined	73.8 [73.6, 74.5]	73.3 [73.3, 74.8]	61.1 [60.6, 62.1]	66.7 [65.9, 67.1]	65.3 [64.8, 66.0]
DASH	Clinical	59.5 [58.8, 59.7]	56.5 [55.4, 56.7]	65.0 [64.4, 65.7]	59.7 [59.1, 60.2]	55.0 [54.6, 55.7]
	DBSI	64.8 [64.4, 65.3]	60.7 [60.1, 61.3]	75.0 [74.5, 75.7]	66.7 [66.1, 67.2]	69.3 [68.8, 69.9]
	Combined	81.0 [80.6, 81.3]	75.0 [74.3, 75.4]	90.0 [89.9, 90.7]	81.8 [81.1, 81.9]	78.6 [78.4, 79.3]
MDI	Clinical	59.5 [58.9, 59.8]	30.8 [29.9, 31.5]	33.3 [32.3, 34.0]	32.0 [30.3, 31.7]	61.7 [60.9, 61.9]
	DBSI	81.0 [80.3, 81.0]	70.0 [68.7, 70.6]	58.3 [56.6, 58.4]	61.9 [61.1, 62.7]	87.8 [87.2, 88.0]
	Combined	97.6 [97.6, 97.9]	92.3 [92.2, 93.2]	100 [100, 100]	96.0 [95.8, 96.3]	100 [100, 100]
NASS	Clinical	66.7 [66.7, 67.2]	70.6 [70.2, 71.6]	63.2 [62.5, 63.9]	66.7 [65.6, 66.8]	69.7 [69.3, 70.3]
	DBSI	91.7 [91.2, 91.8]	94.4 [94.1, 94.8]	89.5 [89.0, 89.9]	91.9 [91.4, 91.9]	97.2 [97.1. 97.4]
	Combined	94.4 [94.3, 94.8]	100 [100, 100]	89.5 [89.2, 90.1]	94.4 [94.1, 94.6]	97.5 [97.3, 97.6]

PAPER 40

Diffusion basis spectrum imaging correlates with baseline severity and long-term clinical outcomes in cervical spondylotic myelopathy

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Introduction: Cervical spondylotic myelopathy (CSM) is the leading cause of progressive disability in patients over 65 years of age. Despite increasing knowledge, the complex pathophysiology, heterogeneous presentation, and widely variable treatment response in CSM make management decisions particularly difficult. Quantifiable microstructural diffusion-weighted imaging modalities, such as diffusion tensor imaging (DTI), have emerged in recent years to combat these limitations. Recently, our lab developed diffusion basis spectrum imaging (DBSI), a highly specific diffusion-weighted imaging modality designed to control for extra-axonal vasogenic edema and cellularity that often confound DTI analyses. Despite these advancements, associations between DTI and DBSI markers and CSM-specific clinical domains in the pre-and post-operative setting remain unknown. Therefore, we assess the relationship between DTI and DBSI measures and key CSM clinical assessments at initial presentation and 2 years following surgical decompression.

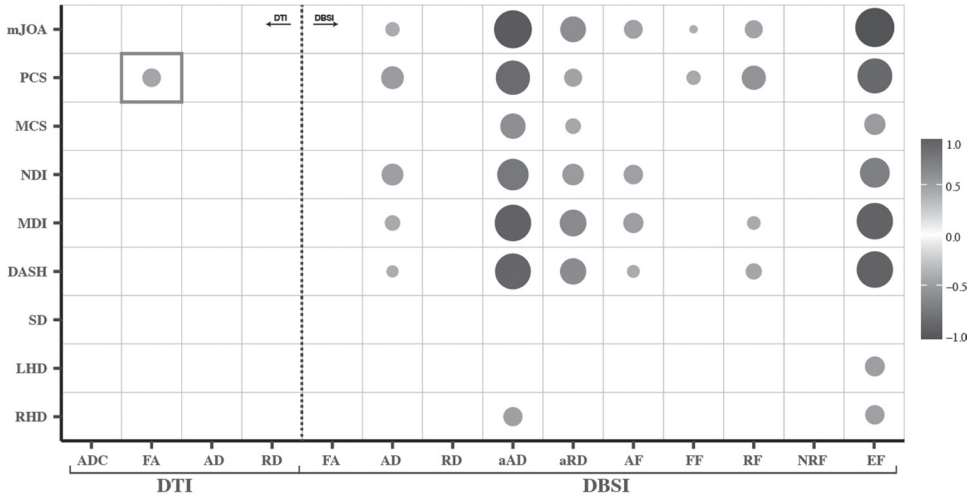
Materials and Methods: A single-center prospective cohort study enrolled fifty CSM patients who underwent surgical decompression and twenty healthy controls from 2018-2021. All patients underwent DTI, DBSI, and complete clinical evaluations at baseline and 2-years follow-up. DTI and DBSI metrics included fractional anisotropy (FA), axial diffusivity (AD), radial diffusivity (RD), and fiber fraction (FF). DBSI quantifies extra-axonal pathology (i.e., cellularity and edema) via restricted fraction (RF), non-restricted fraction (NRF), and extra-axonal fraction (EF). In addition, DBSI can provide greater specificity in evaluating the intra-axonal compartment through axonal AD, axonal RD, and axonal fraction (AF). Clinical assessments included the mJOA, SF-36 physical (PCS) and mental component summary (MCS), neck disability index (NDI), myelopathy disability index (MDI), and disabilities of the arm shoulder and hand (DASH). A lower score for the mJOA and higher score for the MDI and DASH reflect worse neurofunctional status. A higher score for the SF-36 PCS and SF-36 MCS indicates higher quality-of-life (QoL), whereas a higher score on the NDI denotes greater pain. Hand grip dynamometer (HD) readings and symptom duration (SD) were assessed at initial evaluation. Pearson's correlation was utilized to compare associations between DTI and DBSI metrics and clinical outcome measures. A False Discovery Rate (FDR) correction was applied to account for multiple comparison's testing.

Results: At baseline presentation, of 36 correlations analyzed between DTI metrics and CSM clinical measures, only DTI FA showed weak positive correlation with SF-36 PCS (r=0.36, p=0.02, Fig. 1, red box). In comparison, there were 36/90 (40%) significant correlations among DBSI measures. Increased DBSI AD, RD, RF, and AF were associated with *worse* clinical presentation (i.e., decreased mJOA, SF-36 PCS/MCS and increased NDI, MDI, and DASH). At latest follow-up, increased preoperative DBSI axonal AD and EF were significantly correlated with improved functional outcome, quality-of-life, and pain assessments (Fig. 2).

Conclusion: Quantifiable microstructural imaging modalities such as DBSI provide highly

PAPER 40 continued

specific assessments of CSM pathology that may improve management strategies. In our cohort, we found DBSI to correlate with multiple CSM-specific measures, including neuromuscular function, quality-of-life, and pain, preoperatively and at long-term follow-up. DBSI may have substantial promise as an objective, non-invasive marker for both preoperative CSM disease severity and postoperative outcome.



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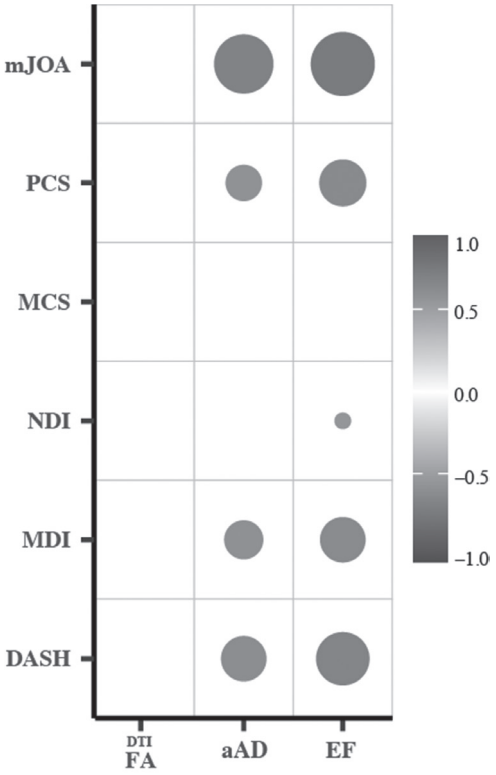

PAPER 41

Which Patients Benefit from a Combined Anterior-Posterior Approach in Cervical Deformity Surgery?

Bailey Imbo, BA, Tyler Williamson, MS, Rachel Joujon-Roche, BS, Peter Tretiakov, BS, Oscar Krol, BA, Lara Passfall, MD, Salman Ahmad, DO[1], Djani Robertson, MD, Stephane Owusu-Saprong, MD, Tomi Lanre-Amos, MD, Rivka Ihejirika-Lomedico, MD, Michael Dinizo, MD, Heiko Koller, MD, Nima Alan, MD[2], Themistocles Protopsaltis, MD, Andrew Schoenfeld, MD MSc, Bassel Diebo, MD, Shaleen Vira, MD, Peter Passias, MD[3]

NYU Langone Orthopaedic Surgery[1] UPMC[2] New York Spine Institute/NYU Medical Center[3]

Introduction: A combined anterior-posterior approach for cervical deformity (CD)-corrective surgery has been associated with a greater mechanical advantage. There is paucity in the literature investigating the patient profile which warrants the more invasive combined approach in CD patients.

Materials and Methods: Included: operative CD patients with baseline (BL) and two-year (2Y) follow-up data. Patients who had an anterior-only approach were excluded. Patients with any presenting sensory or motor neurological deficits or severe CD as previously defined by Kim et al. were isolated. Means comparison tests and adjusted logistic regression analysis compared patient improvement by surgical approach.

Results: 165 CD patients were included (102 Posterior, 63 Combined). Age (61.0 vs 62.4), gender (F: 67.0% vs 58.0%), body mass index (28.6 vs 29.1), and Charlson Comorbidity Index (0.90 vs 1.23) were similar between groups, all $p>.05$. Combined patients had longer operative times (549.3 vs 336.6), less levels fused (7.5 vs 9.4), and less osteotomies (46.5% vs 74.1%), all $p < 0.05$. EBL, decompressions, and osteoporosis were similar between groups, all $p > 0.05$. Despite similar neurological deficits at baseline between groups, patients who had a combined procedure were more likely achieve resolution of paresthesia, abnormal gait, or Hoffman's sign, all $p < 0.05$. Radiographically, patients with a flatneck deformity were more likely to improve in at least one of Ames-ISSG radiographic modifiers by 2Y following a combined procedure (70.0% vs 23.1%), $p < 0.05$. When controlling for age, comorbidities, and invasiveness, improvement in paresthesia and Ames-ISSG radiographic modifiers were lost. However, resolution of gait abnormalities and Hoffman's sign remained significantly correlated with undergoing a combined approach.

Conclusion: A combined anterior-posterior surgical approach was associated with greater radiographic improvement and resolution of neurological symptoms compared to a posterior-only approach. Given the substantial benefits gained despite less invasiveness, this technique may offer superior advantages for patients with neurological deficits presenting for surgical correction of cervical deformity.

PAPER 42

Comparative Analysis of the Occurrence and Clinical Impact of Dramatic Global Kyphosis in the Unfused Thoracic Spine Relative to Distal Junctional Failure Following Adult Cervical Deformity Surgery

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New York Spine Institute/NYU Medical Center[1] NYU Langone Orthopaedic Surgery[2] Medical College of Wisconsin[3] UPMC[4] Hospital for Special Surgery[5]

Introduction: There remains a paucity of literature regarding the outcomes of patients developing reciprocal unfused thoracic kyphosis (TK) in comparison to junctional failure after ACD corrective surgery. We hypothesize that higher unfused thoracic kyphosis after ACD surgery has significant effects on outcomes.

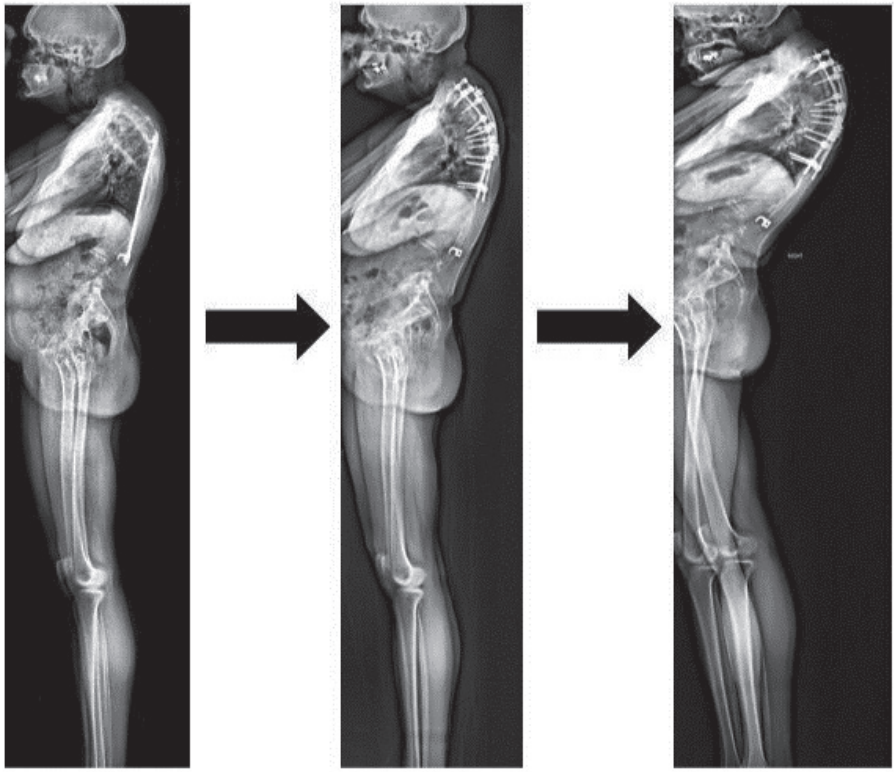
Materials and Methods: Included: CD pts with up to 2Y data and LIV proximal to T6. Virk et al. Good Clinical Outcome (GCO) defined as ≥2: NDI <20 or meeting MCID, mJOA ≥14, NRS-Neck ≤5 or improved by ≥2. Optimal outcome defined as meeting GCO without reoperation. Reciprocal TK (rTK) calculated as the ratio of unfused TK (T4-T12) divided by number of unfused segments by 2Y. High rTK was deemed a ratio <6.75 by 2Y, using TK thresholds from Lafage et al. Cohort was stratified into High rTK, DJK-only, Combined (developing DJK and High rTK). Multivariate analysis controlling for age, BL TS-CL, and frailty evaluated outcome rates between subgroups.

Results: 133 ACD pts included. Of cohort, 23% developed High rTK, 31% DJK, 13% mechanical failure. There were 15% developing both High rTK and DJK[Combined]. High rTK were older, more osteoporotic (19% vs 7%), lower Hounsfield units at the LIV (227 vs. 259) with more severe cervical deformity than DJK-only pts. After correction, High rTK-only were less likely to maintain horizontal gaze (per McGregor's slope) compared to DJK-only (22% vs 50%, p=.04). High rTK had worsening global deformity, becoming three times more likely to develop severe thoracolumbar deformity than DJK-only. Combined had the lowest rates of Optimal Outcome (24%, p=.003) and highest rates of mechanical failure (41.2%, p=.010). Adjusted analysis showed pts developing DJK had higher rates of DJF when accompanied by High rTK (OR: 2.3; p=.04). While no differences seen in onset of high rTK, Combined developed DJK much earlier than DJK-only (4.5 vs. 9.3 months, p=.03).

Conclusion: High reciprocal thoracic kyphosis was seen in a quarter of patients and more often precedes the timing of DJK. This prevalent occurrence is seen in those with poor bone quality, and accompanied by worsening global deformity and increased likelihood of cervical deterioration. Patients should be monitored for dramatic global kyphosis, given its significant detrimental consequences following cervical deformity correction, especially in the context of junctional failure.

PAPER 42 continued

Figure. Case Example of High Reciprocal Thoracic Kyphosis



PAPER 43

Best Realignment Strategies in the Radiographic Parameter Toolbox: Hierarchical Approach to Surgical Planning in Adult Cervical Deformity Surgery

Tyler Williamson, MS, Peter Tretiakov, BS, Bailey Imbo, BA, Rachel Joujon-Roche, BS, Oscar Krol, BA, Salman Ahmad, DO[1], Shaleen Vira, MD, Bassel Diebo, MD, Nima Alan, MD[2], Jordan Lebovic, MD MBA, Stephane Owusu-Saprong, MD, Lauren Seo, MD, Heiko Koller, MD, M. Burhan Janjua, MD, Andrew Schoenfeld, MD MSc, Themistocles Protopsaltis, MD, Justin Smith, MD, PhD, Renaud Lafage, MS, Virginie Lafage, PhD[3], Peter Passias, MD[4]

NYU Langone Orthopaedic Surgery[1] UPMC[2] Hospital for Special Surgery[3] New York Spine Institute/NYU Medical Center[4]

Introduction: Research has been concentrated on cervical deformity realignment thresholds for achieving desired clinical outcomes while decreasing worrisome complications, like distal junctional failure (DJF) and reoperation. The present study aims to establish a hierarchical order for realignment of spinopelvic parameters during ACD surgery. Therefore, we sought to determine which hierarchical approach to cervical parameter realignment produces better 2-year HRQL metrics and decrease the risk of junctional failure during ACD surgery.

Materials and Methods: Included: Operative CD pts with up to 2-year(2Y) HRQL data. Outcome variables: distal junctional kyphosis(DJK) and failure(DJF), reoperation, and *Virk* et al Good Clinical Outcome: [Meeting 2 of 3: 1) an NDI>20 or meeting MCID, 2) mJOA >=14), 3) an NRS-Neck<=5 or improved by 2 or more points from baseline]. Optimal Outcome was defined as meeting Good Clinical Outcome without developing DJF or undergoing reoperation. Descriptive analysis identified cohort demographics and radiographic parameters (C2 Slope, Cervical Lordosis, McGregor's Slope, TS-CL, cSVA, T1 slope). Using conditional inference tree (CIT) analysis, thresholds for each parameter were derived based on meeting Optimal Outcome. Patients meeting the best performing threshold in terms of Optimal Outcome were isolated and the threshold derivation was repeated for the remaining parameters. ANCOVA, controlling for age and baseline deformity, assessed outcome rates in patients meeting the hierarchical realignment.

Results: 133 ACD patients (61.8±9.9yrs, 27.6±5.8 kg/m2, CCI: 1.0±1.4, CD-FI: 0.4±0.1) who underwent surgery (7.6±4.0 levels fused, EBL: 781±853 mL, op time: 383±218 min, LOS: 5.9±4.4 days) were included. Twenty percent underwent an anterior approach, 46% posterior, 34% combined. Decompressions were performed in 52%, 83% underwent an osteotomy. After correction, there was a significant difference in meeting Optimal Outcome when correcting C2 Slope below 10° (85% vs. 34%, p<.001), along with lower rates of DJF (7% vs. 42%, p<.001). Next, after isolating patients above the C2 Slope threshold, correction of T1 Slope below 26° demonstrated lower rates of DJK and higher odds of meeting Optimal Outcome (OR: 4.2, p=.011). The best third step was correction of cSVA below 35 mm. This hierarchical approach (11% of cohort) led to significantly lower rates of DJF (0% vs. 15%, p<.007), reoperation (8% vs. 28%, p<.001), and higher rates of meeting Optimal Outcome (93% vs. 36%, p<.001), and maintained significance after controlling for age and baseline deformity.

Conclusion: This ordered realignment of cervical parameters has demonstrated strong correlation to HRQL metrics and complications. Correction of C2 slope should be prioritized during cervical deformity surgery, with subsequent correction of T1 slope and cervical SVA

PAPER 43 continued

below the derived thresholds. Amongst the numerous radiographic parameters used in cervical deformity, these findings help the surgeon prioritize realignment in certain parameters to achieve successful outcomes.

Hierarchical Approach to Cervical Deformity	1) Correct C2 Slope below 10° 2) Then correct T1 Slope below 26° 3) Finally, correct cSVA below 35 mm

PAPER 44

Predictive Survival Analysis of Adult Cervical Deformity Patients with Ten-Year Follow-Up

Peter Passias, MD[1], Peter Tretiakov, BS, Rachel Joujon-Roche, BS, Bailey Imbo, BA, Tyler Williamson, MS, Oscar Krol, BA, Lara Passfal, BS, Salman Ahmad, DO[2], Bassel Diebo, MD, Shaleen Vira, MD, Muhammad Janjua, MD, Stephane Owusu-Saprong, MD, Djani Robertson, MD, Tomi Lanre-Amos, MD, Rivka Ihejirika-Lomedico, MD, Michael Dinizo, MD, Nima Alan, MD[3], Andrew Schoenfeld, MD MSc, Heiko Koller, MD, Themistocles Protopsaltis, MD

New York Spine Institute/NYU Medical Center[1] NYU Langone Orthopaedic Surgery[2] UPMC[3]

Introduction: Previous studies have demonstrated that adult cervical deformity patients may be at increased risk of death in conjunction with increased frailty or weakened physiologic state. However, such studies have often been limited to two years, and longer-term studies are needed to better assess temporal changes in CD patients and associated mortality risk. We hypothesize that patients with decreased comoborbities and physiologic burden will be at lessened risk of death for a greater length of time after undergoing adult cervical deformity surgery.

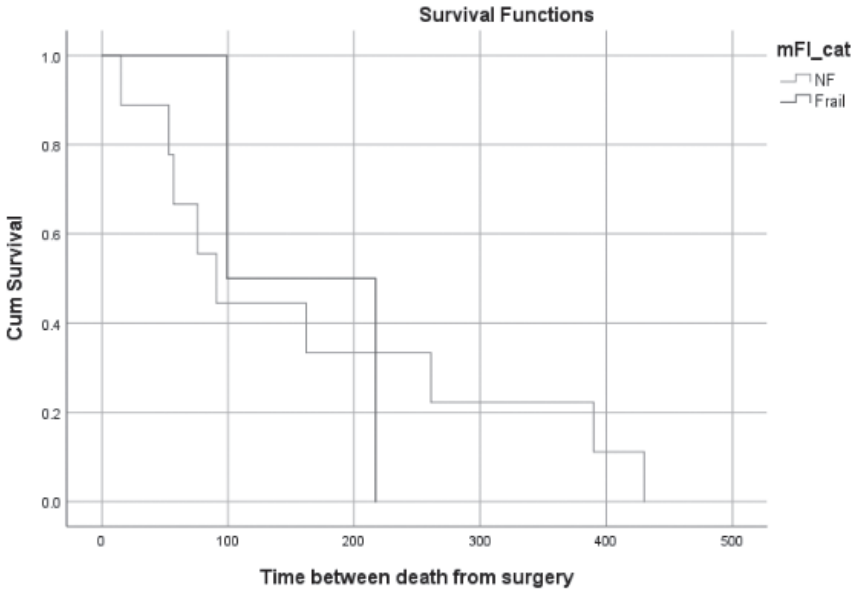
Materials and Methods: Operative CD patients ≥18yrs with pre-(BL) and ten-year (10Y) data were included. Patients were stratified as Expired vs Living, as well as temporally grouped by Expiration prior to 5Y or between 5Y and 10Y. Group differences were assessed via means comparison analysis. Backstep logistic regression identified mortality predictors. Kaplan-Meier analysis assessed survivorship of expired patients. Log rank analysis determined differences in survival distribution groups.

Results: 66 total patients were included (58.11 ± 11.97 years, 48% female, 29.13 ± 6.89 kg/m2). Within 10Y, 20 (27.3% of CD cohort). At baseline, patients were comparable in age, gender, BMI, and CCI total on average (all p>.05). Furthermore, patients were comparable in BL HRQLs (all p>.05). However, patients who expired between 5Y and 10Y demonstrated higher BL EQ5D and mJOA scores than their earlier expired counterparts at 2Y (p<.021). Furthermore, patients who presented with no CCI markers at BL were significantly more likely to survive until the 5Y-10Y follow-up window. Surgically, the only differences observed between patients who survived until 5Y was in undergoing osteotomy, with longer survival seen in those who did not require it (p=.003). Logistic regression revealed independent predictors of death prior to 5Y to be increased BMI, increased frailty, and increased levels fused (model p<.001). KM analysis found that by Passias et al. frailty, not frail patients had mean survival time of 170.56 weeks, versus 158.00 in frail patients (p=.949).

Conclusion: This study demonstrates that long-term survival after cervical deformity surgery may be predicted by baseline surgical factors. By optimizing BMI, frailty status, and minimizing fusion length when appropriate, surgeons may be able to further assist CD patients in increasing their survivability post-operatively.

PAPER 44 continued

Table 1. Time between death from surgery against cumulative survival



PAPER 45

The Additional Burden of the Existence of Baseline Cervical Deformity When Undergoing Thoracolumbar Adult Spinal Deformity Corrective Surgery

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Introduction: A substantial portion of adult spinal deformity patients presenting for surgery simultaneously suffer from cervical deformity. Cervical deformity may have a synergistic debilitating effect on patients. The additional impact of cervical deformity on adult spinal deformity patients and outcomes following surgery had not been adequately explored. Our purpose was to investigate the effect of baseline cervical deformity on outcomes in patients undergoing adult spinal deformity.

Materials and Methods: Operative ASD patients with available baseline (BL) and 2-year (2Y) radiographic and HRQL data were included. Baseline cervical deformity (CD) was defined by cervical kyphosis >10°, coronal scoliosis >10°, cSVA >4cm, TS-CL >10°, CBVA >25°, or MGS >20°. Means comparison tests followed by bivariate analysis assessed differences in demographic, clinical, surgical, complication, post-operative alignment, durability of alignment and patient reported outcomes. IHS-adjusted PROMS were investigated as defined in the previous work of Passias et al.)

Results: 381 ASD patients met inclusion criteria. Average age was 61.1yrs±14.0. At BL, CD patients were older (61 vs 57), more frail (3.4 vs 2.8), with a larger comorbidity burden (1.7 vs 1.3), and higher rates of osteoporosis (23% vs 10%, all $p<.05$). CD patients showed a greater degree of disability in ODI, lower SRS-Activity, SRS-Total, and SF-36 PCS (all $p<.05$). Additionally, CD patient had a larger thoracic (38 vs 29) and global deformity (8.3 vs 4.3cm). Surgically, CD patients had an increased invasiveness, and usage of 3CO. Table 1. At two-year follow-up, CD patients showed worse clinical outcomes in ODI, SF-36 physical functioning and greater rates of PJF (14% vs 6%) and medical complications (22% vs 14%, $p<.05$). Additionally, by two-years CD patients maintained a greater degree of deformity in thoracic kyphosis T4-T12 (48 vs 41), SVA C2-C7 (3.6cm vs 2.8cm), SVA C7-S1 (3.7cm vs 2.7cm), and T1 slope (37 vs 28, all $p<.05$). Patients with IHS-Adjusted recovery kinetics show patients with CD had a worse overall recovery in their NRS Leg-Pain scores, and SRS-Total scores.

Conclusion: Patients with cervical deformity presenting for adult spinal deformity surgery are significantly older, more frail, with a greater number of comorbidities and degree of deformity. At two-year follow, patients with both cervical deformity and thoracolumbar deformity showed inferior patient reported outcomes and a higher degree of post-operative deformity.

PAPER 45 continued

Table 1. Differences between patient with and without baseline cervical deformity

	CD at Baseline	ASD only	p-value
Age	61	57	**.006**
Gender	75% F	79% F	.945
BMI	28.2	27.7	.885
Charlson Comorbidity	1.7	1.3	**.001**
Frailty Index	3.4	2.8	**.001**
Bowel Incontinence	10%	8%	.53
Bladder Incontinence	20%	18%	.47
Leg Numbness	58%	61%	.44
Leg Weakness	59%	56%	.42
Loss of Balance	49%	47%	.72
Steady Gait	81%	86%	.25
Able to Heel Walk	85%	84%	.57
Able to Toe Walk	86%	87%	.70
Prior Fusion	43%	28%	.002
Prior Revision	38%	36%	.79
Surgical Details			
Invasiveness	97	86	**.004**
Levels Fused	11	10.8	.22
Decompressions	59%	56%	.31
Three-Column Osteotomy	27%	14%	**.003**
Baseline HRQLs			
ODI	46	43	**.013**
SRS-Activity	2.8	3	**.004**
SRS-Pain	2.3	2.4	.076
SRS-Appearance	2.4	2.5	**.025**
SRS-Mental	3.4	3.4	.932
SRS-Satisfaction	2.8	2.8	.523
SRS-Total	2.7	2.8	**.035**
EQ5D	.75	.75	.19
EQ5D VAS	58	60	.25
Baseline Radiographs			
PT	25	24	.055
PI	55	55	.909
PI-LL	17	16.4	.708
Lumbar Lordosis	38	39	.658
TK T4-T12	38.6	29.3	**<.001**
TS-CL	19.5	19.2	.727
CL	16	2.6	**<.001**
SVA C2-C7	33.4	24	**<.001**
SVA C7-S1	80.5	52	**<.001**
C2-T3	14.5	3.5	**<.001**
SVA C2-T3	72.3	48.4	**<.001**
Two Year HRQLs			
ODI	27	22	**.017**
PCS	38	41.4	**.013**
SRS-Activity	3.6	3.4	.09
SRS-Pain	3.4	3.5	.455
SRS-Appearance	3.5	3.6	.241
SRS-Mental	3.8	3.8	.848
SRS-Satisfaction	4.2	4.2	.994
SRS-Total	3.6	3.7	.210
EQ5D	.8	.81	.282

PAPER 46

Achievement and Maintenance of Optimal Alignment and Functional Improvement Following Cervical Deformity Surgery: A 2-Year Outcome Analysis

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Introduction: Goals of surgical correction of cervical deformity (CD) are superior alignment and functional outcomes. Isolated predictors of such optimal outcomes have been published for various postoperative time points. However, there is a paucity in the literature with regard to the factors that contribute to the sustainability of optimal radiographic and functional status. The purpose of this study is to assess the factors contributing to the sustainability of ideal alignment and favorable functional outcomes in operative cervical deformity patients.

Materials and Methods: Operative CD patients with pre-(BL) and up to 2-year(2Y) postop radiographic/HRQL data were included. At both the 1Y and 2Y time points, a favorable outcome was defined as meeting ≥3 of the following criteria: 1) no DJF or mechanical failure with reoperation, 2) met *Virk et al.* good clinical outcome [≥2 of the following: NDI <20 or meeting MCID, mild myelopathy (mJOA ≥14), NRS-Neck ≤5 or improved by ≥2 points from BL], 3) improved in ≥1 radiographic Ames modifier, and 4) no worsening in any radiographic Ames modifier. A robust outcome was defined as having a favorable outcome at both 1Y and 2Y. Means comparison tests assessed differences in demographic and clinical data between the robust and non-robust groups. Predictors of robust outcomes were identified using multivariate regression analysis, with conditional inference tree (CIT) for continuous variables.

Results: 154 CD patients met inclusion criteria (57.2±10.3yrs, 56%F, BMI 28.7±7.0kg/m2, CCI: 0.76±1.1) and underwent surgery (levels fused 5.3±3.3, EBL 733.3±820.5 mL, op time 337.7±201.4min). By approach, 18.1% anterior-only, 49.3% posterior-only, and 31.3% combined. BL Ames modifiers assessment found severe deformity in 0% for cSVA, 64.5% for TS-CL, 26.8% for Horizontal gaze, and 8.2% of SVA. Mean BL HRQLs were as follows: NRS back 6.2, NRS neck 7.3, NDI 55.3, mJOA 13.2, and EQ5D 6.9. 46.5% were identified as having a favorable outcome at 1Y postop. At 2Y, 54.1% had a favorable outcome. Of the patients with a 1Y favorable outcome, 55.0% (33.7% of full cohort) also met the 2Y criteria, thereby qualifying them as having a robust outcome. By univariate analysis, robust patients did not differ from non-robust patients in terms of baseline demographics ($p>0.05$). Robust patients had higher preop TS-CL and cSVA (both $p<0.05$). Multivariate regression analysis identified the following independent predictors of a robust outcome: undergoing combined approach (OR: 9.6), undergoing osteotomy (OR: 8.0), cSVA greater than 29.0mm (OR: 6.3), and SVA less than 40.0mm (OR: 5.8); all $p<0.05$.

Conclusion: In our study, 1 in 3 CD patients had a robust outcome, with favorable radiographic alignment and functional status up to 2 years postoperatively. Robustness was more likely in patients with adequate global sagittal alignment, without baseline cervical hyperlordosis, and in those undergoing more invasive procedures for deformity correction.

PAPER 47

Surgical Management of Adult Cervical Deformity: Are We Getting Better at Optimal Realignment?

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Introduction: The definition of "optimal surgical realignment" in adult cervical deformity (ACD) has shifted with improved understanding the drivers of deformity and advancements in surgical planning. Ideally, this progress has led to improved outcomes in ACD surgery. Therefore, we sought to assess changes in achieving optimal surgical realignment outcomes of ACD patients.

Materials and Methods: This is a retrospective analysis of patients prospectively enrolled in a single center ACD database. Patient ≥18 years-old with 2-year (2Y) data were included. Patients were ranked by date of surgery, into early (E) and (L) groups. Deformity was assessed via TS-CL and cSVA Ames deformity modifiers (Ames et al.) as well as separate modifiers published by Passias et al. including: C2-T3 Angle, C2 Slope, and C2-C7. Means comparison tests assessed differences in BL and 2Y alignment as well as HRQL outcomes. ANCOVA and logistic regressions were utilized to analyze outcomes of interest while accounting for covariates such as baseline age and deformity as appropriate.

Results: 87 patients were included (61.3yrs, 87%F, BMI: 29.5/m^2, CCI: 0.75). There were no significant differences in baseline demographics, deformity, or surgical details between the E- and L-Groups. Logistic regression found that significantly more patients improved in cSVA modifier (90% vs. 70%, p=.006). At 2Y, more patients in the L-Group had improved in TS-CL modifier, while E-Group patients tended to deteriorate. ANCOVA found patients in the late group had significantly better mJOA scores at follow-up (15.1 vs. 13.7, p=.011). With respect to HRQL outcomes, logistic regression analysis found patients in the L Group were 3.2x more likely to reach MCID in EQ-5D (OR: 3.161, [1.082, 9.240], p=.035).

Conclusion: Advancements in understanding the drivers of cervical deformity has led to improved deformity classification and realignment schema. In this cohort, the late group demonstrated superior realignment in cSVA and more durable TS-CL correction at 2Y. Moreover, patients in the late group demonstrated better mJOA scores and were more likely to reach MCID in EQ-5D. Although surgeon experience and patient selection may account for some of these differences, these results demonstrate the impact of improved operative realignment on patient outcomes in adult cervical deformity.

PAPER 48

Semispinalis Cervicis Sarcopenia is Associated with Worsening Cervical Sagittal Balance and Junctional Alignment following Posterior Cervical Fusion for Myelopathy

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Introduction: No study has investigated the association between sarcopenia and postoperative alignment following cervical spine surgery. The purpose of the present study was to investigate whether cervical paraspinal sarcopenia is associated with cervicothoracic sagittal alignment parameters following posterior cervical fusion (PCF).

Materials and Methods: We retrospectively reviewed patients undergoing PCF from C2-T2 at a single institution between the years 2017-2020. Two independent reviewers utilized axial cuts of T2-weighted MRI sequences to perform Goutalier classification of the bilateral semispinalis cervicis (SSC) muscles (Figure 1). Cervical sagittal alignment parameters were compared between subgroups based upon severity of SSC sarcopenia.

Results: We identified 61 patients for inclusion in this study, including 19 patients with mild SSC sarcopenia and 42 patients with moderate or severe SSC sarcopenia. The moderate-severe sarcopenia subgroup demonstrated a significantly larger change in C2-7 SVA (+6.8mm) from the 3-month to 1-year postoperative follow-up in comparison to the mild sarcopenia subgroup (-2.0mm; P=0.02) (Table 2). The subgroup of patients with moderate-severe sarcopenia also demonstrated an increase in T1-4 kyphosis (10.9 to 14.2, P=0.007), T1 slope (28.2 to 32.4, P=0.003), and C2 slope (24.1 to 27.3, P=0.05) from 3 months to 1 year postoperatively and a significant decrease in C1-Occiput distance (6.3 to 4.1, P=0.002) during this same interval (Table 3).

Conclusion: In a uniform cohort of patients undergoing PCF from C2 to T2, semispinalis cervicis sarcopenia was associated with worsening cervicothoracic alignment from 3 months to 1 year postoperatively.

PAPER 48 continued

Table 2: The Impact of Semispinalis Cervicis Sarcopenia⁺ on Global Cervical Sagittal Alignment

	Mild (n=19)	Moderate - Severe (n=42)	P Value
*C2-7 SVA**			
Preoperative	42.8 (20.3)	38.4 (17)	0.40
3 Month Postoperative	46.6 (20.1)	39.0 (17.3)	0.14
Δ Preoperative to 3 Month Postop	3.8 (12.0)	0.6 (15)	0.38
P Value	0.12	0.66	
1 Year Postoperative	44.6 (22.6)	45.8 (19.1)	0.83
Δ 3 Month Postop to 1 Year Postop	-2.0 (14.2)	6.8 (11.6)	**0.02**
P Value	0.53	**<0.001**	
# of Patients with Preoperative C2 SVA <40 >40	 9 (47.4%) 10 (52.6%)	 22 (52.4%) 20 (47.6%)	0.72
# of Patients with 3 Month Postop C2 SVA <40 >40	 8 (42.1%) 11 (57.9%)	 21 (50.0%) 21 (50.0%)	0.57
# of Patients with 1 Year Postop C2 SVA <40 >40	 8 (42.1%) 11 (57.9%)	 16 (38.1%) 26 (61.9%)	0.68
C2-7 Lordosis			
Preoperative	4.2 (16.6)	12.2 (14.4)	0.07
3 Month Postoperative	8.2 (11.0)	10.1 (8.4)	0.47
Δ Preoperative to 3 Month Postop	4.0 (17.9)	-2.1 (14.6)	0.24
P Value	0.43	0.42	
1 Year Postoperative	9.0 (12.1)	9.7 (11.8)	0.69
Δ 3 Month Postoperative to 1 Year Postop	0.8 (7.2)	-0.4 (9.3)	0.79
P Value	0.63	0.11	

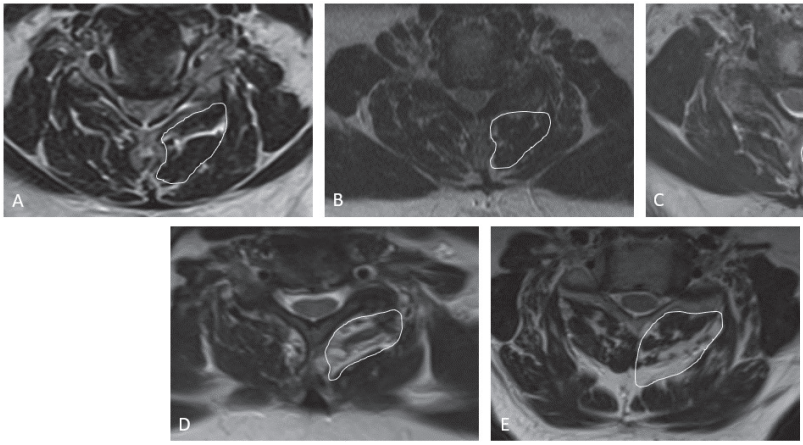
*Abbreviations: Sagittal Vertical Axis (SVA)
⁺Semispinalis cervicis sarcopenia was assessed on preoperative MRI at the C5/6 interspace and is based upon the Fuchs Modification of the Goutalier grading system
Continuous variables are displayed as mean (standard deviation), categorical variables are displayed as number (percent).

PAPER 48 continued

Table 3: The Impact of Semispinalis Cervicis Sarcopenia⁺ on Distal Junctional Alignment			
	Mild (n=19)	Moderate - Severe (n=42)	P Value
T1 Slope			
Preoperative	27.5 (11.0)	26.9 (10.5)	0.83
3 Month Postoperative	28.6 (12.0)	28.2 (11.1)	0.91
Δ Preoperative to 3 Month Postop	1.1 (15.0)	1.3 (9.3)	0.97
P Value	0.72	0.43	
1 Year Postoperative	30.7 (12.1)	32.4 (11.7)	0.79
Δ 3 Month Postoperative to 1 Year Postop	2.1 (10.2)	4.2 (7.9)	0.45
P Value	0.41	**0.003**	
T1-4 Kyphosis			
Preoperative	10.0 (4.8)	8.9 (7.5)	0.67
3 Month Postoperative	8.6 (7.3)	10.9 (6.2)	0.20
Δ Preoperative to 3 Month Postop	-1.4 (4.6)	2.0 (6.3)	0.07
P Value	0.37	**0.04**	
1 Year Postoperative	10.9 (6.0)	14.2 (9.2)	0.89
Δ 3 Month Postoperative to 1 Year Postop	2.3 (7.7)	3.3 (6.4)	0.36
P Value	**0.02**	**0.007**	

⁺Semispinalis cervicis sarcopenia was assessed on preoperative MRI at the C5/6 interspace and is based upon the Fuchs Modification of the Goutalier muscle grading system
Continuous variables are displayed as mean (standard deviation), categorical variables are displayed as number (percent).

PAPER 48 continued



PAPER 49

Surgical treatment of dropped head syndrome: range of fixations and postoperative complications

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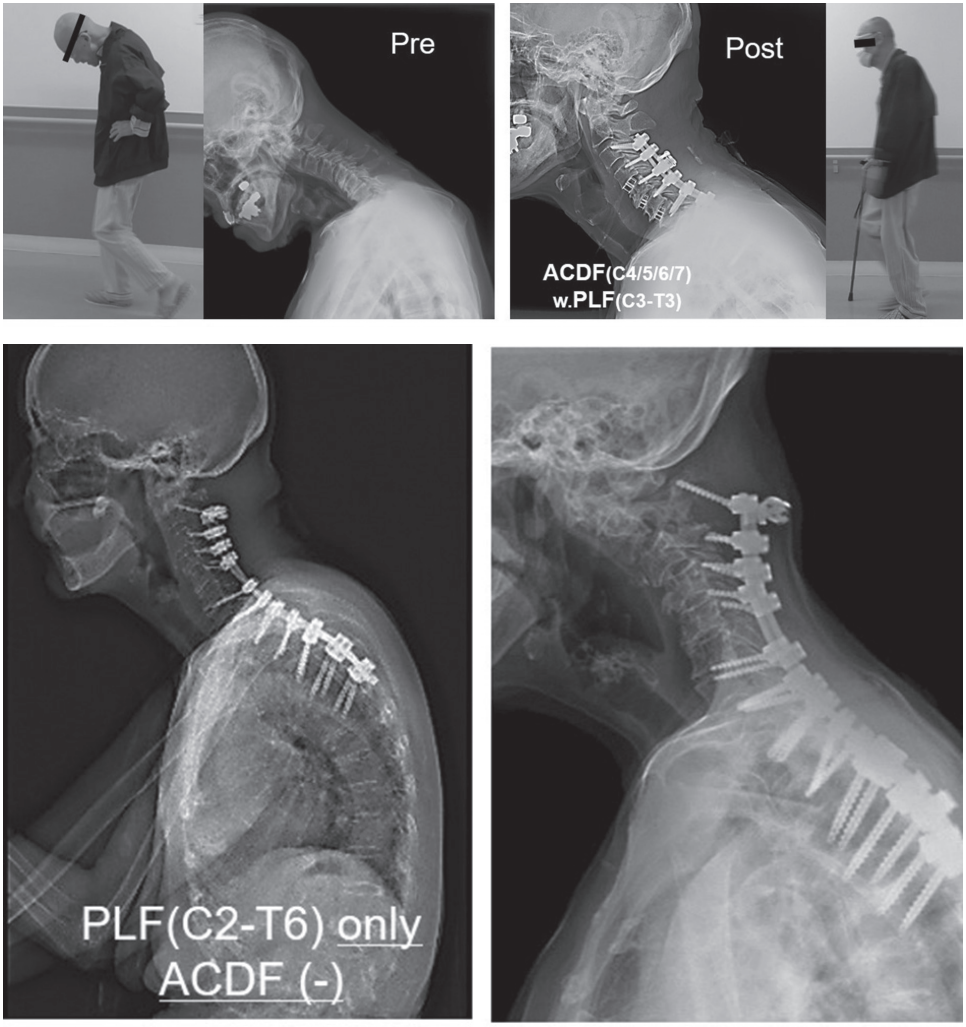
Introduction: Dropped head syndrome (DHS) is a condition defined by difficulty of keeping the head up against gravity with a severe kyphotic posture of the cervical spine. The diverse etiologies of DHS have been reported and include spinal pathologies. And not only the cervicothoracic spinal lesion, but also the thoracolumbar spinal lesion can cause DHS. However, effective surgical procedures for DHS are not still established. This study aimed to assess surgical procedures and complications in surgery for DHS.

Materials and Methods: We retrospectively analyzed surgical procedures and postoperative complications on surgery for DHS by cervicothoracic lesion in 29 consecutive patients. Eleven patients had surgical history of cervical laminoplasty within four years. Among them, one patient had also history of anterior cervical discectomy and fusion (ACDF) and another had history of posterolateral fusion (PLF) at C1/2.

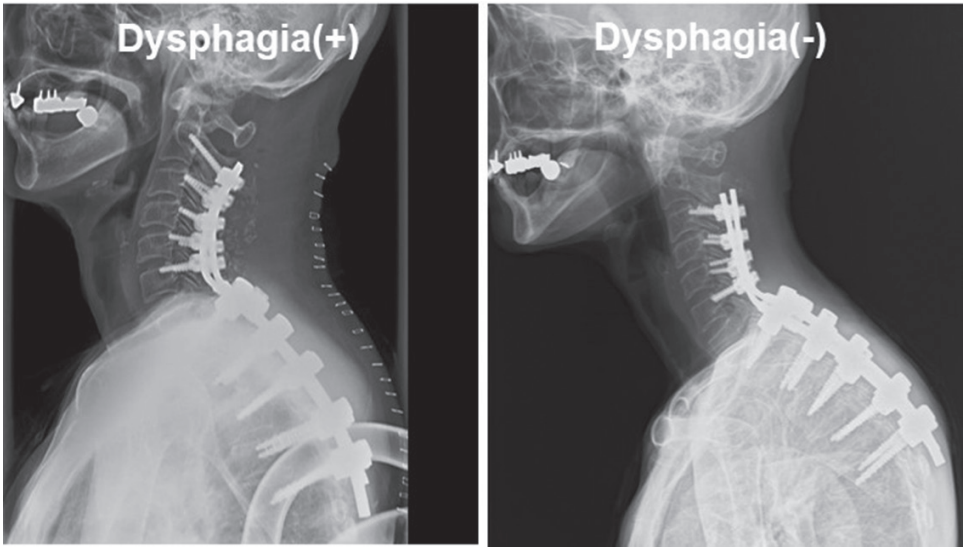
Results: Surgical procedures were Multilevel ACDF with PLF (Fig.1) in 22, PLF in 5 and pedicle subtraction osteotomy (PSO) with PLF for rigid deformity in 2 patients. The upper instrumented vertebrae (UIV) of PLF were C1 in 1. C2 in 13 and C3 in 15 patients. The lower instrumented vertebrae (LIV) were C7 in 1, T1 in 1, from T2 to T4 in 23 and T5 or T6 in 4 patients. Mean rages of ACDF were 3.3 levels and most of cases included C5/6 and C6/7. We performed additional PSO as revision surgery in two patients. Myelopathy reappeared by instrumentation failure at LIV of C7 in one and by insufficient correction in the other. Another patient with PLF alone showed the back-out of rostral screws (Fig. 2). However, she could not undergo revision surgery because of the onset of cerebral infarction. Another two patients presented with postoperative dysphagia. Mild dysphagia was spontaneously recovered in several months after multilevel ACDF in one patient. Severe dysphagia soon after PLF alone was resolved by the reoperation of lessening cervical lordosis in the other (Fig. 3). Furthermore, she underwent additional revision surgery of multiple rod construct for rod breakage 14 months after the reoperation.

Conclusion: Multilevel ACDF with PLF is basically recommended in surgery for DHS, in order to keep a great correction of the cervicothoracic junction (CTJ) against gravity. LIV of PLF must be extended to at least upper thoracic spine (T2-4) for including the CTJ. And UIV at C3 may be sufficient when bilateral pedicle screws could be inserted at C3 and C4. Multilevel ACDFs includes C5/6 and C6/7, because of main pathology of DHS at the CTJ. Excessive formation of cervical lordosis should be avoided, because it can cause severe dysphagia. Furthermore, preoperative assessment of swallowing function may be necessary in elderly patients, because they have a risk of latent swallowing disturbance.

PAPER 49 continued



PAPER 49 continued



PAPER 50

Do flare-ups in systemic Disease Activity correlate to cervical deformity in patients with Rheumatoid Arthritis?

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Introduction: Following the introduction of biological DMARDs in Rheumatoid Arthritis (RA) treatment, cervical spine deformity seems to be less prevalent in those patients. It seems that this vast decline in patients with Atlanto-axial Subluxation (AAS), Subaxial Subluxation (SAS) or Vertical Subluxation (VS) is correlated to better control of systemic disease activity (DAS). However, results of systematic literature review and of an observational study on the correlation between mean DAS values and prevalence of cervical spine deformities could not establish a relation. The aim of the current study is to correlate the frequency of flare-ups in DAS to cervical spine deformity.

Materials and Methods: This research is observational and uses collected data of patients diagnosed with early RA and randomized to four treatment strategies aiming at optimizing medical treatment to lower systemic inflammation with 10 years of follow-up (BeSt Trial; medication is stopped if remission is accomplished, and restarted upon a flare). AAS and SAS were evaluated blindly by two observers on lateral cervical X-rays at 5 and 10 years of follow-up and systemic DAS was measured 41 times during a period of 10 years. Remission of RA is defined as a DAS lower than 1.6 during at least six consecutive months. A flare-up was defined as a DAS of 1.6 or higher after reaching remission.

Results: 272 RA patients were included and AAS was observed in 62 patients (23%) and SAS was present in 60 patients (22%). Cervical deformity (AAS and/or SAS) was observed in 108 patients. 84 (31%) patients were in remission at 10 years FU and 206 (75%) of patients reached remission at least once during 10 years FU. 193 of these patients demonstrated at least one flare-up, with a mean of 1.5 flares. Patients with cervical spine deformity at 10 years had less flare-ups (1.26) in DAS than patients without cervical spine deformity (1.58; 95% CI: 0.013-0.627).

Conclusion: It was observed that even though the BeSt Trial was designed to optimize treatment, 40% of the patients still developed RA-associated cervical spine deformity. Reaching remission after 10 years of treatment did not correlate to presence of cervical spine deformity, but the flare ups in DAS did appear to do so. However, remarkably, patients with more flares had less cervical deformity. This may be explained by the treatment regimen that anti-inflammatory medication is augmented upon measuring a systemic flare-up. This raises the hypothesis that RA medication treatment regimes should not be solely aimed at DAS values, as they are currently defined, in order to avoid cervical deformity in RA in the long term.

PAPER 51

Do Patients with Preoperative Marijuana Use have Similar Outcomes following Anterior Cervical Discectomy and Fusions?

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Introduction: A growing number of states have legalized recreational and/or medical marijuana, thus increasing the number of patients who report preoperative ACDF marijuana use. The effects of marijuana use on clinical outcomes and PROMs in the postoperative period are unknown. Therefore, the purpose of this study was to determine if 1) preoperative marijuana use increased complications, readmission, or reoperation rates following anterior cervical discectomy and fusion (ACDF), 2) identify if preoperative marijuana use resulted in worse patient-reported outcome measures (PROMs), and 3) investigate if preoperative marijuana use affects the quantity of opioid prescriptions in the perioperative period.

Materials and Methods: All patients $\geq$ 18 years of age who underwent primary one- to four-level ACDF with preoperative marijuana use were retrospectively identified. A 3:1 propensity match was conducted to compare patients who used marijuana versus those who did not. Patient demographics, surgical characteristics, clinical outcomes, and PROMs were compared between groups. The total quantity of opioid prescriptions in morphine milligram equivalents (MME) was recorded for each patient and collected through our state's Prescription Drug Monitoring Program (PDMP) database from the one-year preoperative to the one-year postoperative time point. Descriptive statistics including mean and standard deviation were used to report patient demographics, surgical characteristics, and surgical outcomes. A Shapiro-Wilk test was used to analyze the normality of each continuous variable, and parametric data was analyzed with independent t-tests while non-parametric data was analyzed with Mann-Whitney U tests. Categorical variables were analyzed with Pearson's chi-square tests. A multivariate linear regression model was developed to measure the effect of marijuana use on the likelihood of undergoing a spine reoperation for any cause when accounting for age, smoking status, ECI, and ACDF construct length. Multivariate linear regression models were developed to determine the independent association of marijuana use on delta PROM scores at the one-year postoperative point. Statistical significance was set a $P < 0.05$.

Results: Of the 236 included patients, 59 (25.0%) used marijuana preoperatively. There were no significant differences in baseline demographics include age (p=0.901), sex (p=0.940), BMI (p=0.658), smoking status (p=0.940), or ECI (p=0.902) between patients. Additionally, preoperative symptom duration (p=0.21) and number of levels fused (p=0.25) was similar between groups with a higher percent of marijuana users have a preoperative diagnosis of radiculopathy (p=0.002) (Table 1). Patients who used preoperative marijuana had a higher surgically related readmissions (5.08% vs. 0%, p=0.015). However, there was no significant difference in all-cause spine reoperations (22% vs 12.4%, p=0.113) (Table 2). Multivariate logistic regression analysis identified marijuana use (OR=2.36, p=0.041) as a predictor of a cervical

PAPER 51 continued

spine reoperation after ACDF. Patients who used marijuana preoperatively had worse one-year postoperative PCS-12 (p=0.003), NDI (p=0.022), and VAS Neck (p=0.026). Multivariate linear regression identified preoperative marijuana use as a predictor of worse delta (postoperative minus preoperative) PCS-12 (b=-7.61, p=0.044) and delta NDI (b=15.33, p=0.022) at the one-year postoperative period (Table 3).

Conclusion: Preoperative marijuana use increased the risk of a cervical spine reoperation after ACDF and it was also a predictor of worse improvement in PCS-12 and NDI at the one-year postoperative period.

PAPER 51 continued

Table 1: Demographics and Surgical Characteristics

Demographics and Surgical Characteristics	No Marijuana	Marijuana	P-Value[1]
	N=177	*N*=59	
Age (years):	54.4 (10.7)	54.2 (11.7)	0.901
Sex:			0.940
Female	87 (49.2%)	28 (47.5%)	
Male	90 (50.8%)	31 (52.5%)	
BMI (kg/m^2):†	28.3 (5.21)	28.2 (5.81)	0.658
Elixhauser Comorbidity Index:†	1.67 (1.55)	1.71 (1.55)	0.902
Tobacco Smoker:			0.940
No	84 (47.5%)	27 (45.8%)	
Yes	93 (52.5%)	32 (54.2%)	
Preoperative Diagnosis:			**0.002***
Radiculopathy	72 (40.7%)	35 (59.3%)	
Myelopathy	23 (13.0%)	12 (20.3%)	
Myeloradiculopathy	82 (46.3%)	12 (20.3%)	
Duration of Symptoms:			0.211
<6 Months	69 (39.0%)	17 (28.8%)	
>6 Months	108 (61.0%)	42 (71.2%)	
Construct Length:			0.252
1-Level	54 (30.5%)	23 (39.0%)	
2-Level	68 (38.4%)	25 (42.4%)	
3-Level	45 (25.4%)	8 (13.6%)	
4-Level	10 (5.65%)	3 (5.08%)	
Opioid Use (MME):			
Preoperative†	232 (424)	218 (293)	0.790
1 Year Postoperative†	257 (418)	226 (236)	0.827
Total Preoperative to 1 Year Postoperative†	402 (731)	374 (450)	0.783
Data is listed as either: mean (standard deviation) or *n* (%)			

Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

PAPER 51 continued

Table 2: Surgical Outcomes

Surgical Outcomes	No Marijuana	Marijuana	P-Value[1]
	N=177	*N*=59	
Epidural Hematoma:			0.250
No	177 (100%)	58 (98.3%)	
Yes	0 (0.00%)	1 (1.69%)	
Epidural Abscess:			0.062
No	177 (100%)	57 (96.6%)	
Yes	0 (0.00%)	2 (3.39%)	
CSF Leak:			0.250
No	177 (100%)	58 (98.3%)	
Yes	0 (0.00%)	1 (1.69%)	
90-Day All-Cause Readmission:			**0.012***
No	175 (98.9%)	54 (91.5%)	
Yes	2 (1.13%)	5 (8.47%)	
90-Day Surgical Readmission:			**0.015***
No	177 (100%)	56 (94.9%)	
Yes	0 (0.00%)	3 (5.08%)	
All-Cause Spine Reoperation:			0.113
No	155 (87.6%)	46 (78.0%)	
Yes	22 (12.4%)	13 (22.0%)	
Adjacent Segment Disease:			0.895
No	162 (91.5%)	53 (89.8%)	
Yes	15 (8.47%)	6 (10.2%)	
Pseudarthrosis:			0.240
No	167 (94.4%)	53 (89.8%)	
Yes	10 (5.65%)	6 (10.2%)	

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

PAPER 51 continued

Table 3: Multiple Linear Regression – Delta PROMs at 1 Year

	Δ PCS-12			Δ MCS-12			Δ NDI			Δ VAS Arm			Δ VAS Neck		
Predictors	Estimate	95% CI	P-Value	Estimate	95% CI	P-Value	Estimate	95% CI	P-Value	Estimate	95% CI	P-Value	Estimate	95% CI	P-Value
Marijuana Use	-7.61	-14.81 – -0.41	**0.044***	0.37	-6.52 – 7.26	0.916	15.33	2.69 – 27.98	**0.022***	-0.83	-2.91 – 1.24	0.434	0.17	-1.89 – 2.23	0.870
Age	0.15	-0.17 – 0.46	0.358	-0.19	-0.49 – 0.11	0.230	-0.19	-0.75 – 0.37	0.504	-0.06	-0.15 – 0.03	0.215	-0.01	-0.10 – 0.08	0.874
Male Sex	4.61	-1.57 – 10.79	0.150	1.42	-4.49 – 7.33	0.640	-5.16	-16.09 – 5.77	0.360	-0.97	-2.75 – 0.81	0.292	-0.67	-2.44 – 1.10	0.460
BMI	0.01	-0.71 – 0.72	0.988	-0.28	-0.96 – 0.40	0.425	0.70	-0.49 – 1.90	0.253	0.16	-0.05 – 0.36	0.139	0.07	-0.13 – 0.27	0.501
Elixhauser	-0.29	-2.80 – 2.22	0.821	0.02	-2.38 – 2.42	0.984	-1.94	-6.51 – 2.63	0.410	0.19	-0.97 – 0.58	0.632	-0.10	-0.87 – 0.67	0.800
Current Smoker	-0.71	-7.09 – 5.67	0.828	-2.66	-8.76 – 3.44	0.397	-2.88	-13.95 – 8.20	0.613	-1.14	-2.93 – 0.65	0.219	-1.52	-3.30 – 0.25	0.100
Construct Length	0.13	-3.44 – 3.70	0.943	-0.09	-3.51 – 3.32	0.958	1.66	-4.27 – 7.58	0.586	0.52	-0.43 – 1.47	0.290	-0.46	-1.40 – 0.49	0.347
Pre-Op Diagnosis															
Radiculopathy	Ref.			Ref.			Ref.			Ref.			Ref.		
Myelopathy	1.45	-7.98 – 10.87	0.765	1.26	-7.75 – 10.28	0.784	-3.39	-18.76 – 11.98	0.668	1.61	-0.99 – 4.21	0.233	-0.57	-3.15 – 2.02	0.669
Myeloradiculopathy	-4.08	-11.18 – 3.03	0.266	-2.94	-9.73 – 3.85	0.401	11.98	0.24 – 23.72	0.051	1.55	-0.38 – 3.48	0.123	2.36	0.44 – 4.28	**0.020***

*Indicates statistical significance (p<0.05)

PAPER 52

Long-term Outcomes of Vertebral Body Sliding Osteotomy for the Treatment of Cervical Myelopathy: A Minimum of 5-year Follow-up

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Dongguk University Hospital[1] Asan Medical Center[2]

Introduction: Vertebral body sliding osteotomy (VBSO) is an anterior decompression and fusion technique involving the anterior vertebral body translation along with ossification of posterior longitudinal ligament or spondylotic lesion causing cord compression (Figure 1). VBSO has been reported to result in fewer complications, better lordosis restoration, and faster bone union than corpectomy. However, previous studies demonstrated the outcomes of VBSO with ≥2 years of follow-up, but its long-term outcome was not reported. Maintaining the advantages of VBSO in the early postoperative period during the long-term follow-up remained unclear. Therefore, this study aimed to 1) demonstrate the long-term outcomes of VBSO with a minimum of 5-year follow-up and 2) compare the results with other anterior reconstruction techniques including anterior cervical discectomy fusion (ACDF) and anterior cervical corpectomy fusion (ACCF).

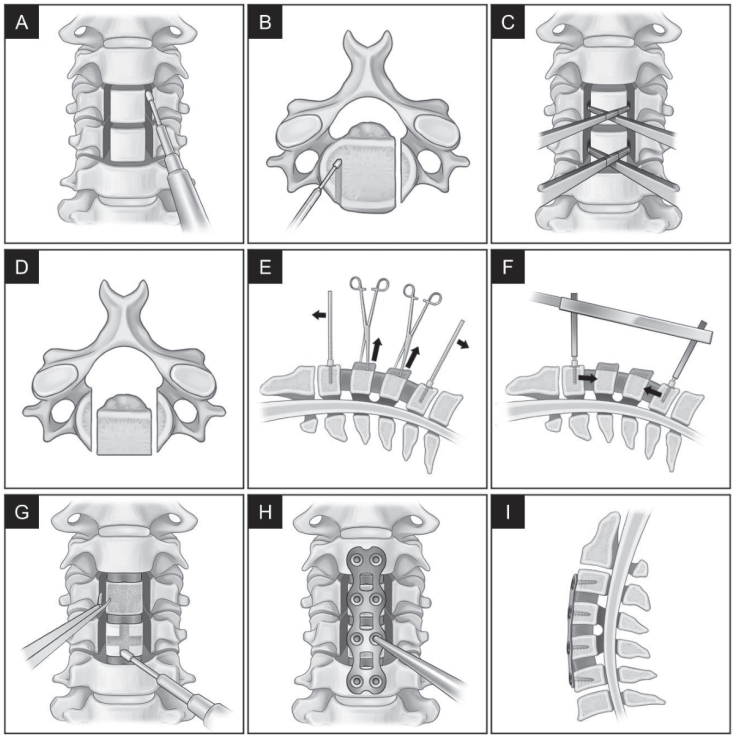
Materials and Methods: A total of 128 patients, who underwent VBSO, ACDF, or ACCF for cervical myelopathy treatment and were followed up for >5-years, were retrospectively reviewed. Fusion, subsidence, C0–2 lordosis, C2–7 lordosis, segmental lordosis, C2–7 sagittal vertical axis (SVA), surgical complications, neck pain visual analog scale (VAS), neck disability index (NDI), and Japanese Orthopedic Association (JOA) score were assessed. Statistical comparisons between the VBSO, ACDF, and ACCF groups were made.

Results: The VBSO, ACDF, and ACCF groups included 38 (29.7%), 62 (48.4%), and 28 (21.8%) patients, respectively. No cases experienced dural tear, postoperative neurologic deterioration, infection, graft dislodgement and no patient required revision operation during the follow-up in the VBSO group. The VBSO revision rate (0/38, 0.0%) was significantly less than that of ACDF (8/62, 12.9%. $p = 0.023$) or ACCF (5/28, 17.9%, $p = 0.011$) (Table 1). VBSO demonstrated higher fusion rate at 6-month and 1-year follow-up, but the fusion rate at 5 years (97.4%) was not significantly different compared to ACDF (85.5%, $p = 0.054$) and ACCF (85.7%, $p = 0.077$). Segmental lordosis at the 5-year follow-up was significantly higher in the VBSO group (16.1 ± 7.6) than the ACDF ($p = 0.002$) or ACCF ($p < 0.001$) groups. Furthermore, C2–7 lordosis at the 5-year follow-up was significantly higher in the VBSO group compared to the ACCF group ($p = 0.017$) (Table 2). Neck pain VAS, NDI, JOA score, and JOA recovery rate did not show significant intergroup differences during the postoperative 5-year period (Table 1).

Conclusion: No cases required revision operation in VBSO during a 5-year follow-up, which demonstrated significant results compared to ACDF or ACCF. VBSO reached stable construct earlier than other techniques, as demonstrated with a higher 6-month and 1-year fusion rate, which would have enhanced the long-term safety and decreased the need for reoperation. Furthermore, VBSO showed a greater capacity to restore lordosis than ACDF or ACCF since it preserves the vertebral body and includes multiple lordotic shape interbody spacer insertion, which was maintained during the long-term follow-up. Therefore, VBSO demonstrated advantages over ACDF or ACCF regarding revision rate and lordosis restoration in long-term follow-up and is considered a safe anterior reconstruction technique for cervical myelopathy treatment.

PAPER 52 continued

Figure 1. (A-I) Schematic images of the vertebral body sliding osteotomy procedure.
(A) Two longitudinal gutters are made by a high-speed burr at the base of the bilateral uncinate processes. (B) Axial image: The vertebral body is cut to make a box-shaped and freely mobile segment. (C) Using several Allis forceps, anterior migration of each mobile fragment of the vertebral bodies was performed. (D) Anterior translated vertebral body with ossification of the posterior longitudinal ligament mass. (E) While holding the vertebral body in an anteriorly translated position, interbody cages are inserted. (F) Releasing the traction force made by a Caspar retractor. (G) The protruding portion of the translated body was shaved down using a high-speed burr and pituitary forcep. (H, I) The anterior cervical plate is applied for additional stability.



PAPER 52 continued

Table 1. Surgical complications and patient-reported outcome measures

	ACDF (n = 62)	VBSO (n = 38)	ACCF (n = 28)	*p*-value		
				ACDF vs. VBSO	ACDF vs. ACCF	VBSO vs. ACCF
Surgical complications						
Neurologic deterioration	2 (3.2%)	0 (0.0%)	1 (3.6%)	0.524	1.000	0.424
Dural tear	0 (0.0%)	0 (0.0%)	2 (7.1%)	1.000	0.094	0.176
Infection	0 (0.0%)	0 (0.0%)	1 (3.6%)	1.000	0.311	0.424
Reoperation	8 (12.9%)	0 (0.0%)	5 (17.9%)	0.023*	0.536	0.011*
Dysphagia	8 (12.9%)	6 (15.8%)	4 (14.3%)	0.684	1.000	1.000
C5 palsy	5 (8.1%)	1 (2.6%)	0 (0.0%)	0.403	0.319	1.000
Graft dislodgement	2 (3.2%)	0 (0.0%)	2 (7.1%)	0.524	0.586	0.176
Neck pain VAS						
Preoperative	3.4 ± 2.6	2.9 ± 2.6	3.9 ± 3.0	0.207	0.275	0.125
Postop 1 y	2.1 ± 1.9	2.2 ± 2.4	2.6 ± 2.1	0.390	0.214	0.319
Postop 5 y	2.4 ± 2.4	2.1 ± 2.3	2.4 ± 2.6	0.302	0.488	0.326
NDI						
Preoperative	11.4 ± 7.0	13.7 ± 7.9	17.2 ± 11.1	0.115	0.017*	0.125
Postop 1 y	8.0 ± 5.1	9.6 ± 8.0	10.2 ± 6.0	0.158	0.111	0.416
Postop 5 y	6.9 ± 5.2	7.5 ± 6.5	9.6 ± 6.4	0.355	0.056	0.148
JOA						
Preoperative	13.9 ± 2.1	13.6 ± 2.1	15.3 ± 1.2	0.240	0.023*	0.006*
Postop 1 y	14.8 ± 1.9	14.4 ± 2.0	15.9 ± 0.7	0.211	0.033*	0.008*
Postop 5 y	15.5 ± 1.4	15.3 ± 1.6	16.1 ± 0.5	0.256	0.094	0.052
JOA Recovery rate (5 y)	41.4 ± 43.5	45.7 ± 40.6	35.6 ± 40.3	0.352	0.343	0.240

ACDF, anterior cervical discectomy and fusion; VBSO, vertebral body sliding osteotomy; ACCF, anterior cervical corpectomy and fusion; VAS, visual analog scale; NDI, neck disability index; JOA, Japanese Orthopaedic Association

Surgical complications were analyzed using a chi-square test or Fisher's exact test

Neck pain VAS, NDI, JOA, and JOA recovery rate were analyzed using a student's t-test

* *p*-value < 0.05

PAPER 52 continued

Table 2. Radiographic outcome

		ACDF (n = 62)	VBSO (n = 38)	ACCF (n = 28)	*p*-value		
					ACDF vs. VBSO	ACDF vs. ACCF	VBSO vs. ACCF
Fusion rate	ISM 6 m	27 (43.5%)	27 (71.1%)	9 (32.1%)	0.007*	0.307	0.002*
	ISM 1 y	47 (75.8%)	35 (92.1%)	17 (60.7%)	0.039*	0.209	0.002*
	ISM 5 y	53 (85.5%)	37 (97.4%)	24 (85.7%)	0.054	1.000	0.077
	InGBB 1 y	43 (69.4%)	34 (89.5%)	17 (60.7%)	0.020*	0.421	0.006*
	ExGBB 1 y	35 (56.5%)	33 (86.8%)	4 (14.3%)	0.002*	<0.001*	<0.001*
Subsidence (1y)	Subsidence (mm)	1.7 ± 1.0	1.5 ± 1.2	2.4 ± 2.2	0.290	0.013*	0.019*
	Subsidence>3mm	7 (11.3%)	4 (10.5%)	10 (35.7%)	1.000	0.009*	0.017*
Preoperative alignment	C0-2 lordosis (°)	35.7 ± 8.3	40.4 ± 8.2	36.4 ± 8.2	0.004*	0.373	0.025*
	C2-7 lordosis (°)	11.2 ± 8.7	9.2 ± 6.9	8.5 ± 5.7	0.121	0.068	0.321
	Seg. lordosis (°)	4.0 ± 11.0	4.6 ± 11.0	1.3 ± 9.7	0.393	0.128	0.100
	C2-7 SVA (mm)	19.6 ± 9.5	19.5 ± 12.3	21.2 ± 12.5	0.481	0.249	0.288
Postop 1 year alignment	C0-2 lordosis (°)	30.6 ± 7.1	29.5 ± 6.7	32.5 ± 8.8	0.220	0.142	0.061
	C2-7 lordosis (°)	13.5 ± 7.8	14.5 ± 8.5	10.1 ± 6.5	0.283	0.023*	0.013*
	Seg. lordosis (°)	12.9 ± 5.4	15.2 ± 7.6	9.0 ± 9.8	0.041*	0.009*	0.003*
	C2-7 SVA (mm)	18.4 ± 9.4	18.2 ± 9.6	17.8 ± 10.0	0.448	0.392	0.444
Postop 5 year alignment	C0-2 lordosis (°)	30.3 ± 6.8	29.0 ± 8.0	31.4 ± 9.7	0.200	0.268	0.139
	C2-7 lordosis (°)	12.7 ± 8.0	14.2 ± 8.5	10.0 ± 6.5	0.194	0.061	0.017*
	Seg. lordosis (°)	11.9 ± 6.2	16.1 ± 7.6	6.5 ± 10.1	0.002*	0.001*	<0.001*
	C2-7 SVA (mm)	17.2 ± 10.1	18.2 ± 8.8	18.9 ± 10.6	0.310	0.226	0.373

ACDF, anterior cervical discectomy and fusion; VBSO, vertebral body sliding osteotomy; ACCF, anterior cervical corpectomy and fusion; ISM, interspinous motion; InGBB, intragraft bone bridging; ExGBB, extragraft bone bridging; seg., segmental; SVA, sagittal vertical axis; m, month; y, years

Fusion rate, subsidence of >3mm and ASD were analyzed using a chi-square test or Fisher's exact test

Subsidence (mm), lordosis and SVA were analyzed using a student's t-test

* *p*-value < 0.05

PAPER 53

Serum GFAP and NF-L are Biomarkers of Injury Severity and Predictors of Recovery After Acute Cervical Spinal Cord Injury

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University of British Columbia[1]

Introduction: The severity of paralysis after traumatic cervical spinal cord injury (SCI) is assessed with the ISNCSCI examination, which is impossible to do in many acutely injured patients and is subjective and highly dependent upon patient participation and assessor experience/training. Neurochemical biomarkers could serve an important role in objectively characterizing the severity of injury and more precisely predicting neurologic recovery, even in those who are un-examinable. While biomarkers within CSF may be most sensitive and specific for spinal cord trauma, there would be clear benefits to establishing biomarkers within more easily obtained blood samples Here, we sought to determine if serum neurofilament light (NF-L) and glial fibrillary acidic protein (GFAP) levels could be used as biomarkers of injury severity and predictors of neurologic recovery after cervical SCI.

Materials and Methods: 68 patients with acute traumatic cervical SCI (AIS A, B, and C) were enrolled in a prospective multi-centre North American observational trial. Paired serial serum and CSF samples were collected daily over the first 3-5 days post-injury. NF-L and GFAP were quantified using Quanterix Simoa™ technology. Neurologic assessments were performed to define the ASIA Impairment Scale (AIS) grade and motor score (MS) at presentation and at 6-months post-injury. We tested the association between NF-L and GFAP and demographic and injury characteristics using two-sided Spearman rank correlation tests, Mann-Whitney U-tests, Kruskal-Wallis tests for continuous variables or Fisher exact tests for categorical variables. Data were log transformed, and receiver operating characteristics (ROC) curves were produced to assess biomarker performance.

Results: Serum NF-L and GFAP levels were highly correlated to CSF levels, and both NF-L and GFAP levels distinguished between baseline AIS A, B, and C grades of injury (Figure 1). Both serum biomarkers distinguished between those AIS A who converted and those who did not (Figure 2). Even in the absence of a baseline examination AIS grade, serum NF-L and GFAP levels could predict with 90% accuracy whether a patient at 6 months post-injury would be classified as "motor complete" (AIS A/B) or "motor incomplete" (AIS C/D) (Figure 3). Interestingly, the "strength" of this prediction of outcome at 6 months post-injury was optimal for GFAP with samples taken at 72-96 hours post-injury, indicating that a blood sample drawn even days post-injury could be very informative about prognosis. Serum GFAP and NF-L levels also predicted which cervical patients would gain more than 8 points of motor recovery at 6-months – an important threshold for recovery in clinical trials of neurotherapeutic agents.

Conclusion: This is the largest study to date to demonstrate the potential of acute serum levels of GFAP and NF-L in cervical SCI. Blood biomarkers can inform on the biology of the injury to better delineate the spectrum of injury severity, and thus recovery potential. As objective markers of injury severity, blood biomarkers will have utility in patient stratification

PAPER 53 continued

and prognostication in clinical trials of acute SCI. Furthermore, they may assist spine surgeons in their difficult discussion with patients about their prognosis for neurologic recovery after cervical SCI.

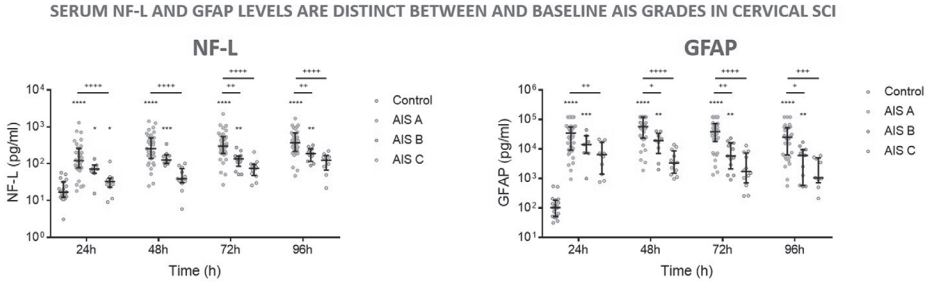


Figure 1. Evaluation of serum NF-L and GFAP as biomarkers of injury severity (AIS grade) in cervical SCI patients. Within each day, data was compared within SCI severities and control (non-SCI patients) using a Kruskal Wallis test with Dunn's multiple comparison test, where * p<0.05, ** p<0.01, and *** p<0.0001 compared to control (shown once in 24h bin) and + p<0.05, ++ p<0.01, and +++ p<0.001 compared within SCI groups.

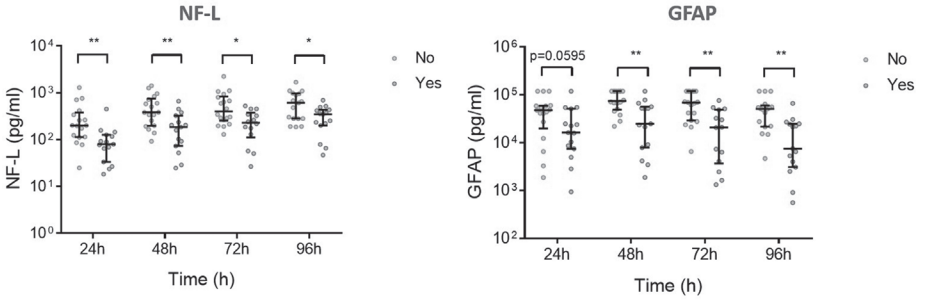


Figure 2. Comparison of serum NF-L and GFAP in cervical AIS A patients, distinguished by whether AIS grade conversion occurred (Yes/No) at 6-months post-injury. Of the 36 AIS A patients with outcome assessed at 6-months, 16 (44%) remained an AIS A (no conversion, orange or teal), while 20 (56%) improved in their AIS grade (yes conversion, blue or grey). Serum NF-L and GFAP were graphed based on AIS A conversion status at 6-months. Graphs represent median and IQR. Data was analyzed using a Mann-Whitney U test at each time-point, where * p<0.05, ** p<0.01, *** p<0.001, **** p<0.0001.

PAPER 53 continued

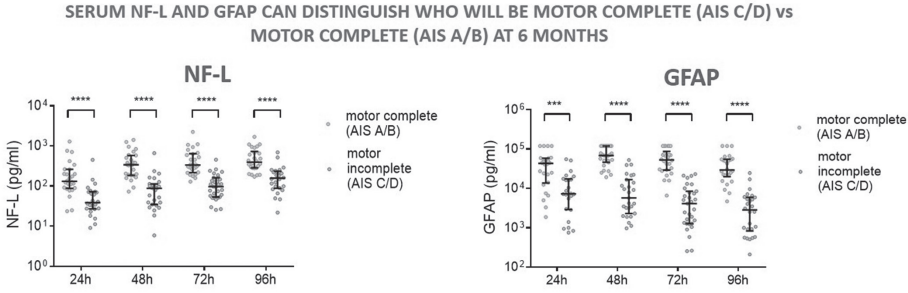


Figure 3. Comparison of serum NF-L and GFAP concentration based on the observed AIS grade at 6-months. 6-month outcome assessments were available in 65/68 (96%) cervical SCI patients. Thirty-one (48%) were classified as AIS A or AIS B (motor complete, orange) while 34 (52%) were classified as AIS C or AIS D (motor incomplete, blue) at 6-months. A,B) Graph of 24h, 48h, 72, and 96h A) NF-L and B) GFAP in SCI patients dichotomized based on 6-month AIS outcome. Graph represent median and IQR. Data pairs at each timepoint were analyzed using a Mann Whitney U test, where ** p<0.01, *** p<0.001, **** p<0.0001. C

PAPER 54

Motorized Robotic Cervical Traction: Proof of Concept

Brandon Sherrod, MD[1], Trevor Schwehr, MS, Andrew Merryweather, PhD, Marcus Mazur, MD
University of Utah[1]

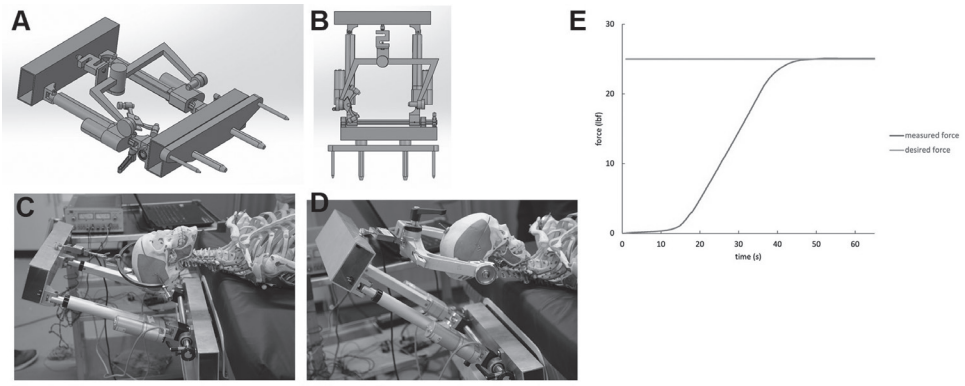
Introduction: In acute distraction-type cervical spine injuries, particularly facet dislocations, manual traction may be necessary to achieve mechanical stability and spinal cord decompression. The most commonly used method for application of cervical traction is the Gardner-Wells device, which consists of tongs with pins connected to the skull pulled away from the body using a series of pullies and weights to achieve traction force along the axis of the cervical spine. This method relies on outdated technology and is dependent on user application without any safeguard in place to prevent over-traction or weights being pulled/released inadvertently. Furthermore, traditional weight and pulley traction is cumbersome to assemble/disassemble and limits efficient patient transport. We propose a novel device with capability of performing automated, robotic cervical traction.

Materials and Methods: In a collaboration between the departments of mechanical engineering and neurosurgery at the University of Utah, a prototype device for performing automated robotic cervical traction was designed with the following capabilities: real-time force measurement with a load cell sensor, non-backdriveable linear actuator kinematic system with force and displacement control, adaptability to either a Gardner-Wells skull tong or a Mayfield head clamp, multiple degrees of freedom (60 degrees of flexion, 30 degrees of extension, and 30 degrees of lateral bending) which are independent of skull pin placement, and an emergency stop feature. Ergonomics and degrees of freedom were assessed using a skeleton model. Mechanical testing in tension loading was performed using a spring model.

Results: Computer assisted design (CAD) modeling of the proposed prototype was performed and the device was subsequently manufactured in-house. The device was successfully able to attach to both a Mayfield head clamp and Gardner-Wells skull tongs. When attached to a full skeleton model, the device was able to perform in multiple degrees of freedom (60 degrees of flexion, 30 degrees of extension, and 30 degrees of lateral bending). In a simple tension spring loading model, a force vs. time curve was generated demonstrating the device's ability to reach a steady state desired force of 25 pounds of traction over approximately 40 seconds. The device weighs approximately 20 pounds and requires fewer steps to assemble than traditional weight and pulley traction. The device does not interfere with lateral radiograph capture.

Conclusion: A preliminary prototype capable of performing automated robotic cervical traction demonstrates proof-of-concept and several advantages over traditional weight and pulley traction. Further studies in cadaver models are needed to evaluate device efficacy and safety.

PAPER 54 continued



PAPER 55

Comparing Those Most Satisfied Versus Least Satisfied Following Surgery for Cervical Spondylotic Myelopathy: Are there Differences in Baseline Characteristics?

Andrew Chan, MD, Christopher Shaffrey, MD[1], Oren Gottfried, MD, Khoi Than, MD, Erica Bisson, MD, MPH[2], Mohamad Bydon, MD, Anthony Asher, MD, Domagoj Coric, MD, Eric Potts, MD, Kevin Foley, MD, Michael Wang, MD, Kai-Ming Fu, MD, John Knightly, MD, Paul Park, MD, Cheerag Upadhyaya, MD, Mark Shaffrey, MD, Luis Tumialan, MD, Dean Chou, MD, Regis Haid, MD[3], Praveen Mummaneni, MD

Duke Clinics (South)[1] University of Utah[2] Atlanta Brain and Spine Care[3]

Introduction: Though a majority of patients operated for cervical spondylotic myelopathy (CSM) are satisfied with their surgical results, there are a minority that remain dissatisfied. Here, we sought to identify factors predicting the most (and least) satisfaction following surgery for CSM.

Materials and Methods: We retrospectively reviewed prospectively-collected data from the CSM Quality Outcomes Database (QOD) module. Baseline and surgical characteristics were compared for patients with CSM reporting the most [North American Spine Society Satisfaction Score (NASS) 1] and least (NASS 4) satisfaction 24 months postoperatively. A multivariable logistic model was constructed using backward elimination to determine significant predictors of most versus least satisfaction. Twenty-four-month patient-reported outcomes (PROs) were compared.

Results: Overall, 1,141 patients were prospectively enrolled. Of these, 610 (87.3%) were most satisfied and 89 (12.7%) were least satisfied. The most satisfied less often presented with numbness (56.4 vs 68.5%,p=0.03) and had fewer neck-pain only presentations (30.3 vs 43.8%,p=0.01). The most satisfied had fewer patients with symptoms >12 months in duration (46.2 vs. 57.8%,p=0.02). Clinically, most satisfied participated in more outside activities (85.6 vs 74.2%,p=0.01) and more activities in the home preoperatively (92.5 vs 83.9%,p=0.01). Surgically, the most satisfied had a higher proportion with listhesis (28.7 vs 18.1%,p=0.04) and more often received surgeries from an anterior approach (72.3 vs 55.1%,p<0.001) with fewer mean levels operated (2.5 vs. 3.1,p=0.001). Demographically, there were a higher proportion of Caucasian patients (81.0 vs 64.0%,p<0.001) and patients with 4 or more years of college education (40.9 vs 27.3%,p=0.01). There were no differences in 30-day readmissions (p=0.97) or 24-month reoperations (p=0.35). At 24 months, the most satisfied more often returned to baseline activities (85.0 vs 17.4%,p<0.001) and had superior neck pain (1.6 vs 6.1,p<0.001), arm pain (1.5 vs 4.7,p<0.001), NDI (14.8 vs 44.5,p<0.001), EQ-VAS (73.6 vs 50.2,p<0.001), EQ-5D (0.79 vs. 0.49,p<0.001), and mJOA (14.7 vs. 11.5,p<0.001). Though there were mean improvements in all 24-month PROs for the most satisfied (p<0.001), there were no significant improvements in 24-month PROs for the least satisfied (p>0.05). Using multivariable logistic modeling, a preoperative symptom of upper extremity weakness (OR=2.5,p=0.003), subjective myelopathy (OR=2.0,p=0.04), the absence of numbness complaints (OR=2.2,p=0.003), symptom duration under 1 year (OR=1.6,p=0.047), Caucasian race (OR=2.3,p=0.001), participation in activities outside of the home (OR=2.0,p=0.04), anterior approach (OR=2.3,p=0.001), and higher baseline quality of life (OR=4.0,p=0.01) were predictive of most satisfaction.

Conclusion: Compared to the least satisfied, those most satisfied following surgery for CSM

PAPER 55 continued

more often held motor and myelopathy complaints, as opposed to numbness complaints. Patients identifying as Caucasian had a higher odds of satisfaction. Those receiving anterior approaches were the most satisfied. Those with shorter symptom durations, ability to participate in activities outside of the home before surgery, and higher baseline quality of life were the most satisfied. This data supports that earlier operative intervention—prior to CSM having a significant impact on a patient's quality of life—may be associated with the highest patient satisfaction.

Factors predicting the most satisfaction following surgery for CSM	Adjusted[1] Odds Ratio (95% CI)	*p* value
Preoperative radicular weakness	2.5 (1.4-4.6)	0.003
Absence of preoperative radicular numbness	2.2 (1.3-3.8)	0.003
Preoperative subjective complaints of myelopathy	2.0 (1.01-3.8)	0.04
Disease duration less than one year	1.6 (1.01-2.6)	0.047
Caucasian race	2.3 (1.4-3.8)	0.001
Preoperative participation in activities outside of the home	2.0 (1.01-4.0)	0.04
Anterior approach	2.3 (1.4-3.8)	0.001
Baseline EQ-5D [per unit higher (better)]	4.0 (1.4-11.8)	0.01

[1]Represents odds predicting the *most* satisfaction—relative to the *least* satisfaction. Model utilized backwards stepwise elimination until all predictors reached $p<0.05$
EQ-5D – EuroQol-5D

PAPER 56

Spinal Cord Reconstitution of Chronic Complete Injury by Hepatocyte Growth Factor-Releasing Scaffold and Human Stem Cell Enhances Functional Recovery

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Introduction: Although recent research has reported several effective treatments for sub-acute phase of spinal cord injury (SCI), there is still little effective treatments for chronic complete SCI. Since accumulating large number of patients suffer from chronic severe SCI, therapeutic development for this serious condition is fundamentally important. During chronic complete SCI, complex pathological conditions prevent the patients from functional recovery, such as cavity, scar formations, a residual inflammatory response, secretion of chondroitin sulphate proteoglycans (CSPGs), myelin-associated proteins (Nogo-A, myelin-associated glycoprotein, oligodendrocyte-myelin glycoprotein) and Sema-3A. Therefore, multi-faceted intervention should be necessary to overcome each obstacle. Here, the present study aimed to establish treatments for chronic complete SCI by combining implantation of hepatocyte growth factor (HGF) releasing scaffold and transplantation of human induced pluripotent stem cell-derived neural stem/progenitor cells (hNS/PCs).

Materials and Methods: Collagen scaffold were established to release recombinant human HGF for a few weeks after implantation in chronic complete SCI rat model. First, the scaffold containing HGF was implanted surgically into lesion epicenter on 42 days after complete SCI (chronic phase) to confirm the effect of our scaffold on modifying spinal cord microenvironment around lesion. Protein quantifications, histological analyses, and comprehensive single nuclei RNA expression analysis were conducted on 7 days after implantation (49 days after SCI). To assess the effectiveness of combination therapy of HGF releasing scaffold and hNS/PC transplantation, subsequent to the scaffold implantation, hNS/PCs were transplanted into the lesion epicenter on 49 days after SCI. Histological analyses, WGA trans-synaptic tracing and single nuclei RNA expression analysis were conducted on 42 days after transplantation. To examine regenerated neuronal tracts, retrogradely Adeno Associated Virus tracing was performed on 42 days after hNS/PC transplantation. Motor functions and electrophysiological analysiswere assessed by the Basso, Beattie and Bresnahan (BBB) score, kinematics, and motor evoked potentials (MEP). Urinary functions were also histologically evaluated by the thickness of bladder wall.

Results: Tissue analysis on day 7 after scaffold implantation showed sustained HGF release, promoted vascularization, anti-inflammatory effects(elevation of neuroprotective microglia/macrophage, reduction of TNF-α and TGF-β), neuroprotective effect (elevation of BDNF), and endogenous axonal regrowth around the lesion, which mainly involved the activation of microglia/macrophage, meningeal cell and astrocyte by single nuclei RNA-seq analysis (Fig.1). Combination therapy of HGF releasing scaffold and hNS/PCs transplantation increased the survival rate of the graft cells, host neuronal regrowth (raphespinal, reticulospinal and propriospinal neurons) beyond the lesion, and also decreased glial and fibrous scar formation (Fig.2). The synaptic formation between host and graft neurons was observed by WGA trans-synaptic tracing and immunoelectron microscopy. In addition, lower limb motor functional recovery was observed by BBB score, kinematics analyses and MEP on 42 days

PAPER 56 continued

after transplantation. Bladder wall thickness and GABAergic tone in dorsal horn of lumbar enlargement were enhanced, suggesting the improvement of urinary function (Fig.3).

Conclusion: Functional recovery could be successfully achieved by modifying microenvironment of lesion by implantation of HGF releasing scaffold and supplying regenerating neurons by transplanting hNS/PCs even if the chronic complete SCI. The present study provided the fundamental basis for the therapy to overcome chronic complete SCI.

Fig.1 Improvement of a spinal cord microenvironment in chronic complete SCI by HGF releasing scaffold

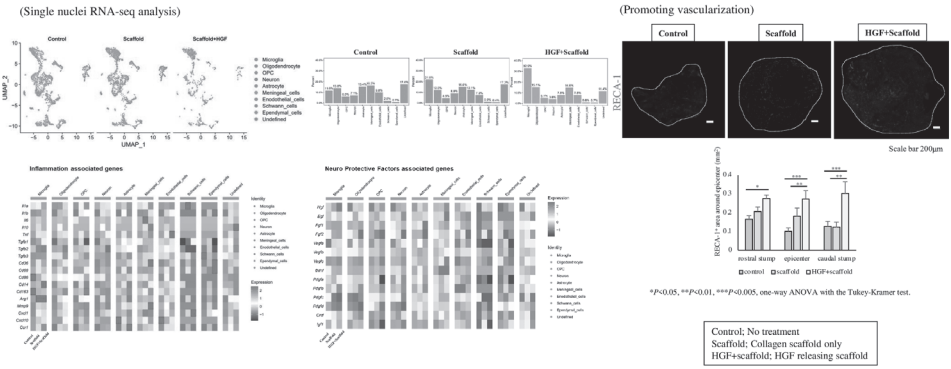
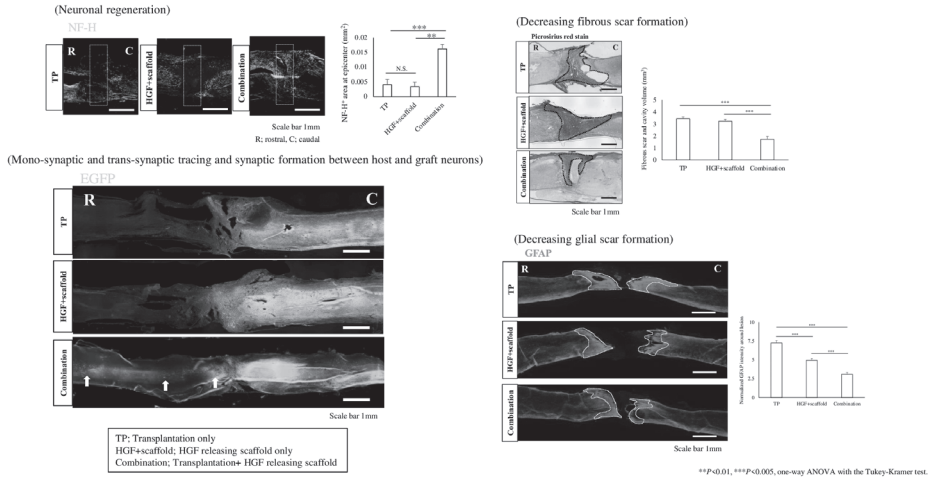
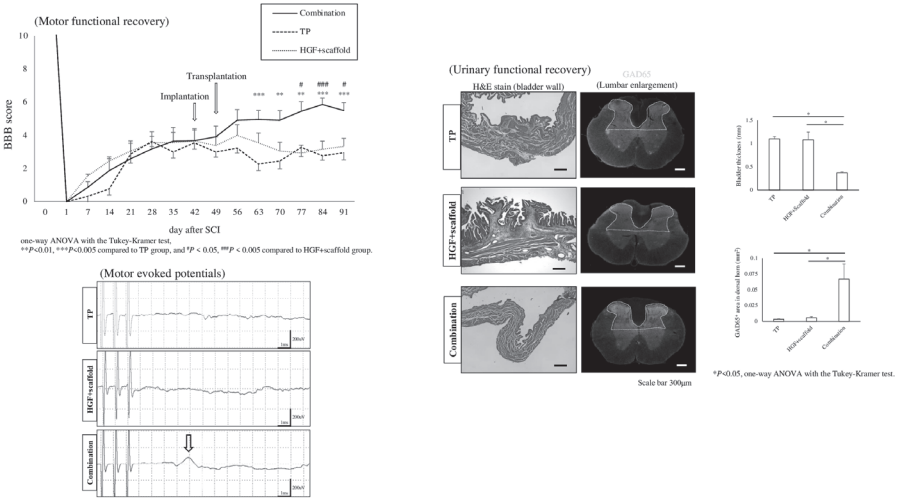


Fig.2 Combination therapy of human stem cell transplantation and HGF releasing scaffold implantation



PAPER 56 continued

Fig.3 The recovery of locomotor and urinary function in chronic complete SCI by combination therapy



PAPER 57

Circulating microRNAs May be Predictive of Degenerative Cervical Myelopathy

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Northwestern University Feinberg School of Medicine[1] Rothman Orthopaedic Institute[2]

Introduction: MicroRNAs (miRNAs) are small, non-coding RNA molecules that function as post-transcriptional gene regulators. Tissue-specific miRNAs also act as cell signaling molecules and are readily detectable in patient serum. Degenerative cervical myelopathy (DCM) is characterized by stepwise spinal cord impairment that culminates in significant neurologic disability; however, early clinical symptoms may be subtle leading to a delay in diagnosis. Specific miRNAs, including miR-223-3p, are differentially upregulated or downregulated following spinal cord injury, highlighting the potential predictive capability of the differential regulation of miRNAs in patients with DCM. The purpose of this study is to determine if unique serum miRNA profiles exist in patients with DCM and characterize the differential expression of these miRNAs compared to healthy controls (HC).

Materials and Methods: Patients with clinical symptoms of DCM undergoing anterior and/or posterior cervical surgery for the treatment of DCM were prospectively enrolled. Patients were excluded if they had a history of previous surgery, trauma, infection, ossification of the posterior longitudinal ligament (OPLL) or ligamentum flavum (OLF), or any systemic chronic illness such as autoimmune disease, diabetes and other endocrine disorders, or malignancy. Whole blood samples were obtained from patients with DCM as well as age- and sex-matched healthy controls from a non-spine orthopaedic clinic. The severity of myelopathy was classified for DCM patients using the modified Japanese Orthopaedic Association (mJOA) score (mild: 15-17, moderate: 12-14, severe: $\leq$ 11). A TaqMan Advanced miRNA assay specific for miR-21-5-p, miR-223-3p, miR-451a, and miR-584-5p and was used for quantitative real-time polymerase chain reaction (RT-qPCR). The expression data were then analyzed using the relative quantification method (2^-delta delta CT) using miR-93-5p and miR-191-5p as endogenous normalization controls. Additionally, a V-PLEX Proinflammatory Panel 1 Human Kit (Mesoscale Discovery) was used to measure concentrations of selected circulating cytokines.

Results: A total of 79 patients were included (36 DCM, 43 HC). The average age for DCM patients was 52.0 $\pm$ 14.4 years, while the average age for HC was 61.5 $\pm$ 9.7 years. Based on preoperative mJOA scores, 16 patients (44.4%) had mild DCM, 11 patients (30.6%) had moderate DCM, and 9 patients (25.0%) had severe DCM. An initial screening assay identified 24 miRNAs that were significantly upregulated or downregulated in DCM patients. After performing further characterization, miR-223-3p showed six-fold upregulation in patients with DCM, with significant differences in mild ($p<0.001$), moderate ($p<0.001$), and severe ($p=0.001$) DCM compared to HCs. Further, miR-451a showed almost two-fold downregulation in patients with DCM, with significant differences in mild ($p<0.001$), moderate ($p=0.021$), and severe ($p=0.012$) DCM compared to HCs (Figure 1). Using multiplex cytokine analysis, IL-8 ($p=0.031$), IL-12p70 ($p=0.044$), IL-13 ($p=0.027$), and TNF-alpha ($p<0.001$) were significantly higher in DCM patients compared to HCs (Figure 2).

Conclusion: Circulating miR-223-3p was significantly upregulated, while miR-451a was

PAPER 57 continued

significantly downregulated in patients with DCM. Taken together, these findings suggest that specific miRNAs may be diagnostic for DCM. Future studies are needed to evaluate other potential miRNAs to create a sensitive serum profile of clinically relevant miRNAs present in DCM.

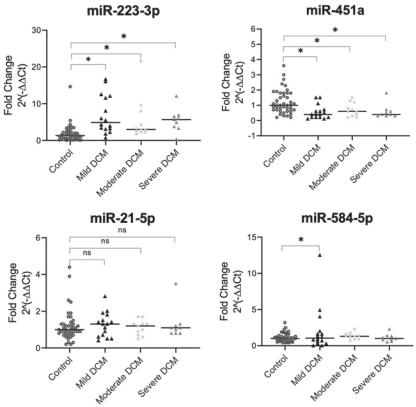

Figure 1. Real-time PCR analysis was used to evaluate miRNA levels. miR-93-5p and miR-191-5p was used to normalize the expression. The expression of miR-223-3p is significantly increased, while the expression of miR-451a is significantly decreased in the serum of patients with DCM compared with controls. *Statistical significance ($p<0.05$)

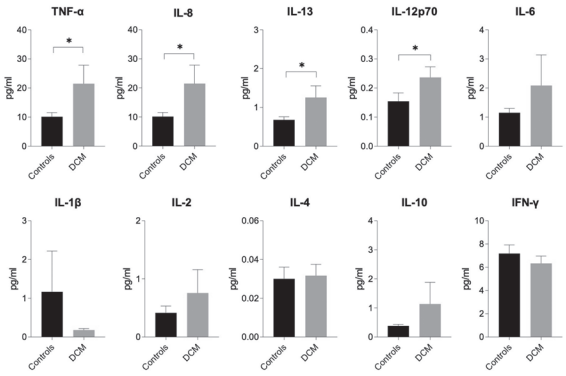

Figure 2. V-PLEX analysis of the main pro-inflammatory cytokines in serum. DCM patients exhibit significant upregulation of TNF-α (+131%), IL-8 (+212%), IL-13 (+184%) and IL-12p70 (+153%) as compared with controls. *Statistical significance ($p<0.05$)

PAPER 58

A Multi-Center, Randomized, Placebo-Controlled, Double-Blinded Trial of Efficacy and Safety of Riluzole in Acute Spinal Cord Injury Study (RISCIS)

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Introduction: Despite the significant societal impact of spinal cord injury (SCI), an effective pharmacological treatment has yet to be established. Riluzole, FDA approved for ALS has shown promising pre-clinical results and is clinically safe in the context of SCI. The goal of the RISCIS trial is to study the efficacy of Riluzole in the context of acute traumatic SCI.

Materials and Methods: The RISCIS trial is an international, multi-center, prospective, double-blinded, randomized, placebo- controlled Phase II/III clinical trial. Patients with ASIA Impairment Scale grade A-C, traumatic C4-C8 SCI and < 12hours from injury were screened. Enrolled patients were randomized 1:1 between Riluzole, at an oral dose of 100 mg BID for the first 24 hours followed by 50 mg BID for the following 13 days after injury, and placebo control. The primary outcome of interest was change in motor scores at 180 days, with Spinal Cord Independence Measure (SCIM, version III) and SF36 considered as secondary outcomes.

Results: Due to the impact of the global COVID-19 pandemic this trial was terminated prior to completion. 193 patients were randomized (61% of the original calculated sample size). The follow-up rate at 180-days was 82.7%. No statistical difference was noted in the demographics and baseline injury characteristics between the two groups (Table 1). At 6 months there was a median gain in total motor scores (TOTM) of 30.0 in the Riluzole group compared to 20.0 for the Placebo group. Patients who had Riluzole on average had a higher improvement in upper motor (16.4 vs. 14.7) and lower motor scores (17.6 vs. 16.1) at 6 months compared to Placebo. This increased in motor scores gained in the Riluzole group did not reach statistical significance (Figure 1). There was no increase in adverse events associated with the administration of Riluzole.

Given the decreased sample size, additional analyses including multivariate logistic regression, Bayesian analyses and sensitivity analyses were conducted. In sub analysis, the ASIA C population showed Riluzole was a significant improver of total motor scores (coefficient estimate: 14.10, p=0.020) and upper motor scores (CE:7.68, p=0.040) at 6 months (Figure 3). ASIA B patients had higher reported independence, as measured by the SCIM score (45.3 vs. 27.3; P:0.071) and change in mental health scores as measured by the SF-36 mental health domain (2.01 vs. -11.58; p:0.0205) at 180 days. The Bayesian analysis revealed that administration of Riluzole has an 83.2% probability of positive change in UEM scores and 71.5% in TOTM scores. P-value fragility index calculation on total motor change at 6 months (dichotomized to +5 and </=5 points) revealed that alternative results in three patients would have resulted in a statistically significant outcome.

Conclusion: Despite the premature termination of the RISCIS trial due to the COVID-19

PAPER 58 continued

pandemic, 193 subjects were recruited into this trial. Primary analysis showed a 10-motor point gain in riluzole-treated subjects which did not reach significance. However, on secondary analysis, incomplete cervical SCI subjects (AIS B and C) showed significant gains in functional recovery. Bayesian analysis favored Riluzole in terms of positively influencing neurological recovery after cervical SCI.

PAPER 58 continued

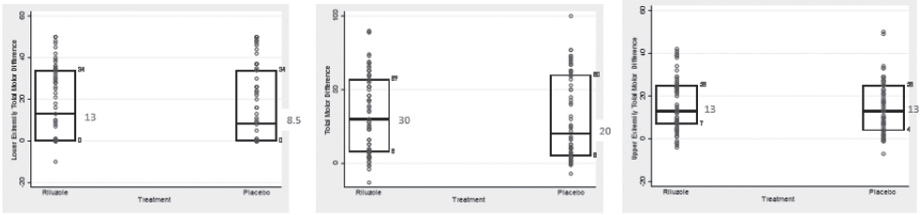
Table 1: Demographic and injury characteristics of traumatic spinal cord injury patients randomized to either placebo control or Riluzole 100 mg PO BID for 24 hours followed by 50 mg PO BID for 13 days after injury.

	Riluzole (N=96)	Control (N=97)	Riluzole - Control	P-value
Age at consent (years)				
n	96	97		0.453
Mean	49.4	47.6	1.8	
95% CI			-2.9 - 6.5	
Median	51	50		
Gender, n (%)				
Male	79 (82.3)	79 (81.4)		1.000
Female	17 (17.7)	18 (18.6)		
Height (cm)				
n	92	90		0.733
Mean	175.5	175.0	0.5	
95% CI			-2.3 - 3.2	
Median	177	177		
Weight (kg)				
n	90	89		0.682
Mean	88.4	87.2	1.3	
95% CI			-4.8 - 7.4	
Median	86	83		
Body mass index				
n	86	84		0.675
Mean	28.8	28.4	0.4	
95% CI			-1.4 - 2.2	
Median	28	27		
Race, n(%)				
White	69 (71.9)	71 (73.2)		0.496
Black or African American	13 (13.5)	15 (15.5)		
Asian	10 (10.4)	7 (7.2)		
Native Hawaiian or other Pacific Islander	1 (1.0)	0		
American Indian or Native American	1 (1.0)	0		
Other	1 (1.0)	4 (4.1)		
Subject did not answer	1 (1.0)	0		
Ethnicity, n(%)				
Hispanic or Latino	2 (2.1)	3 (3.1)		1.000
Not Hispanic or Latino	92 (95.8)	92 (94.8)		
Unknown	2 (2.1)	1 (1.0)		
Subject did not answer	0	1 (1.0)		

PAPER 58 continued

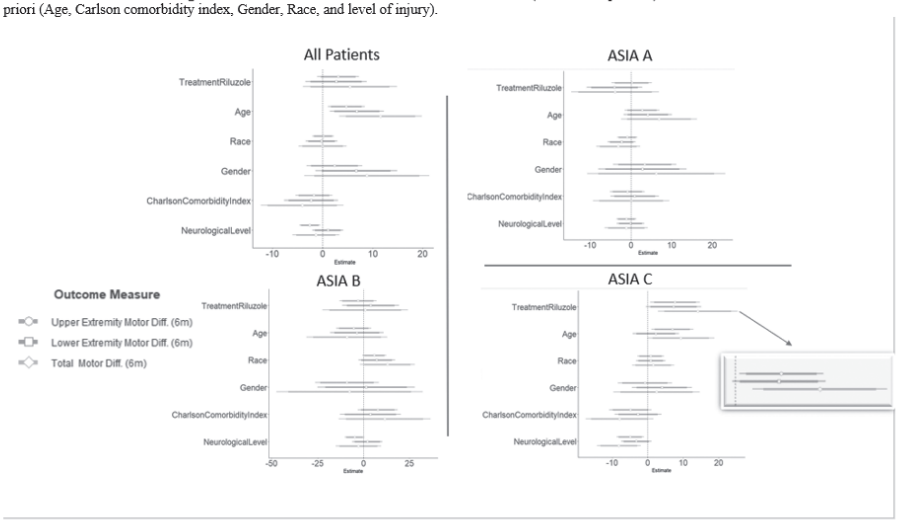
Figure 1: Distribution and mean difference of motor scores gained at 6 months of traumatic spinal cord injury patients randomized to either placebo control or Riluzole 100 mg PO BID for 24 hours followed by 50 mg PO BID for 13 days after injury. P-values calculated using one-tailed t-test with the alternative hypothesis being that the difference in scores is greater in the Riluzole group.

	Placebo (mean)	Riluzole (mean)	P-Value
Change in Upper Extremity Motor Scores at 6 Months	14.65	16.42	0.7907
Change in Lower Extremity Motor Scores at 6 Months	16.10	17.55	0.6767
Change in Total Motor Scores at 6 Months	31.11	34.00	0.7209



LE Motor Score | Total Motor Score | Upper Extremity Motor Score

Figure 2: Multivariate linear regression with the Upper Extremity Motor, Lower Extremity Motor and Total Motor score difference at 6-months stratified based on initial ASIA grade. Co-variates included in the model include treatment (Riluzole vs. placebo) and baseline variables selected a-priori (Age, Carlson comorbidity index, Gender, Race, and level of injury).



PAPER 59

Contemporary Practice Patterns in the Treatment of Cervical Stenosis and Central Cord Syndrome: A Survey of the Cervical Spine Research Society

Erick Kazarian, MD, Sonal Sodha, MD, Zachary Pinter, MD, Brett Freedman, MD, Ahmad Nassr, MD[1], Arjun Sebastian, MD, MSc[1], Michael Fehlings, MD, PhD, FRCSC, FACS, John Rhee, MD, Bradford Currier, MD
Mayo Clinic[1]

Introduction: Degenerative cervical myelopathy, asymptomatic cervical stenosis, and central cord syndrome are common pathologies encountered by spine surgeons. However, controversy remains regarding the relative importance of patient demographics, the presence of clinical symptoms, and the presence of myelomalacia. Consequently, current surgical decision making is based largely on surgeon preference rather than a reliable body of evidence.

Materials and Methods: We administered a survey to attendees of the CSRS 2021 annual meeting to assess practice patterns related to the management of cervical stenosis and central cord syndrome. The survey was conducted using SurveyMonkey. The survey consisted of 28 questions, which were a combination of multiple choice and free response. The questions focused on the management patterns for cervical stenosis and central cord syndrome through patient vignettes.

Results: Overall, 116 of the 330 attendees (35.2%) of the meeting completed this study. 113 of the 116 (97.4%) were spine surgeons, and of these, 98 were orthopedic surgeons (84.4%) and 17 were Neurosurgeons (14.6%). 56 surgeons (48%) identified as having an academic practice. The majority (70%) had been in practice for 10 years or longer. Those who identified themselves as surgeons are tabulated below.

39 surgeons (34.5%) would recommend surgery to an asymptomatic 60-year-old patient with cervical stenosis and myelomalacia (Fig 1a), while only 1.7% would recommend surgery to the same patient without myelomalacia (Fig 1b) ($p< .01$). If the patient instead demonstrated mild symptoms of myelopathy, 96 surgeons (84.9%) would recommend surgery in the presence of myelomalacia while 71 surgeons (62.8%) would recommend surgery in the absence of myelomalacia ($p<0.001$). Comparatively, respondents were less likely to operate on an asymptomatic 85 year old patient with myelomalacia (17.7% vs 34.5%, $p<0.001$) (Fig 2).

For patients with central cord syndrome characterized by a hyperextension neck injury with associated upper extremity weakness, 72.5% of respondents offered surgical intervention during the patient's index admission if the patient had associated myelomalacia versus 65.1% for the same patient without myelomalacia ($p=.20$). A history of pre-existing myelopathy did significantly increase the number of respondents who offered surgery during the index admission for patients with (84.8%) and without (76.9%) myelomalacia ($p<.05$) (Fig 3).

Conclusion: There is substantial variability in the management patterns of cervical stenosis and central cord syndrome. Here we demonstrate that younger age, the presence of myelomalacia, and pre-existing myelopathy are associated with an increased rate of surgical intervention. We also show most respondents treat central cord syndrome with surgery during the patient's index admission, and roughly half would treat urgently within the first 24 hours (Fig 3). A history of pre-existing myelopathy does significantly increase the numbers of surgeons who

PAPER 59 continued

recommend surgery during the current admission (p <0.05).

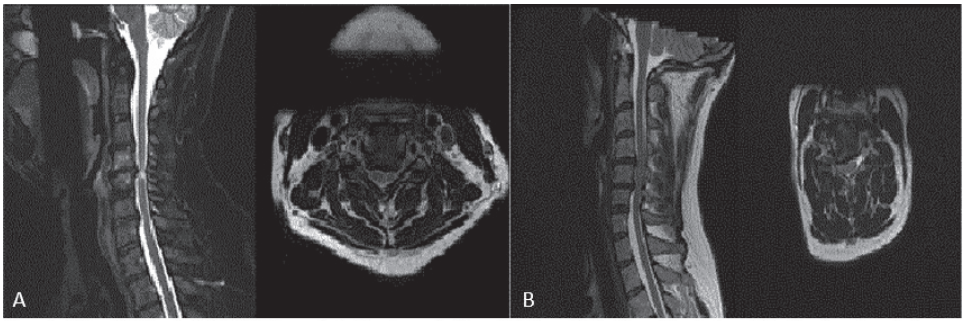
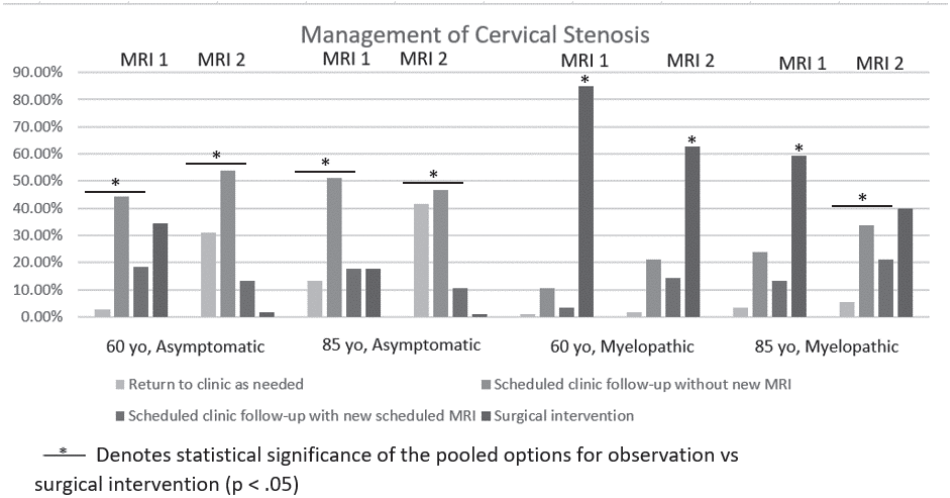
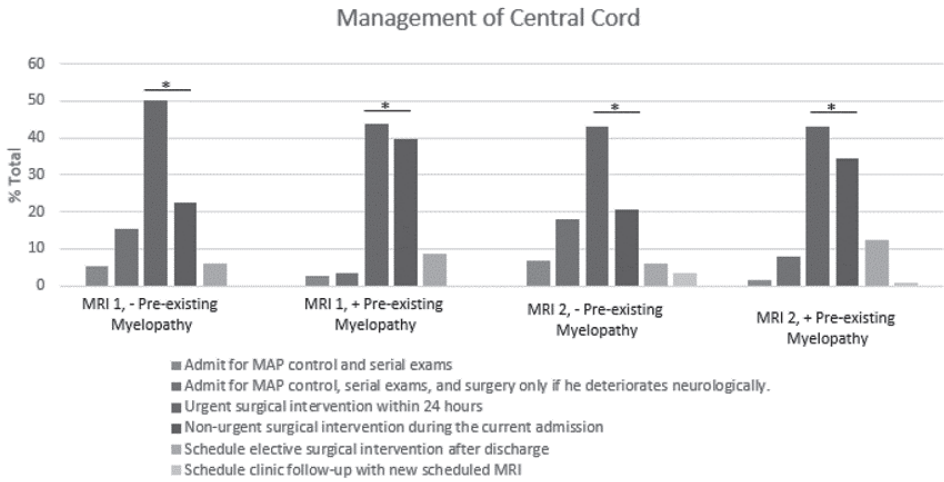


Figure 1: Midsagittal T2-weighted MRI of the cervical spine demonstrating central stenosis (A) with myelomalacia and (B) without myelomalacia.



PAPER 59 continued



—*— Denotes statistical significance of the pooled options for surgery during the index admission vs initial non-operative measures ($p < .05$)

PAPER 60

Current Practice Patterns of Surgical-Site Drain Usage in Cervical Spine Surgery: A Survey of the Cervical Spine Research Society

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Mayo Clinic[1]

Introduction: Surgical-site drains are commonly used in cervical spine surgery, often prophylactically for prevention of hematoma. Although drain usage is widespread, its role in preventing complications remains unclear and therefore usage is surgeon-dependent and highly variable. Currently, drain use in cervical spine surgery is not standardized or protocolized. The objective of this study is to determine current patterns of surgical-site drain usage in both anterior and posterior cervical spine surgery among attendees of the Cervical Spine Research Society (CSRS) annual meeting.

Materials and Methods: An online survey via QR code was administered during the annual 2021 CSRS meeting to all attendees to assess current practice patterns of wound drain usage in cervical spine surgery. The survey consisted of 31 questions, which were a combination of multiple choice and free response. The first 6 questions focused on surgeon demographics and experience level. The remainder of the questions pertained to drain usage in single and multi-level anterior and posterior cervical spine surgery for any indication.

Results: A total of 102 respondents participated in the survey. The majority of respondents practice as orthopedic spine surgeons (88 orthopedics, 14 neurosurgery). 49% of respondents practice in academics. Of the 102 respondents, 68 (67%) were experienced surgeons with greater than 10 years of experience. No significant difference in drain usage was found comparing orthopedic spine surgeons and neurosurgeons.

For anterior cervical surgeries, more surgeons report "always" using a drain for multi-level versus single-level procedures (60% vs. 45%, P=0.035). 35% of surgeons "sometimes" use a drain and 20% "never" use a drain for single-level anterior procedures (Figure 1). For posterior cervical surgeries, significantly more surgeons report "always" using a drain for fusions with decompression versus either decompressions without fusion or fusions without decompression (81% vs. 55% vs. 52%, P<0.001). For both anterior and posterior procedures, the most commonly cited reason for drain usage among the surgeons who only "sometimes" use a drain was excessive intra-operative bleeding.

Across all procedures including single-level anterior, multi-level anterior, and posterior cervical surgeries, most surgeons report that they have not experienced a complication caused by not using a drain (82% vs. 67% vs. 75% respectively, P=0.07). Most surgeons report having experienced a complication despite using a drain (76%, P<0.001). In such cases, the most common complication was hematoma (83% of respondents). Lastly, 54% of respondents report that the surgical indication does not affect the decision to use a drain (P=0.43).

Conclusion: Utilization of surgical-site drains in cervical spine surgery is widespread, especially for multi-level anterior cervical and posterior cervical procedures. Most spine surgeons have not experienced a complication caused by not using a drain and most have experienced complications despite using a drain. This study found substantial variation in practice patterns

PAPER 60 continued

of drain use. These findings may suggest that current practice patterns among spine surgeons could in part be anecdotal or based on training, and not necessarily evidence-based. This study demonstrates surgical equipoise, justifying the clinical need for a prospective randomized controlled trial of drain usage in certain cervical procedures, such as single-level anterior cervical surgery.

FIGURE 1

		"Always"		"Sometimes"		"Never"	
		Number	%	Number	%	Number	%
Anterior Cervical	Single Level	**46**	45	**36**	35	**20**	20
	Multi-level	**61**	60	**31**	30	**10**	10
Posterior Cervical	Decompression without fusion	**56**	55	**32**	31	**14**	14
	Fusion without decompression	**53**	52	**37**	36	**12**	12
	Fusion with decompression	**83**	81	**11**	11	**8**	8

PAPER 61

Revisions and Removals of Cervical Total Disc Replacement Devices in a Single Institution Consecutive Series of 1,473 Patients Beginning with the First Case Experience in 2003

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Introduction: Cervical total disc replacement (TDR) has gained acceptance as an alternative to fusion in appropriately selected patients. Clinical outcomes have consistently been reported to be similar or superior to anterior cervical discectomy and fusion (ACDF). Initially, there were concerns about the safety or these devices. One measure of safety is the need for subsequent surgery related to problems with the devices. The purpose of this study was to investigate the rate of cervical TDR device removal or revision.

Materials and Methods: The consecutive series of 1,474 cervical TDR patients, beginning with the first case experience in 2003 and ending with cases in December of 2019 to allow for minimum 2-year post-operative timeframe, was reviewed. The series included TDRs at one, two, or three levels, and hybrids. Cases of removal//revision were recorded as well as the reason for subsequent surgery, procedure performed, and the duration from the index procedure. General patient descriptive information was also recorded.

Results: In the series of 1,474 patients, there were 20 cases of TDR removal or revision, producing a rate of 1.36%. Removal was performed in 16 cases (1.09%) and revision in 4 cases (0.27%). Based on the 1,879 devices implanted in this patient population, the rate of revision/removal was 1.1% (21 devices). Removals included 5 cases of osteolysis with/without P. acnes, 3 involved device displacement/migration, 4 stenosis/facet changes, and one of each of the following: presumed metal allergy, esophageal tear and related complications, malalignment (also included ASD), and subsidence. The 4 revisions included: replacement with a smaller implant design (original device was too large and migrated anteriorly), repositioning of the TDR (positioned off midline and patient had radiculopathy), treatment of persistent stenosis (treated and replaced TDR with a different device design (all 3 of these revisions occurred within 17 days of index surgery); the remaining revision occurred 39 months post-index and involved replacing the TDR with a different device design due to hypermobility. In all of the revision/removal cases, the procedures were performed as planned without incident. In this series, 157 patients were more than 10 years post-TDR. The longest duration from implant to removal/revision was 67.5 months (performed due to severe osteolysis). This series includes arthroplasty learning curve patients for all surgeons involved.

Conclusion: In this large consecutive series of patients, 1.4% of cervical TDRs were removed/revised. This low rate of removal/revision in this large institutional experience over a long period of time provides support for the safety of these devices.

PAPER 62

Which open side is better in cervical unilateral open-door laminoplasty, compressive side or symptomatic side?

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Introduction: When performing cervical UODL, surgeons should select one side for lamina opening. However, there were few reports that suggest proper standards for deciding which side to open. The aim of this study is to evaluate the impact of opening side in unilateral open-door laminoplasty (UODL) on dominant cord compressive or symptomatic side.

Materials and Methods: Total 193 (male: 135, age: 59.7) patients with multi-level degenerative cervical diseases with 2 years or more follow-up are enrolled in this study. Right-side UODL was performed uniformly in all cases. Patients were subgrouped based on preoperative dominant 3 characteristics: compressive side (right, symmetric, left), myelopathy symptom (right, symmetric, left) and radiculopathy symptom (right, symmetric, left). Using CT/MRI axial images at the most severe stenotic area, compressive sides were determined and dominant myelopathy or radiculopathy side were decided using preoperative medical records. Pre-and postoperative radiographic (C0-2 angle, C2-7 angle, cervical sagittal vertical axis (C-SVA), C2-7 range of motion) and clinical (neck Visual Analog Scale (VAS), arm VAS, Japanese Orthopedic Association (JOA), and Neck Disability Index (NDI)) parameters and incidence of postoperative C5 palsy were compared among groups.

Results: Most of the patients showed significant improvement in radiographic and clinical parameters postoperatively. According to dominant compressive side, there were no significant differences in postoperative radiographic and clinical parameters among three groups. According to dominant myelopathy or radiculopathy symptom side, there were no significant differences of all radiographic and clinical parameters at the last follow-ups, except slightly lower neck VAS in groups of preoperative right dominant myelopathy or radiculopathy symptom side at postoperative 1 month. Postoperative C5 palsies occurred in twelve patients (6.2%), but the incidences were not statistically different among the groups.

Conclusion: In UODL, the lamina opening side does not affect significantly postoperative radiographic and clinical outcomes including postoperative C5 palsy at more than 2 years follow-up. There would be no significant differences no matter which side surgeons choose opening side during UODL.

PAPER 62 continued

TABLE 1. Comparison of outcomes according to dominant compressive side†

Factors	Group A (Right)	Group B (both/symmetric)	Group C (Left)	ANOVA *p*-value	*p*-value (A: B)	*p*-value (B: C)	*p*-value (C: A)
C2-7 ROM (°)							
Preoperative	43.7 ± 14.98	42.8 ± 13.37	42.2 ± 13.49	0.979	0.979	0.087	0.224
Postoperative	33.4 ± 10.41	32.4 ± 10.71	32.4 ± 11.17	0.757	0.476	0.968	0.757
Last f/u	33.9 ± 11.02	35.6 ± 11.7	29.1 ± 12.47	0.271	0.474	0.119	0.271
C0-2 angle (°)							
Preoperative	17.4 ± 6.86	16.0 ± 8.32	16.5 ± 9.43	0.457	0.221	0.892	0.457
Postoperative	18.7 ± 7.56	18.4 ± 8.78	19.4 ± 8.35	0.938	0.819	0.733	0.938
Last f/u	17.7 ± 6.32	18.5 ± 8.38	22.3 ± 8.87	0.321	0.868	0.158	0.321
C2-7 angle (°)							
Preoperative	12.4 ± 7.74	15.7 ± 9.38	14.2 ± 8.42	0.192	0.074	0.494	0.192
Postoperative	9.5 ± 7.07	13.9 ± 8.82	10.1 ± 6.72	0.011	0.008	0.051	0.011
Last f/u	9.7 ± 5.51	12.7 ± 8.5	12.8 ± 7.27	0.457	0.292	0.847	0.457
C-SVA (mm)							
Preoperative	23.3 ± 13.78	23.8 ± 13.75	23.1 ± 12.66	0.982	0.865	0.909	0.982
Postoperative	26.9 ± 12.44	26.6 ± 15.78	22.3 ± 8.82	0.434	0.492	0.350	0.434
Last f/u	22.3 ± 9.98	24.5 ± 12.74	27.7 ± 12.81	0.556	0.856	0.345	0.556
VAS (neck) score							
Preoperative	7.0 ± 0.63	6.1 ± 1.03	6.0 ± 0.89	0.065	0.024	1.000	0.065
Postoperative	2.1 ± 2.41	1.8 ± 1.87	2.2 ± 1.89	0.680	0.997	0.345	0.680
Last f/u	2.3 ± 2.46	1.5 ± 2.19	2 ± 1.75	0.237	0.187	0.185	0.237
VAS (arm) score							
Preoperative	6.6 ± 1.07	6.3 ± 1.4	6.3 ± 0.99	0.786	0.626	0.755	0.786
Postoperative	1.7 ± 1.8	2 ± 2.12	1.1 ± 1.26	0.264	0.691	0.106	0.264
Last f/u	1.9 ± 2.31	1.4 ± 2.05	2.5 ± 2.21	0.115	0.443	0.037	0.115
JOA score							
Preoperative	8 ± 0.76	8.7 ± 1.06	8.3 ± 0.98	0.133	0.060	0.284	0.133
Postoperative	12.9 ± 2.67	13.3 ± 3.1	13.6 ± 2.87	0.566	0.447	0.621	0.566
Last f/u	12.9 ± 2.84	14.1 ± 2.86	12.7 ± 3.54	0.279	0.198	0.246	0.279
NDI score							
Preoperative	21.9 ± 5.49	21.2 ± 4.27	20.2 ± 4.11	0.907	0.704	0.936	0.907
Postoperative	14.9 ± 7.49	12.6 ± 6.33	13.3 ± 5.25	0.238	0.102	0.506	0.238
Last f/u	12.8 ± 5.83	9.5 ± 5.96	12.8 ± 7.08	0.135	0.086	0.190	0.135
C5 palsy (number)	3 (1.6%)	7 (3.6%)	2 (1.0%)	0.930[1)]			

†Data represent the mean values for each group.
** Statistically significant (p-value < 0.05)*
1) Chi-square test
C-SVA indicated cervical sagittal vertical axis; VAS: visual analog scale; JOA: Japanese orthopaedic association, NDI; neck disability index

TABLE 2. Comparison of outcomes according to dominant myelopathy symptom side†

Factors	Group I (Right)	Group II (Symmetric)	Group III (Left)	ANOVA *p*-value	*p*-value (I: II)	*p*-value (II: III)	*p*-value (III: I)
C2-7 ROM (°)							
Preoperative	43.7 ± 14.98	42.8 ± 13.37	42.2 ± 13.49	0.394	0.204	0.506	0.394
Postoperative	31.3 ± 9.7	32.8 ± 11.35	32.3 ± 8.61	0.852	0.649	0.855	0.540
Last f/u	31.6 ± 10.25	33.5 ± 12.12	35.2 ± 11.84	0.886	0.808	0.737	0.560
C0-2 angle (°)							
Preoperative	14.1 ± 8.11	16.5 ± 8.33	18.6 ± 8.09	0.161	0.226	0.233	0.045
Postoperative	16.2 ± 9.07	18.7 ± 8.36	20.9 ± 8.25	0.180	0.169	0.308	0.081
Last f/u	16.6 ± 8.32	17.7 ± 8.82	20.8 ± 8.5	0.744	0.887	0.485	0.462
C2-7 angle (°)							
Preoperative	13.1 ± 9.25	15.6 ± 9.13	12 ± 6.69	0.097	0.130	0.075	0.928
Postoperative	9.4 ± 6.86	12.2 ± 8.94	10.6 ± 6.25	0.089	0.061	0.242	0.466
Last f/u	10.2 ± 7.6	12.1 ± 6.2	9.4 ± 6.23	0.787	0.499	0.991	0.581
C-SVA (mm)							
Preoperative	23.5 ± 13.86	24.5 ± 14.14	20.9 ± 10.78	0.614	0.799	0.326	0.560
Postoperative	26.5 ± 14.71	26.8 ± 15.28	24.7 ± 10.98	0.915	0.983	0.682	0.735
Last f/u	28.5 ± 14.77	27.2 ± 14.42	26.7 ± 13.36	0.773	0.355	0.840	0.291
VAS (neck) score							
Preoperative	6.2 ± 0.76	6.2 ± 1.12	5.8 ± 1.05	0.482	0.909	0.252	0.482
Postoperative	1.8 ± 2.04	1.9 ± 1.98	2.4 ± 1.97	0.392	0.818	0.198	0.250
Last f/u	2 ± 1.8	1.6 ± 2.17	2.2 ± 2.55	0.419	0.250	0.390	0.919
VAS (arm) score							
Preoperative	6.4 ± 1.07	6.4 ± 1.29	5.9 ± 1.38	0.416	0.802	0.193	0.397
Postoperative	0.8 ± 1.1	2.0 ± 2.1	2.3 ± 1.7	0.015	0.019	0.238	0.004*
Last f/u	1.8 ± 2.38	1.6 ± 2.08	2.1 ± 2.18	0.703	0.877	0.392	0.631
JOA score							
Preoperative	8.1 ± 0.88	8.6 ± 1.07	9.0 ± 0.82	0.191	0.219	0.286	0.191
Postoperative	12.5 ± 2.94	13.3 ± 3.07	13.8 ± 2.3	0.365	0.218	0.660	0.185
Last f/u	12.7 ± 3.28	13.7 ± 3.04	14.3 ± 2.05	0.549	0.333	0.879	0.232
NDI score							
Preoperative	22.6 ± 3.37	20.9 ± 4.77	19.9 ± 2.48	0.353	0.310	0.557	0.072
Postoperative	13.8 ± 6.87	13.3 ± 6.48	13.1 ± 6.52	0.977	0.878	0.908	0.830
Last f/u	9.8 ± 6.96	11 ± 6.3	9.5 ± 5.37	0.628	0.417	0.533	0.731
C5 palsy (number)	2 (1.0%)	7 (3.6%)	3 (1.6%)	0.930[1)]			

†Data represent the mean values for each group.
** Statistically significant (p-value < 0.05)*
1) Chi-square test
C-SVA indicated cervical sagittal vertical axis; VAS: visual analog scale; JOA: Japanese orthopaedic association, NDI; neck disability index

PAPER 62 continued

TABLE 3. Comparison of outcomes according to dominant radiculopathy symptom side†

Factors	Group X (Right)	Group Y (both/symmetric)	Group Z (Left)	*p*-value (I: II)	*p*-value (II: III)	*p*-value (III: I)
C2-7 ROM (°)						
Preoperative	40.8 ± 13.95	42.5 ± 14.89	41.3 ± 14.42	0.830	0.999	0.766
Postoperative	31.9 ± 9.66	35.3 ±13.71	30.3 ± 11.48	0.320	0.235	0.983
Last f/u	31.1 ± 11.0	36.1 ± 14.64	31.9 ± 12.33	0.112	0.259	0.823
C0-2 angle (°)						
Preoperative	16.4 ± 8.57	14.6 ± 7.75	17.2 ± 8.27	0.550	0.286	0.822
Postoperative	19.9 ± 9.54	18.8 ± 9.1	20.2 ± 8.27	0.831	0.735	0.977
Last f/u	18.3 ± 8.9	15.6 ± 8.22	18.7 ± 8.75	0.279	0.183	0.955
C2-7 angle (°)						
Preoperative	13.9 ± 8.99	17.9 ± 10.23	14.2 ± 8.50	0.145	0.111	0.860
Postoperative	10.2 ± 7.6	12.6 ± 8.89	11.7 ± 7.44	0.275	0.844	0.423
Last f/u	13.0 ± 11.01	15.1 ± 8.35	12.2 ± 8.06	0.521	0.282	0.852
C-SVA (mm)						
Preoperative	25.4 ± 13.79	21.7 ± 15.69	23.3 ± 12.63	0.385	0.843	0.580
Postoperative	30.6 ± 15.55	29.4 ± 19.17	29.3 ± 14.66	0.919	0.999	0.857
Last f/u	27.8 ± 14.44	26 ± 14.06	27.5 ± 14.33	0.813	0.867	0.989
VAS (neck) score						
Preoperative	4.3 ± 2.06	4.5 ± 2.59	3.4 ± 2.27	0.783	0.387	0.801
Postoperative	1.5 ± 1.5	2.4 ± 2.2	2.4 ± 2.2	0.140	0.990	0.043*
Last f/u	1.7 ± 2.1	1.3 ± 1.03	2.4 ± 2.79	0.864	0.919	0.978
VAS (arm) score						
Preoperative	2.6 ± 1.67	3.8 ± 2.48	4.0 ± 2.38	0.423	0.979	0.261
Postoperative	2.1 ± 2.04	2.8 ± 2.07	2.3 ± 2.17	0.492	0.652	0.915
Last f/u	1.5 ± 1.92	1.5 ± 2.98	1.3 ± 1.52	0.923	0.941	0.999
JOA score						
Preoperative	13.0 ± 3.15	12.4 ± 4.63	12.1 ± 3.57	0.871	0.975	0.695
Postoperative	13.2 ± 3.33	14.0 ± 2.73	13.0 ± 2.9	0.556	0.349	0.921
Last f/u	13.8 ± 3.63	13.4 ± 2.76	14.8 ± 2.06	0.996	0.971	0.975
NDI score						
Preoperative	17.0 ± 9.17	14.6 ± 7.63	14.9 ± 6.90	0.663	0.993	0.663
Postoperative	15.8 ± 5.45	14.4 ± 5.78	15.4 ± 7.39	0.688	0.802	0.949
Last f/u	9.7 ± 7.29	12.6 ± 7.93	8.8 ± 6.01	0.261	0.308	0.995
Patients with C5 palsy	5 (2.6%)	6 (3.1%)	1 (0.5%)	0.141[1)]		

†Data represent the mean values for each group.

** Statistically significant (p-value < 0.05)*

1) Chi-square test

C-SVA indicated cervical sagittal vertical axis; VAS: visual analog scale; JOA: Japanese orthopaedic association, NDI; neck disability index

PAPER 63

Accuracy of navigation assisted pedicle screw placement in cervical spine

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Introduction: Pedicle screw insertion of the cervical spine is challenging due to the small pedicle sizes and the proximity to the vertebral arteries and the spinal cord. Intraoperative 3D navigation has been reported to improve the accuracy of pedicle screw placement, however, there still remains the potential for neurovascular injury. The purpose of this study is to investigate the accuracy of navigation assisted pedicle screw placement in cervical spine, and clarify key points and tips for the safe pedicle screw insertion.

Materials and Methods: We report 158 clinical cases who underwent a cervical pedicle screw insertion using Iso-C3D based navigation. Using this system, real-time instrument tip information was three dimensionally identified in each step of screw insertion. A total of 813 cervical pedicle screws were inserted between C2 and C6. The numbers of the screws inserted at each level of the vertebrae were 83 in C2, 140 in C3, 204 in C4, 188 in C5, and 198 in C6. The accuracy of the postoperative screw positions at each level of the vertebrae was evaluated by a CT-based method. Screw placement was graded into four grades on CT: grade 0, no pedicle perforation; grade 1, screw deviation less than 2 mm; grade 2, deviation more than 2mm and less than 4 mm; and grade 3,deviation more than 4mm. Major breach was defined as grade 2 and grade 3.

Results: Total ratios of pedicle wall breach was identified 23.4%. The ratios of breach at each level were 14.5%, 32,9%, 31.4%, 17.6%, and 17.7% at C2, C3, C4, C5, and C6, respectively ($P < 0.001$). The ratios of major breach were 1.2%, 11.4%, 9.8%, 5.9% and 10.1% at C2, C3, C4, C5, and C6, respectively ($P < 0.05$). We did not encounter any serious complications associated with the operation including neurological deficit, significant bleeding, and thrombotic events.

Conclusion: According to some previous reports about quantitative 3D anatomical data in cervical spines, the greatest medial angulation of pedicles is at C4 and C3, and the least pedicle width is at C3 and C4. This may be difficult to achieve safe screw placement especially at C3 and C4 because the soft tissues tend to cause more sagittal angulation and increase the likelihood of vertebral artery injury. Moreover, our results were consistent with these anatomical findings. More careful attention should be paid to pedicle screw placement at C3 and C4.

PAPER 64

Complications, Readmissions, Reoperations and Patient-Reported Outcomes in Patients with Multiple Sclerosis Undergoing Elective Cervical Spine Surgery- a Propensity Matched Analysis

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Introduction: Background: The effectiveness of elective cervical spine surgery in patients with both MS and cervical myelopathy/radiculopathy has been questioned due to MS symptoms overlapping with myelopathy/radiculopathy, underlying neurologic dysfunction, and negative effects of MS immunomodulatory agents on postoperative recovery. Previous studies investigating this topic have been limited by small sample size and lack of covariate adjustment. The current study sought to determine if patients with MS have worse outcomes after elective spine surgery compared to patients without MS after adjusting for baseline covariates through propensity matching.

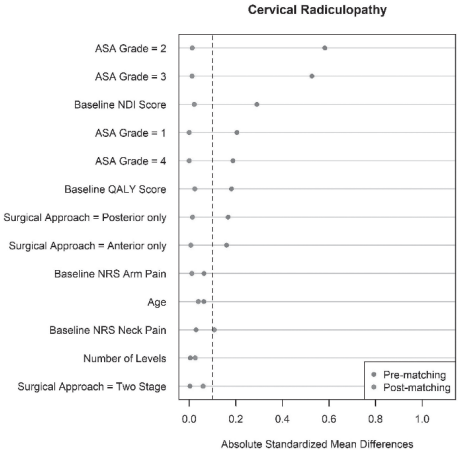
Materials and Methods: The Quality Outcomes Database (QOD), a national, longitudinal multicenter spine outcomes registry, was queried for patients who underwent elective cervical spine surgery for myelopathy or radiculopathy. Patients with any neurodegenerative condition other than MS were excluded. Patients without MS were propensity matched against patients with MS in a 5 to 1 ratio without replacement based on ASA grade, arthrodesis, surgical approach, number of operated levels, age, baseline disability (Neck Disability Index: NDI), neck/arm pain (Numeric Rating Scale: NRS), and health-related quality of life (EQ-5D) scores (Fig 1). Outcomes included 3- and 12-month scores for EQ-5D, NDI, NRS neck/arm pain, mJOA, and NASS patient satisfaction as well as 30-day complication rate, 3-month readmission and reoperation rate, and 12-month reoperation rate. The average treatment effect in the treated (ATT) was estimated in terms of risk difference for binary outcomes and mean difference for continuous outcomes. Linear regression on group indicator (MS vs. non-MS) with cluster-robust standard errors was used to estimate ATT.

Results: For the cervical myelopathy cohort, 6,426 patients without MS were matched against 91 patients with MS. Patients with MS had a lower rate of reoperation at 12 months (risk difference=-0.036, p=0.007) and worse 3-month mJOA scores (mean difference=-1.044, p=0.004) compared to patients without MS (Table 1). For the radiculopathy cohort, 13,751 patients without MS were propensity matched against 103 patients with MS. Patients with MS had a lower rate of reoperation at 3 months (risk difference=-0.019, p=0.018) and 12 months (risk difference=-0.029, p=0.007) compared to those without MS.

Conclusion: Patients with MS had similar Patient Reported Outcomes (PROs) after elective cervical surgery for myelopathy or radiculopathy compared to patients without MS when adjusting for baseline covariates through propensity matching, except for MS patients having inferior 3-month mJOA scores in the myelopathy cohort. Reoperation rates were found to be lower in patients with MS undergoing elective cervical surgery for both myelopathy and radiculopathy. These results suggest that when analyzed independently, a diagnosis of MS does not significantly impact complication, readmission and reoperation rates or PROs, and

PAPER 64 continued

therefore should not represent a major contraindication to elective cervical spine surgery. Surgical decisions in this patient population should be made based on careful consideration of patient factors including other comorbidities as well as baseline patient functional status.



PAPER 64 continued

	Cervical Myelopathy		Cervical Radiculopathy	
	Mean difference or Risk Difference (95% CI)	p-value	Mean difference or Risk Difference	p-value
EQ-5D Score at 3 months	-0.030 (-0.089-0.028)	0.309	-0.007 (-0.053-0.039)	0.768[1]
NDI Score at 3 months	4.055 (-0.978-9.088)	0.115	-0.007 (-3.954-3.940)	0.997[1]
NRS Neck Pain at 3 months	0.248 (-0.581-1.077)	0.559	-0.237 (-0.844-0.371)	0.445[1]
NRS Arm Pain at 3 months	-0.379 (-1.55-0.396)	0.338	-0.012 (-0.720-0.695)	0.972[1]
mJOA Score at 3 months	-1.044 (-1.757-(-0.330))	0.004		
Patient Satisfaction Score at 3 months	-0.025 (-0.265-0.214)	0.836	0.019 (-0.211-0.248)	0.874[2]
EQ-5D Score at 12 months	-0.031 (-0.107-0.045)	0.424	-0.062 (-0.130-0.006)	0.077[1]
NDI Score at 12 months	1.065 (-5.078-7.208)	0.734	4.889 (-1.661-11.440)	0.145[1]
NRS Neck pain at 12 months	-0.581 (-1.478-0.317)	0.206	-0.017 (-0.989-0.956)	0.973[1]
NRS Arm Pain at 12 months	-0.469 (-1.492-0.554)	0.370	0.111 (-0.993-1.214)	0.845[1]
mJOA Score at 12 months	-0.900 (-1.849-0.049)	0.064		
Patient Satisfaction Score at 12 months	-0.252 (-0.511-0.006)	0.057	0.109 (-0.269-0.488)	0.572[2]
Complications within 3 months	-0.001 (-0.075-0.074)	0.989	0.049 (-0.018-0.115)	0.154[2]
Readmissions within 3 months	0.021 (-0.048-0.089)	0.558	0.029 (-0.026-0.085)	0.300[2]
Revision Surgery within 3 months	0.005 (-0.027-0.037)	0.745	-0.019 (-0.034-(-0.003))	0.018[2]
Revision Surgery within 12 months	-0.036 (-0.063-(-0.010))	0.007	-0.029 (-0.050-(-0.008))	0.007[2]
Patient Mortality within 30 days	-0.007 (-0.014-0.001)	0.080	0	NA

ATT (Average treatment effect for the treated), 95% CI (95% Confidence Interval), EQ-5D (EuroQol 5-Dimensions), NDI (Neck Disability Index), NRS (Numeric Rating Scale), mJOA (Modified Japanese Orthopaedic Association Scale),
Test Used: [1]Mean Difference, [2]Risk Difference

PAPER 65

Clinical and radiological outcomes of Hybrid Surgery (HS) in double level Cervical Degenerative Disc Disease (CDDD) at 3 years follow-up

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Introduction: Cervical Degenerative Disc Disease (CDDD) is a common cause of pain associated with radiculopathy, myelopathy or both. Anterior Cervical Discectomy and Fusion (ACDF) is a widely performed surgery for CDDD. However adjacent level degeneration is commonly associated with ACDF in the literature. Cervical Total Disc Arthroplasty (TDA) is a motion preserving surgical option available nowadays, with encouraging outcomes. Optimum management of multilevel CDDD is debatable. Hybrid Surgery (HS) with ACDF and TDA for multilevel CDDD has encouraging results. This study presents our experience with HS in double level CDDD and clinical and radiological outcomes at 3 years follow-up.

Materials and Methods: Single center, single surgeon, retrospective observational study was performed on 21 patients with symptomatic double level CDDD who were treated with ACDF coupled with TDA. All patients underwent the HS in a single stage procedure. Clinical evaluation was based on Neck Disability Index (NDI) and Japanese Orthopaedic Association (JOA) score. Radiographic evaluation included the angular ROM from C2 to C7 at one month, three months, one year and three years. All patients were followed up for a minimum of 36 months. Biological fusion was analysed at 3 months and 12 months follow-up.

Results: All patients exhibited significant improvement in NDI and JOA scores compared to pre operative scores. All improved scores were maintained at 3 years follow-up. The angular ROM improved significantly at 12 months follow-up. Cervical lordosis was maintained and patients had significant symptomatic relief at 3 months follow-up, which was maintained at 3 years follow-up. No patients had adjacent level degeneration, nor device migration. Adequate biological fusion could be seen in all the patients.

Conclusion: Motion-preserving TDA combined with ACDF has promising and encouraging results. HF is a safe, single stage procedure with good patient compliance.

PAPER 66

Is Severe Mechanical Neck Pain a Contraindication to Performing Laminoplasty in Patients with Cervical Spondylotic Myelopathy?

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Introduction: For many spine surgeons, severe neck pain remains a relative contraindication to the performance of laminoplasty in patients with cervical spondylotic myelopathy (CSM) due, primarily, to the belief that mechanical neck pain likely arises from degenerative arthropathy that would not be addressed through a motion-preserving operation such as laminoplasty. The primary purpose of the present study was to investigate whether patients with severe mechanical preoperative neck pain achieve acceptable outcomes after laminoplasty. Secondarily, this study sought to identify preoperative variables contribute to differences in neck pain in patients with myelopathy.

Materials and Methods: We retrospectively reviewed a cohort of consecutive patients undergoing laminoplasty between the years 2010-2021 at a single academic institution. Patients were included if they underwent laminoplasty for cervical spondylotic myelopathy with or without radiculopathy. Patient demographics and surgical variables were collected. Patients were then subdivided into mild (VAS Neck 0-3), moderate (4-6), and severe (7-10) neck pain groups based upon accepted visual analog scale (VAS) neck cutoffs. Patient reported outcome measures (PROMs) including neck disability index (NDI), VAS neck, and VAS arm were then compared between subgroups preoperatively, at 6 months postoperatively, and at 1 year postoperatively. Subgroups were then compared based upon baseline demographics, presenting clinical symptoms, radiographic variables, degree of qualitative paraspinal sarcopenia, and complications. Analysis of variance (ANOVA) was utilized to compare differences between subgroups, and student's t-test was utilized to compare within group changes in perioperative PROMs.

Results: We identified 91 patients for inclusion in this study. There were no differences identified in baseline demographic variables or perioperative clinical symptoms between groups (Table 1). Patients with severe neck pain (VAS neck ≥ 7) had higher preoperative VAS neck, NDI, and VAS arm scores. However, there was no difference in any of these measures at 6 months or 1 year postoperatively between subgroups subdivided according to preoperative VAS neck. The mild, moderate, and severe neck pain groups all experienced significant improvement in NDI, VAS neck, and VAS arm from preoperative to 1 year postoperatively (Table 2). There were no differences in complication rates between subgroups. Furthermore, there were no differences identified in preoperative radiographic variables between subgroups, including maximum spinal cord compression, maximum canal compromise, the presence of myelomalacia, the degree of qualitative sarcopenia, C2 sagittal vertical axis, C2 slope, C2-7 lordosis, T1 slope, C0-2 cobb angle, and C1-occiput distance.

Conclusion: Patients with severe mechanical neck pain preoperatively experience a significant postoperative improvement in reported neck disability, neck pain, and arm pain. As a result, these patients experience similar neck pain and disability at 6 months and 1 year

PAPER 66 continued

postoperatively as their counterparts with less severe preoperative neck pain. The results of this study suggest that mechanical neck pain is not a contraindication to laminoplasty in patients with CSM. This study was unable to identify radiographic or demographic variables that may explain the etiology of severe neck pain in patients with CSM.

Table 1: Demographics and Clinical Symptoms Based upon Preoperative VAS Neck

	Mild Neck Pain (N=47)	Moderate Neck Pain (N=22)	Severe Neck Pain (N=22)	P Value
Demographics				
Age	60.7 (13.0)	62.3 (13.2)	57.1 (15.7)	0.44
Gender (Male)	11 (23.4%)	10 (45.5%)	9 (40.9%)	0.13
BMI	28.7 (4.5)	30.4 (6.4)	28.7 (6.0)	0.46
Active smoker	4 (8.5%)	3 (13.6%)	5 (22.7%)	0.27
CKD	4 (8.5%)	1 (4.5%)	2 (9.1%)	0.81
Chronic Steroid Use	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Inflammatory Arthritis	3 (6.4%)	1 (4.5%)	2 (9.1%)	0.83
mFI	10.8 (15.2)	8.7 (12.4)	13.2 (18.8)	0.63
CCI	2.6 (3.0)	2.5 (2.7)	3.0 (3.1)	0.86
Clinical Symptoms				
Lhermitte's Phenomenon				0.08
None Preop	43 (91.5%)	20 (90.9%)	16 (72.7%)	
Resolved	4 (8.5%)	2 (9.1%)	6 (27.3%)	
Upper Extremity Motor Neuron Symptoms				0.94
None Preop	5 (10.6%)	2 (9.1%)	3 (13.6%)	
Unchanged	4 (8.5%)	1 (4.5%)	2 (9.1%)	
Worse	1 (2.1%)	1 (4.5%)	0 (0.0%)	
Improved	26 (55.3%)	10 (45.5%)	11 (50.0%)	
Resolved	11 (23.4%)	8 (36.4%)	6 (27.3%)	
Gait Instability				0.53
None Preop	10 (21.3%)	10 (45.5%)	6 (27.3%)	
Unchanged	3 (6.4%)	2 (9.1%)	2 (9.1%)	
Worse	2 (4.3%)	0 (0.0%)	0 (0.0%)	
Improved	15 (31.9%)	5 (22.7%)	5 (22.7%)	
Resolved	17 (36.2%)	5 (22.7%)	9 (40.9%)	
Radiculopathy Symptoms				0.34
None Preop	21 (44.7%)	10 (45.5%)	6 (27.3%)	
Unchanged	2 (4.3%)	2 (9.1%)	0 (0.0%)	
Worse	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Improved	12 (25.5%)	7 (31.8%)	7 (31.8%)	
Resolved	12 (25.5%)	3 (13.6%)	9 (40.9%)	

PAPER 66 continued

Table 2: Patient Reported Outcome Measures Based upon Preoperative VAS Neck				
	Mild Neck Pain (N=47)	Moderate Neck Pain (N=22)	Severe Neck Pain (N=22)	P Value
Neck Disability Index				
Preoperative	10.3 (7.9)	18.1 (7.5)	17.7 (8.7)	< 0.001
6 Months Postoperative	11.9 (9.6)	12.0 (8.6)	12.7 (7.2)	0.96
Δ Preop to 6 Months Postop	1.3 (6.2)	-5.9 (7.2)	-4.4 (6.6)	< 0.001
P Value	0.23	<0.001	0.02	
1 Year Postoperative	8.3 (7.0)	8.6 (6.9)	8.6 (7.9)	0.99
Δ Preop to 1 Year Postop	-2.3 (5.5)	-10.0 (7.2)	-7.1 (8.4)	< 0.001
P Value	0.02	<0.001	0.01	
VAS Neck				
Preoperative	1.6 (1.1)	4.7 (0.7)	7.8 (1.0)	< 0.001
6 Months Postoperative	1.7 (1.9)	1.6 (1.9)	2.2 (2.4)	0.59
Δ Preop to 6 Months Postop	0.1 (2.0)	-3.1 (2.2)	-5.6 (2.8)	< 0.001
P Value	0.75	<0.01	<0.01	
1 Year Postoperative	0.9 (1.4)	1.6 (2.2)	2.1 (2.5)	0.09
Δ Preop to 1 Year Postop	-0.5 (1.3)	-3.1 (2.5)	-5.8 (2.6)	< 0.001
P Value	0.01	<0.001	<0.001	
VAS Arm				
Preoperative	1.6 (2.2)	3.5 (2.7)	6.0 (3.8)	< 0.01
6 Months Postoperative	1.4 (2.0)	1.1 (1.8)	2.5 (3.3)	0.37
Δ Preop to 6 Months Postop	-0.1 (2.4)	-2.8 (2.7)	-3.5 (3.2)	< 0.01
P Value	0.81	0.01	0.02	
1 Year Postoperative	1.0 (1.6)	1.3 (1.9)	1.1 (1.6)	0.89
Δ Preop to 1 Year Postop	-0.7 (1.9)	-2.6 (3.3)	-4.9 (3.2)	< 0.01
P Value	0.06	0.048	<0.01	

Table 3: Complications			
	No Foraminotomy (N=73)	Yes Foraminotomy (N=74)	P Value
Superficial Infection	3 (4.1%)	1 (1.4%)	0.3
Deep Infection	-	-	-
Delayed Wound Healing	1 (1.4%)	2 (2.7%)	0.57
New or Progressive Neurologic Deficit	7 (9.6%)	4 (5.4%)	0.34
Hematoma Requiring Intervention	-	-	-
Dysphagia	-	-	-
Hinge Fracture	9 (12.3%)	4 (5.4%)	0.14
Reoperation	3 (4.1%)	4 (5.4%)	0.71

PAPER 67

Prosthesis Design and Likelihood of Achieving Physiological Range of Motion After Cervical Disc Arthroplasty: Analysis of Data from Seven IDE Clinical Trials

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Introduction: The functional goals of cervical disc arthroplasty (CDA) are to (1) restore enough range of motion (ROM) to reduce the risk of accelerated adjacent segment degeneration and (2) limit excessive motion in order to obtain a biomechanically stable index segment; herein termed "Physiological Motion-Range." Yet, clinical studies do not report what proportion of reconstructed segments yield ROM in the Physiological Motion-Range following CDA. We analyzed postoperative data reported by 1-level IDE clinical trials of various FDA-approved cervical disc prostheses to calculate the proportions of reconstructed segments that yield flexion-extension ROM (FE-ROM) in the Physiological Motion-Range, defined as 5-16 degrees.

Materials and Methods: We analyzed 24-month post-CDA FE-ROM data from 1,173 patients reported in the 1-level IDE clinical trials of 7 of the 8 FDA-approved artificial cervical discs (as of March 2022). The inclusion and exclusion criteria were common across these trials. The FE-ROM histograms available in public domain allowed calculation of the proportion of implanted levels with postoperative FE-ROM in the following motion-ranges: [0–4], [5–16], and [≥17] degrees. The 5-degree lower bound of the physiological motion-range was based on clinical data showing significantly reduced incidence of progressive radiographic adjacent-level degeneration in patients with ≥5 degrees ROM after CDA. The 16-degree upper bound was based on laboratory data from 133 C5-C6 and C6-C7 segments from 102 cervical spines with mild-to-moderate degeneration which showed average FE-ROM of 12.1±4.0 degrees. ROM-histogram data for Simplify disc were not reported in public domain and not available for analysis. Preoperative ROM-histograms for 6 of the 7 prostheses were not available for analysis.

Results: 762 of the 1,173 implanted levels in the 7 clinical trials yielded post-CDA FE-ROM in the physiological motion-range [5–16 degrees]. The proportions ranged from 60%-79% across the 7 disc-prostheses, with a cohort-average of 65.0±6.2% (Table 1). 302 of 1,173 implanted levels yielded ROM below the 5-degree lower bound. The proportions ranged from 15%-38% with a cohort-average of 25.7±8.9%. 109 of 1,173 implanted levels yielded ROM of ≥17 degrees with a range of 2%-21% and a cohort-average of 9.3±7.9%. 18.6% (65/350) of discs implanted with the 2 mobile-core-designs in this cohort yielded ROM≥17 degrees, twice the cohort-average of 9.3% (109/1,173) and comprised 61% (65/109) of the post-CDA hypermobile levels.

Conclusion: On average, only 65% of implanted segments in this cohort of 1,173 patients from 7 IDE studies achieved 2-year post-CDA ROM in the physiological motion-range with mean 9.4±3.2 degrees (Table 2), meeting the functional goals of mobility and stability after CDA. Prosthesis-design significantly influenced the likelihood of achieving FE-ROM in the physiological motion-range, thus avoiding hypomobility (ROM<5 degrees) or hypermobility (ROM≥17 degrees) (P<.001). The prosthesis with design features that provided built-in stiffness yielded the highest proportion (103/131 or 79%) of implanted segments in the physiological motion-range, compared to the cohort-average of 65% (P<.05), suggesting built-in stiffness is a desirable deign-feature. The role of preoperative motion in influencing this outcome

PAPER 67 continued

measure should be investigated. We propose the proportion of index levels achieving post-CDA motions in the physiological motion-range (5–16 degrees) as a potentially useful outcome measure for future clinical trials.

Table 1. Proportions of implanted segments falling into the 3 postoperative motion ranges calculated using public-domain data from IDE clinical trials. Data are shown for each prosthesis and for the cohort of all 7 prostheses.

Motion Range	ProDisc-C	PCM	Prestige	Bryan	Mobi C	Secure-C	M6-C	All Prostheses	
24-month Postop	n1 (%)	n2 (%)	n3 (%)	n4 (%)	n5 (%)	n6 (%)	n7 (%)	N	Proportion
0 - 4 deg.	19 (20%)	68 (38%)	77 (29%)	52 (34%)	26 (17%)	40 (21%)	20 (15%)	302	25.7%±8.9%
5 - 16 deg.	61 (64%)	107 (60%)	175 (66%)	97 (63%)	96 (62%)	123 (63%)	103 (79%)	762	65.0%±6.2%
≥17 deg.	16 (17%)	3 (2%)	12 (5%)	5 (3%)	33 (21%)	32 (16%)	8 (6%)	109	9.3%±7.9%
Sub Total	**96 (100%)**	**178 (100%)**	**264 (100%)**	**154 (100%)**	**155 (100%)**	**195 (100%)**	**131 (100%)**	**1173**	**100.0%**

Table 2. Average ROM of the implanted segments falling into each of the 3 motion ranges. Data are shown for each prosthesis and the cohort of 7 prostheses.

Motion Range	ProDisc-C	PCM	Prestige	Bryan	Mobi C	Secure-C	M6-C	All Prostheses	
24-month Postop	n1 (ROM)	n2 (ROM)	n3 (ROM)	n4 (ROM)	n5 (ROM)	n6 (ROM)	n7 (ROM)	N	ROM
0 - 4 deg.	19 (2.8±1.0)	68 (2.7±1.1)	77 (2.5±1.0)	52 (2.5±1.3)	26 (2.0±1.6)	40 (1.8±1.5)	20 (2.5±1.1)	302	2.4±1.2
5 - 16 deg.	61 (10.1±3.3)	107 (8.1±2.9)	175 (9.7±3.2)	97 (9.2±3.1)	96 (9.8±3.3)	123 (9.6±3.0)	103 (9.6±3.1)	762	9.4±3.2
≥17 deg.	16 (19.4±1.7)	3 (18±0)	12 (19.2±2.7)	5 (18.2±1.3)	33 (20.4±3.4)	32 (19.7±2.0)	8 (19.1±2.0)	109	19.6±2.6
Average ROM	**96 (10.2±5.7)**	**178 (6.2±3.9)**	**264 (8.0±4.9)**	**154 (7.3±4.6)**	**155 (10.7±6.5)**	**195 (9.7±6.0)**	**131 (9.1±4.6)**	**1173**	**8.6±5.4**

PAPER 68

The Impact of Motion on Adjacent Level Degeneration After Cervical Disc Arthroplasty: Results of Post-hoc Analysis from a Prospective Study With 7-Year Follow-up

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Introduction: Cervical disc arthroplasty (CDA) is a well-accepted surgical treatment for many patients with cervical radiculopathy and/or myelopathy who have failed appropriate nonsurgical treatment. The rationale for CDA is that maintenance of index level range of motion will decrease adjacent level stresses and ultimately reduce the development of adjacent level degeneration (ALD) compared to anterior cervical discectomy and fusion (ACDF). However, little information is available on the impact of hypermobility on the development of ALD after CDA.

Materials and Methods: This study involved secondary analysis of data collected in a prospective, randomized (2:1), multicenter, 2-arm, noninferiority FDA IDE clinical trial (ClinicalTrials.gov Identifier: NCT00389597). The current analysis focuses on radiographic outcomes seven years following a 1-level CDA. Radiographic assessments were evaluated for flexion-extension range of motion (ROM) and ALD. Quartiles were computed for index level flexion – extension ROM to evaluate the relationship between ROM and ALD, and quartile splits were as follows: 0-5.5, 5.5-9.6, 9.6-15.6, and 15.6-28.5. Continuous data was assessed using one-way analysis of variance (ANOVA). Dichotomous variables such as ALD progression were assessed using the chi-square test. Alpha was set at 0.05.

Results: There was an association between ALD progression and surgery type. Patients who underwent CDA experienced significantly less ALD progression compared with patients who underwent ACDF (Figure 1, =9.24, p=0.002 at the superior and=3.88, p=0.049 at the inferior level).

Further, there was an association between ALD progression and ROM (Figure 2, =12.42, p=0.014 at the superior level and = 9.48, p=0.050 at the inferior level). Specifically, patients with mid-ROM after CDA experienced the lowest frequency of ALD progression at the superior and inferior levels. Patients with the lowest and highest ROM after CDA experienced a lower frequency of ALD progression than ACDF patients but a greater frequency of ALD progression than patients with mid-ROM after CDA.

Change in ALD from baseline (range 0-4 with four indicating severe ALD) was investigated to better evaluate this relationship. There was a significant association between change in ALD and ROM groupings at the inferior level (Figure 3, p=0.046) whereby the lowest and highest ROM groups experienced the greatest increases in ALD scores.

Finally, demographic variables were assessed in relation to ROM groupings; sex and age were associated with ROM groups (p=0.001 and p=0.023, respectively) where women had greater representation in the highest ROM group. Patients with the highest ROM were younger.

Conclusion: CDA patients experienced significantly less ALD than ACDF at 7-years. While index level ROM is felt to be protective after CDA, patients with the greatest ROM developed ALD at similar rates to patients with the lowest ROM in our study. This is the first study demonstrating that hypermobility after CDA is associated with the development of ALD. Patients with the highest segmental ROM after CDA were more likely to be female and younger.

PAPER 68 continued

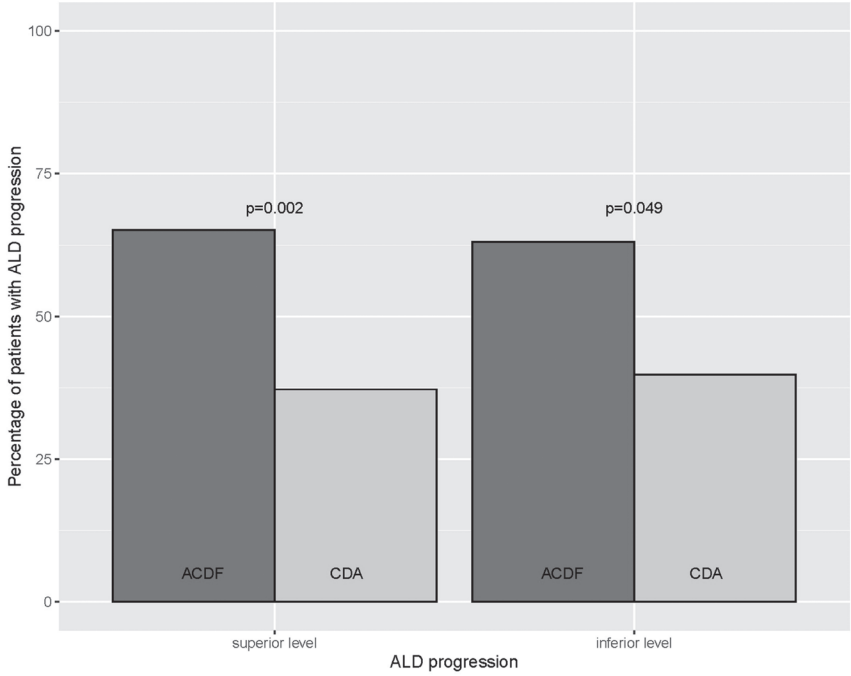

Figure 1. Percentage of patients with ALD progression at final follow-up. There was significantly more ALD progression in patients who underwent ACDF compared with patients who underwent CDA (p=0.002 at the superior level and p=0.049 at the inferior level).

PAPER 68 continued

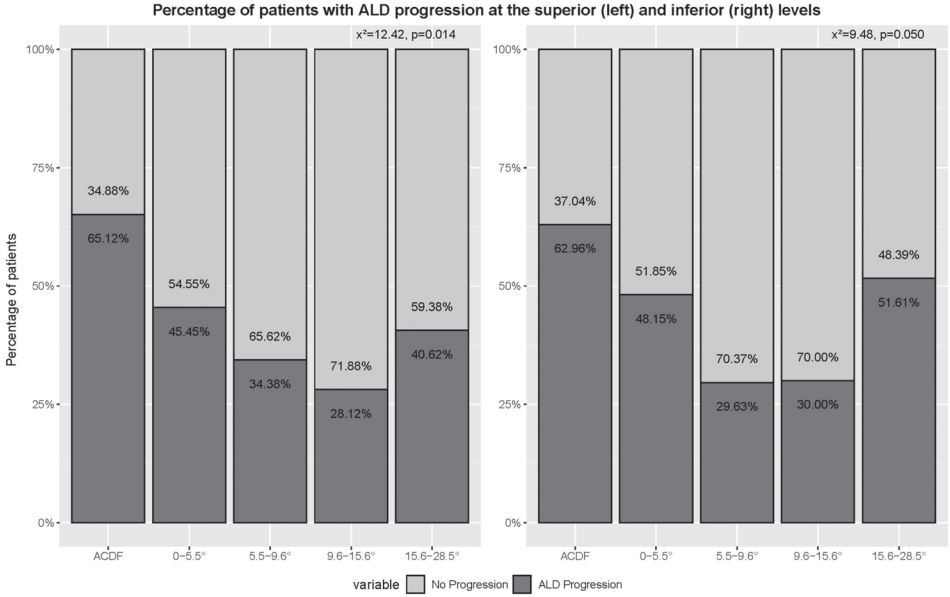

Figure 2. Percentage of patients who experienced ALD progression at the superior and inferior levels, categorized according to treatment arm (ACDF vs. CDA) and further categorized by ROM quartiles. The frequency of patients with ALD progression is significantly different among the groups (χ^2=12.42, p=0.014 at the superior level and χ^2= 9.48, p=0.05 at the inferior level). ALD progression was greatest in ACDF patients, followed by CDA with the lowest and highest ROM.

PAPER 68 continued

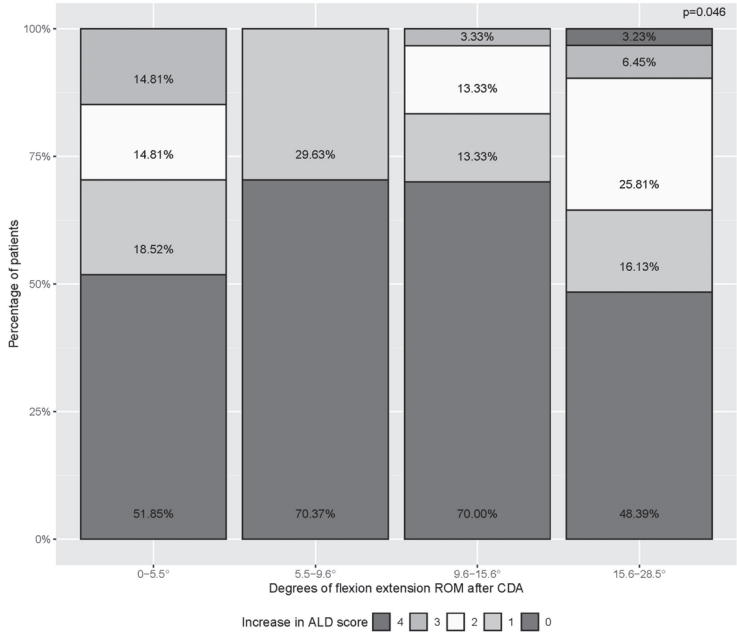

Figure 3. Change in ALD score from baseline grouped by ROM quartiles. Increase in ALD score is significantly different between quartiles (p = 0.046). Patients with the lowest and highest ROM experienced the most change from baseline ALD.

PAPER 69

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

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Introduction: The utility of intraoperative neurophysiological monitoring (IOM) for anterior cervical surgery remains controversial. Despite insufficient evidence demonstrating a clear benefit, IOM continues to be utilized and in some areas is considered standard of care. The aim of this study was to evaluate the effects of IOM on anterior cervical surgery outcomes by utilizing data from the Michigan Spine Surgery Improvement collaborative.

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

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

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

PAPER 70

3-Level vs. 4-Level Anterior Cervical Discectomy and Fusion: Differences in Complications and Perioperative Characteristics

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Introduction: Anterior cervical discectomy and fusion (ACDF) is the current standard treatment for symptomatic cervical myelopathy and radiculopathy not amenable to nonoperative management. One- and two-level fusions are much more common and widely studied, however pathology occasionally extends over multiple levels necessitating the need for multilevel ACDF. There is limited data in spine literature comparing outcomes for three- and four-level ACDFs. Therefore, the purpose of this study was to compare perioperative factors, resource utilization, and clinical outcomes between 3-level and 4-level ACDF at a single, urban, academic medical institution.

Materials and Methods: This was a retrospective study utilizing data from elective ACDFs performed between 2008-2019 at an urban, academic tertiary medical center. 376 cases of 3- and 4-level ACDF were identified from our institutional database using CPT codes 22551, 22552, and 22554. Exclusion criteria included age <18 and surgeries performed for cervical trauma, fracture, infection, or tumor. Surgeries that involved a posterior approach and non-cervical procedures were also excluded. ACDF patients were stratified into two groups based on the number of levels fused (3 and 4 levels). Patient demographics, perioperative characteristics, and clinical outcomes (readmissions, all-cause complications, discharge status, and length of stay [LOS]) were compared between the groups using chi-square analysis. Multivariate logistic regressions analyses were performed as well for the clinical outcomes.

Results: The 3-level (n=321) and 4-level (n=35) ACDF groups were well matched in baseline demographics such as age (p=0.17), BMI (p=0.59), race (p=0.29), ASA status (p=0.38), preoperative diagnosis (p=0.183), Elixhauser comorbidity index score (p=0.666), and insurance status (p=0.27). There were no significant differences in 30-day readmissions (3-level: 2.7%, 4-level: 7.9%, p=0.22), 90-day readmissions (3-level: 5.7%, 4-level: 7.9%, p=0.86), and LOS (3-level: 2.00 days, 4-level: 2.21 days, p=0.80) between the two groups. The overall complications rate was higher for 4-level ACDFs (18.4%) compared to the 3-level group (7.5%) (p=0.05). Specifically, 4-level ACDF patients had higher rates of dysphagia (p=0.01). With regard to perioperative variables, time under anesthesia (p<0.01) and length of surgery (p<0.01) was greater for 4-level ACDFs. On multivariate analysis, 4-level ACDFs were associated with increased risk of complications (OR 3.19, 95% CI 1.25 - 8.16, p=0.02), particularly dysphagia (OR: 5.02, 95% CI 1.60 - 15.76, p=0.01). Four-level ACDF surgery was not associated with an increased risk for 30-day readmissions (OR 2.99, 95% CI 0.76 - 11.83, p=0.12), 90-day readmissions (OR 1.42, 95% CI 0.39 - 5.17, p=0.60), or non-home discharge (OR 1.60, 95% CI 0.27 - 9.34, p=0.61).

Conclusion: While 4-level ACDF does not result in an increased risk for readmissions and non-home discharge when compared to 3-level ACDF, providers must pay attention to the increased risk for intraoperative complications, particularly dysphagia when performing a 4-level procedure.

PAPER 71

Change in physical and mental well-being between the short-and mid-term periods after cervical surgery for myelopathy: A retrospective cohort study with minimum 5 years follow-up

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Introduction: The mid- to long-term surgical outcomes of laminoplasty, evaluated using the cervical Japanese Orthopedic Association (cJOA) score, have been reportedly satisfactory.[1-4] The cJOA score is a physician-oriented score used to assess the severity of myelopathy rather than the parameter of the patient's well-being. Although several studies have demonstrated the change in well-being after surgery for CSM, most only reported short-term follow-up findings.[5,6]

Additionally, no study has reported the predictive factors at the short-term follow-up for the change in well-being afterwards, which could significantly assist physicians in identifying patients who require long-term follow-up. Therefore, the current study aimed to demonstrate the change in mental and physical well-being between short-term and mid-term follow-ups. Additionally, we aimed to determine the predictive factors at short-term follow-up for the deterioration of patient well-being after short-term observation.

Materials and Methods: This is a retrospective cohort study performed in Japan. In all, 80 consecutive patients who underwent laminoplasty for cervical spondylotic myelopathy (CSM) with complete clinical data preoperatively and at 3 months, 2 years, and 5 years postoperatively were enrolled. The Short Form-36 Physical Component Summary (PCS) and Mental Component Summary (MCS) scores were considered as the parameters of physical and mental well-being. PCS and MCS at the 2- and 5-year postoperative time points were compared using t-tests with Bonferroni correction after repeated measurement one-way analysis of variance. The "deterioration" of PCS and MCS was defined as a decrease of more than minimum clinically important difference (4.0 points).[7] Additionally, a multivariate logistic regression model was used to identify the predictive factors for deterioration after 2 years of surgery. Significant factors in the logistic regression analysis were analyzed using receiver operating characteristic curves to determine the cutoff value.

Results: The mental well-being of the patients who underwent surgery for CSM did not deteriorate after follow-up at 2 years postoperatively (p=0.912, Figure 1). Meanwhile, physical well-being significantly declined between 2 and 5 years postoperatively (p=0.008, Figure 1). In the regression model, the cJOA score at 2 years postoperatively was significantly associated with PCS deterioration after 2 years of follow-up, independent of age, sex, and PCS score at 2 years postoperatively (p=0.008, Table 1). The area under curve of the cJOA score at 2 years postoperatively was 0.711 (p=0.001, Figure 2). The optimal cutoff value was 13.0 (sensitivity, 86.8%; specificity, 56.1%). Therefore, patients with a cJOA score <13.0 at 2 years postoperatively experienced a deterioration of PCS more frequently than patients with cJOA scores ≥13.

Conclusion: The mental well-being of patients who underwent surgery for CSM did not deteriorate after a short-term follow-up. Meanwhile, more than half of the patients experienced deterioration in physical well-being after short-term periods. A cJOA score >13 points at short-term follow-up potentially predicted the deterioration of physical well-being afterwards. The current results suggest that physicians continue follow-up for patients with a cJOA score <13

PAPER 71 continued

for over 2 years. Furthermore, additional intervention may be planned for patients with a cJOA score <13 at the short-term follow-up.

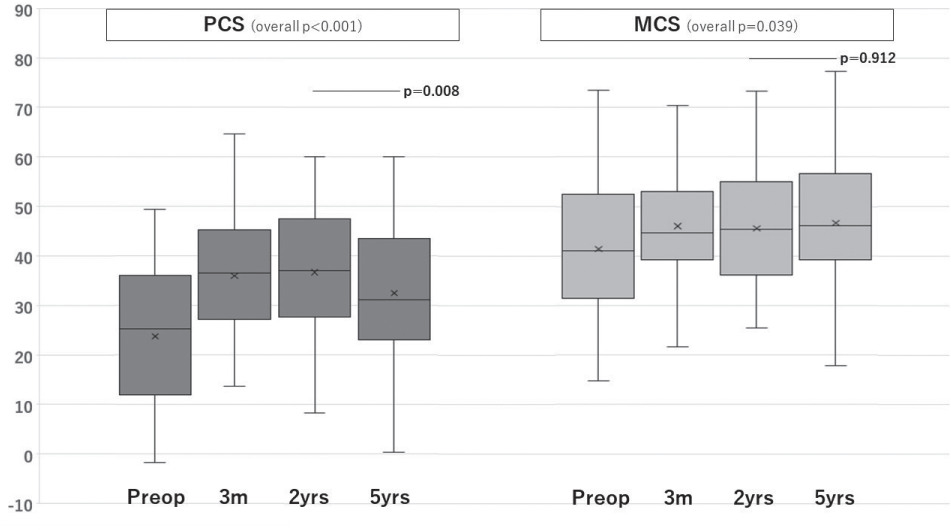
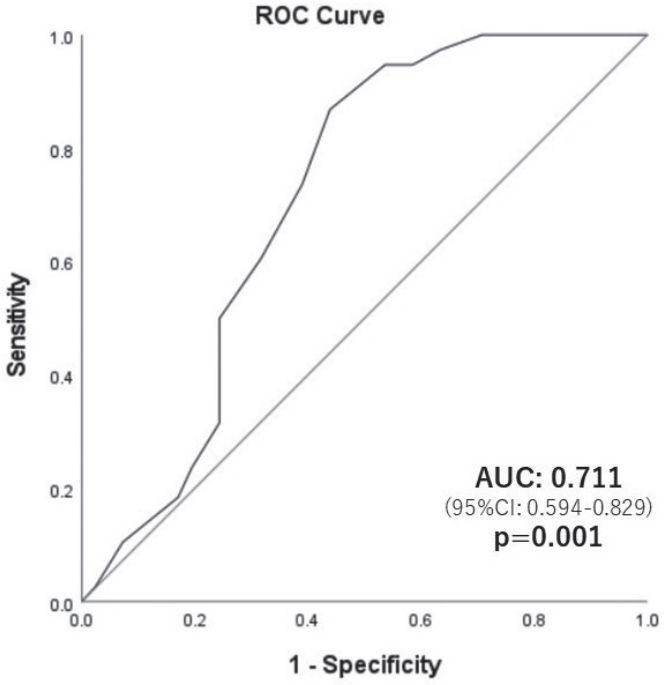


Table 1. Multivariate logistic regression analysis of factors associated with PCS deterioration 2 years postoperatively.

Explanatory variables	Reference	Adjusted OR	p-value	95% CI
Age	Continuous	1.05	0.131	0.98-1.11
Sex (Male)	Female	1.05	0.937	0.36-3.08
cJOA at 2 ys postop	Continuous	0.57	0.008	0.38-0.86
PCS at 2 ys potop	Continuous	1.07	0.052	0.99-1.14

cJOA: cervical Japanese Orthopaedic Association, PCS: physical component summary, summary, 3m: 3 months, 2ys: 2 years, postoperative: postoperative

PAPER 71 continued



PAPER 72

Risk factors for progression of ossification of posterior longitudinal ligament in asymptomatic subjects

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Introduction: The incidence and risk factors for the progression of ossification of posterior longitudinal ligament (OPLL) have been previously reported in surgically [1, 2] and non-surgically [3, 4] treated symptomatic patients. However, the incidence and risk factors for OPLL progression in asymptomatic subjects with OPLL are not well characterized. This study aimed to analyze the natural course of OPLL mass in asymptomatic subjects and clarify the incidence and risk factors for OPLL progression based on long-term computed tomography (CT) follow-up data (> 5 years).

Materials and Methods: We retrospectively reviewed 2585 healthy subjects who underwent whole-body CT scan at a single health center from September 2007 to December 2011. This study included asymptomatic subjects with OPLL who underwent CT scan twice with an interval of at least 5 years. OPLL measurements (maximum sagittal thickness and length of OPLL mass) were assessed at the initial and final CT examinations. OPLL progression was defined as an increase of more than 2-mm in the sagittal thickness and/or length of ossified mass. Based on these findings, the subjects were divided into two groups: non-progression (OPLL-NP) and progression (OPLL-P) groups. We compared clinical characteristics (age, sex, and body mass index), laboratory data, bone mineral status, OPLL types, and OPLL involvement of multiple vertebrae levels (≥ 3 vertebrae levels) between the two groups. Risk factors for progression of OPLL were identified by logistic regression analysis after propensity score adjustment.

Results: 109 subjects (mean age; 61.6 years, 91 men; 18 women) were included in this study. Out of the 109 subjects with OPLL, 20 subjects exhibited OPLL progression (OPLL-P group) and the incidence of OPLL progression was 18.3%. Subjects in the OPLL-P group were significantly younger ($p = 0.031$), had higher prevalence of multiple-level OPLL involvement ($p = 0.041$) and continuous type of OPLL ($p = 0.015$), and had higher uric acid (UA) levels ($p = 0.004$) at the timing of initial CT examination compared to OPLL-NP group (Table 1). Younger age (adjusted odds ratio [aOR], 0.95; 95% confidence interval [CI], 0.90 to 0.99), OPLL involvement of multiple vertebrae levels (aOR, 2.88; 95% CI, 1.06 to 7.83), continuous type of OPLL (aOR, 4.21; 95% CI, 1.35 to 13.10), and higher UA levels (aOR, 2.09; 95% CI, 1.24 to 3.53) were significant risk factors for OPLL progression (Table 2).

Conclusion: OPLL progression occurred in 18.3% of asymptomatic subjects at more than 5 years from baseline. Younger age, OPLL involvement of multiple vertebrae levels, continuous type of OPLL, and higher UA levels were identified as significant risk factors for OPLL progression in asymptomatic subjects. A better understanding of the risk factors for progression of ossified mass in asymptomatic subjects with OPLL will facilitate better clinical management of OPLL patients without symptoms or those with minor symptoms.

PAPER 72 continued

	OPLL-NP n = 89 (81.7%)	OPLL-P n = 20 (18.3%)	P
Age, years	62.6 (10.2)	57.1 (10.3)	0.031
Males, n (%)	73 (82.0%)	18 (90.0%)	0.517
BMI, kg/m^2	24.9 (2.9)	25.6 (3.9)	0.387
OPLL ≥ 3 levels, n (%)	30 (33.7%)	12 (60.0%)	0.041
Continuous type, n (%)	10 (11.2%)	7 (35.0%)	0.015
Segmental type, n (%)	73 (82.0%)	9 (45.0%)	0.001
Mixed type, n (%)	3 (3.4%)	3 (15.0%)	0.074
Localized type, n (%)	3 (3.4%)	1 (5.0%)	0.561
HbA1c, %	6.0 (0.8)	5.7 (0.7)	0.159
TG, mg/dL	129.3 (79.0)	127.1 (72.5)	0.903
TC, mg/d	199.4 (32.8)	191.5 (38.2)	0.351
UA. mg/dL	5.8 (1.1)	6.7 (1.1)	0.004

Table 1
Comparison of demographic and laboratory data between OPLL-NP and OPLL-P groups. Values are reported as mean (standard deviation).

Factors	Adjusted OR	95% CI	P
Age	0.95	0.90 - 0.99	0.036
OPLL ≥ 3 levels	2.88	1.06 - 7.83	0.038
Continuous type	4.21	1.35 - 13.10	0.013
UA	2.09	1.24 - 3.53	0.006

Table 2
Multivariable logistic regression analysis for OPLL progression
OR, odds ratios; *95% CI*, 95% confidence interval
Adjusted for sex and body mass index.

PAPER 73

The association of the time-dependent response of microglia activation at the injured spinal cord and brain with neuropathic pain after spinal cord injury

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Introduction: Spinal cord injury (SCI) causes loss of locomotor function and chronic neuropathic pain. Hematogenous macrophages and activated microglia are key monocytic lineage cell types in the response to SCI. Knowledge of the distribution of the microglia/macrophage at the injured site and remote region (lumbar enlargement and brain) after SCI is important for understanding the pathomechanisms and establishing novel therapeutic strategies for neuropathic pain. Recently, activation of microglia in the brain has attracted attention to the chronic neuropathic pain, especially at the amygdala and hippocampus in addition to the thalamus. In the present study, we investigated the expression of activated microglia/macrophage and pain-related molecules from the injured spinal cord at the acute to chronic phase after SCI.

Materials and Methods: C57BL/6 mice were subjected to SCI induced with the Infinite Horizon impactor (60kdyn). Behavioral and sensory testing were recorded at times indicated post-SCI. To evaluate the expression of activated microglia/macrophage and pain-related molecules (MAPK signaling) at injured site, lumbar enlargement, and brain (thalamus, cerebral cortex, amygdala, and hippocampus), immunohistochemistry (CD11b, p-p38, p-ERK1/2) and western blotting (inflammatory cytokine: TNF-α, IL-12; anti-inflammatory cytokine: IL-4, IL-10) were performed.

Results: The prevalences of activated microglia and pain-related molecules increased at day 14 after SCI, at the time of most severe pain hypersensitivity, at the injured site. In the lumbar enlargement, the expression of activated microglia and pain-related molecules were observed until the chronic phase after SCI. In the amygdala and hippocampus, the expression of microglia was gradually increased up to 12 weeks after SCI. In addition, persistent expression of pain-related molecules in the thalamus, amygdala and hippocampus. Peak expression of TNF-α occurred on day 4 post-SCI at the injured site, but not until day 14 at the lumbar enlargement. Expression of IL-4 peaked at 14 days after SCI at lumbar enlargement.

Conclusion: The results of this study show that the distribution of activated microglia and pain-related molecules after SCI differs between an injured site and the remote region. In the results of this study, it was indicated that the suppression of the expression of the inflammatory cytokines by decreasing the number of microglia/macrophage at acute phase after SCI was important for the provision of a permissive environment for reduction of neuropathic pain. Activation of microglia at the lumbar enlargement in response to inflammatory cytokines from the injured site might be important in chronic below-level pain. In the chronic phase, persistent expression of microglia and pain-related molecules in the limbic system (amygdala and hippocampus) might be associated with chronic neuropathic pain. These findings are useful for establishment of a therapeutic target for prevention of neuropathic pain in the time-dependent response to SCI.

PAPER 74

Prevalence and Prognosis of Gait Dysfunction in Patients Operated for Cervical Spondylotic Myelopathy

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Introduction: Ambulation is an important factor affecting quality of life in patients with cervical spondylotic myelopathy (CSM). However, the prevalence and the prognosis of gait dysfunction in patients operated for CSM remains unclear. Here, we establish the prevalence of gait dysfunction and investigate whether there exist predictors of improved ambulation after surgery for CSM.

Materials and Methods: This was a bispective analysis of the CSM Quality Outcomes Database (QOD) module. Patients with any gait dysfunction preoperatively (defined as having a modified Japanese Orthopedic Association [mJOA] lower limb motor dysfunction score of <4) were compared to those without such dysfunction to identify significant differences in patient and clinical characteristics. Within those who had any gait dysfunction preoperatively, we also compared those who improved versus those who stayed the same/worsened postoperatively at 24 months to determine the predictors of improvement in ambulation.

Results: Of the 1,141 patients included in the study, 883 (77.4%) had gait dysfunction and 258 (22.6%) did not. At baseline, more patients with gait dysfunction were older (61.5±11.6 vs 57.2±11.7, p<0.001), had higher body mass index (30.4±6.55 vs 29.3±5.98, p=0.009), were less likely to have private insurance (45.9% vs 67.4% p<0.001), and had higher number of comorbidities (such as diabetes mellitus, coronary artery disease, peripheral vascular disease, depression, arthritis, chronic kidney disease, all p<0.05). Preoperatively, patients with gait dysfunction had worse VAS neck (5.43±3.27 vs 4.56±3.14, p<0.001) and arm (5.02±3.53 vs 4.42±3.07, p=0.008) pain, NDI (40.9±20.8 vs 30.2±18.4, p<0.001), EQ-VAS (56.1±21.3 vs 69.9±18.9, p<0.001), and EQ-5D (0.53±0.21 vs 0.67±0.19, p<0.001) compared to those without disability. Surgically, more patients with gait dysfunction underwent anterior surgery (36.7% vs 29.1%, p=0.047) compared to those without dysfunction. Postoperatively at 24 months, 512 (44.9%) improved in ambulation and 629 (55.1%) did not (within the cohort with dysfunction at baseline). Those who experienced improvement also demonstrated greater improvement in VAS neck (-3.1±3.1 vs -2.1±3.6) and arm (-3.0±3.6 vs -2.2±3.7) pain, NDI (-21.7±19.2 vs -13.4±20.6), EQ-VAS (+13.9±24.7 vs +4.52±25.4), and EQ-5D (+0.2±0.2 vs 0.1±0.2) (all p<0.001). After controlling for significant covariates with multivariable adjusted analyses, there were no independent predictors associated with improved ambulation.

Conclusion: More than 75% of patients who undergo surgery for CSM demonstrate gait dysfunction. Although patients with preoperative gait dysfunction presented with worse clinical characteristics, almost half of these patients reported improvement in ambulation postoperatively. Furthermore, those who experienced improvement in ambulation also reported larger magnitudes of improvement in other measured patient-reported outcomes.

PAPER 74 continued

Lower Extremity Motor Subscore	Description
0	*Unable to walk*
1	*Can walk on a flat surface with a cane or walker*
2	*Can walk up and down stairs with support of a handrail*
3	*Lack of stability and smooth gait (walking in a smooth manner)*
4	*No problem walking*

PAPER 75

Earlier Tracheostomy Reduces Complications in Complete Cervical Spinal Cord Injury: Analysis of a Multi-Center Cohort of 2004 Patients

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University of Toronto[1]

Introduction: Patients with traumatic cervical spinal cord injury (SCI) typically experience severe respiratory complications necessitating prolonged ventilatory support. Tracheostomy is frequently employed in these circumstances, although there is currently no consensus on the optimal time to perform this technique. Previous studies have commonly used a threshold of 7 days to dichotomize patients into receiving either early or late tracheostomy. It is thought that early tracheostomy in patients with cervical SCI may lessen the risk of developing complications and reduce the duration of mechanical ventilation and critical care stay. This study aims to assess clinical practices and the safety of performing tracheostomy early across a large sample of North American trauma centers.

Materials and Methods: We conducted an observational cohort study using data from the American College of Surgeons (ACS) Trauma Quality Improvement Program (TQIP) database from 2010 to 2018. Adult patients with a complete cervical SCI (ASIA A) who underwent surgery and tracheostomy were included. Patients were stratified into those receiving tracheostomy at or before 7 days and those receiving delayed tracheostomy. Propensity score matching was then used to assess the association between delayed tracheostomy and the risk of in-hospital adverse events including mortality, major complications, and immobility-related complications. Risk-adjusted variability in tracheostomy timing across trauma centers was also investigated using mixed-effects regression.

Results: 2004 patients from 377 North American trauma centers were included. Median time-to-tracheostomy was 9.1 days (interquartile range [IQR]: 6.0-13.1 days), with 663 patients (33.74%) undergoing tracheostomy within 7 days. After propensity score matching, the odds of having a major complication were significantly lower for patients that had a tracheostomy within 7 days (odds ratio [OR]: 0.90; 95% CI: 0.85 to 0.95). Patients were also significantly less likely to experience an immobility-related complication (OR: 0.91; 95% CI: 0.86 to 0.96). Patients in the early group spent 5.07 fewer days in the critical care unit on average (95% CI: -6.40 to -3.74) and 6.12 fewer days on ventilation (95% CI: -9.00 to -3.24). Furthermore, case-mix and hospital-level characteristics explained only 1.1% and 6.6% of the variability in tracheostomy timing both between-centers and within-centers.

Conclusion: Physicians should strive to implement tracheostomy in this patient population within the 7-day threshold to improve outcomes and reduce length of stay. Further research is important to fully characterize the impact of early tracheostomy on mortality risk, in addition to its effects on patient comfort and long-term outcomes.

PAPER 76

Similar Rates of Revision Surgery after Anterior Cervical Discectomy and Fusion Using Interbody Cage and Structural Allograft

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Introduction: Anterior Cervical Discectomy and Fusion (ACDF) is a widely recognized treatment for cervical myelopathy, radiculopathy, and myeloradiculopathy. An average of 132,000 ACDF procedures are performed annually in the United States. A range of graft options are available for use in ACDF including interbody cages and structural allograft. The current literature has not reached a consensus on the impact of graft choice on outcomes and revision surgery. The purpose of this study was to compare revision rates between ACDF using interbody cage and structural allograft.

Materials and Methods: Patients who underwent ACDF for degenerative cervical disease were retrospectively reviewed at a high-volume, tertiary academic center. Adult patients undergoing primary ACDF with interbody cage or allograft and a minimum of 2-year follow up were eligible for inclusion. Patient undergoing a combined anterior and posterior approach or an ACDF for infection, tumor, trauma or revision were excluded. Interbody cages were filled with local bone combined with allograft at the surgeon discretion. Revision rates at final follow-up and a 2-year follow up were compared between patients undergoing ACDF with interbody cage and those with structural allograft. A propensity match was conducted using age, sex, number of surgical levels, BMI, and surgical indication. Statistical analysis of the matched cohorts included Student's T-test or Wilcoxon's rank-sum test for continuous variables and Chi-squared analysis for categorical variables.

Results: A total of 248 patients who underwent ACDF for degenerative cervical disease with a mean age of 55.1 years (39.9% male) and mean follow-up of 3.76 years were included. After propensity matching, 32 patients undergoing ACDF with interbody cage and 134 with structural allograft were included in the matched cohorts (Table 1). There was no significant difference in rate of reoperation within 2 years (11.9% vs. 6.3%) or at final follow-up (19.4% vs. 9.4%) between the allograft and cage cohorts, respectively. The most common reason for revision was adjacent segment disease in both cohorts. The allograft cohort had a significantly shorter LOS ($p<0.001$) and a higher proportion of patients discharged home ($p=0.036$). There was no difference in estimated blood loss between the cohorts (Table 2). In the multivariate analysis, 3-level ACDFs were 5.623 times more likely to require a revision surgery compared to single level ACDFs ($p=0.009$, Table 3).

Conclusion: There was no difference in revision rates between ACDF using interbody cage and structural allograft. The most common indication for revision after ACDF using interbody cage and structural allograft was adjacent segment disease.

PAPER 76 continued

Table 1. Comparison of Matched Cohorts of Allograft vs. Cage			
	Allograft	**Cage**	**p-value**
Number of Patients	134	32	
Age (Years)	56.7 ± 10.0 (95% CI, 55.0 - 58.4)	58.0 ± 9.5 (95% CI, 54.5 - 61.4)	0.515
Age			0.837
<50 Years	32 (23.9%)	7 (21.9%)	
50-65 Years	71 (53.0%)	16 (50.0%)	
>65 Years	31 (23.1%)	9 (28.1%)	
Sex			0.368
Female	85 (63.4%)	23 (71.9%)	
Male	49 (36.6%)	9 (28.1%)	
BMI	30.4 ± 6.8 (95% CI, 29.3 - 31.6)	32.7 ± 6.8 (95% CI, 30.3 - 35.2)	0.101
BMI ≥ 30	60 (44.8%)	17 (53.1%)	0.395
Smoking Status			0.165
Current	32 (23.9%)	3 (9.4%)	
Former	41 (30.6%)	10 (31.3%)	
Never	61 (45.5%)	19 (59.4%)	
Surgery Indication			0.141
Radiculopathy	57 (42.5%)	15 (46.9%)	
Myelopathy	18 (13.4%)	8 (25.0%)	
Myeloradiculopathy	59 (44.0%)	9 (28.1%)	
Number of Fused Levels			0.496
One-Level	50 (37.3%)	14 (43.8%)	
Two-Level	72 (53.7%)	17 (53.1%)	
Three-Level	12 (9.0%)	1 (3.1%)	

PAPER 76 continued

Table 2. Impact of Allograft Vs. Cage on Reoperation Rates and Postoperative Outcomes			
	Allograft	**Cage**	**p-value**
Number of Patients	134	32	
Reoperation within 2 Years	16 (11.9%)	2 (6.3%)	0.352
Overall Reoperation Rate	26 (19.4%)	3 (9.4%)	0.180
Reasons for Reoperation			
Adjacent Segment Disease	11 (42.3%)	3 (100%)	
Pseudarthrosis	8 (30.8%)	0.0%	
Infection	3 (11.5%)	0.0%	
Subsidence	3 (11.5%)	0.0%	
Persistent Symptoms	1 (3.9%)	0.0%	
Estimated Blood Loss (mL)	65.9 ± 76.5 (95% CI, 52.8 - 78.9)	47.0 ± 43.3 (95% CI, 31.4 - 62.7)	0.298
Length of Stay (Days)	1.1 ± 0.5 (95% CI, 1.0 - 1.2)	1.6 ± 1.0 (95% CI, 1.2 - 2.0)	**<0.001**
Home Discharge	133 (99.3%)	30 (93.8%)	**0.036**

Table 3. Risk Factors for Reoperation within 2 Years following ACDF					
Variable	**Reference**	**Odds Ratio**	**95% Confidence Interval**		**p-value**
Age > 65 Years	Age < 50 Years	1.773	0.507	6.203	0.369
Age 50 - 65 Years	Age < 50 Years	0.55	0.183	1.653	0.286
Sex: Female	Male	2.463	0.878	6.909	0.087
BMI > 30	BMI < 30	0.649	0.245	1.721	0.383
Current Smoker	Never Smoker	0.89	0.25	3.178	0.858
Former Smoker	Never Smoker	1.029	0.357	2.967	0.958
Three-Level ACDF	One-Level ACDF	5.623	1.535	20.597	**0.009**
Two-Level ACDF	One-Level ACDF	0.888	0.3	2.624	0.829
Cage	Allograft	0.858	0.218	3.384	0.826

PAPER 77

Elective Primary Anterior Cervical Decompression and Fusion for Degenerative Spondylotic Cervical Myelopathy is Associated with Decreased Resource Utilization versus Posterior Cervical Decompression and Fusion

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Introduction: With ever-rising healthcare costs, the value of surgical interventions should be evaluated closely. Degenerative Spondylotic Cervical Myelopathy (DSCM) is a debilitating condition that is commonly treated with surgical intervention in the form of either anterior cervical decompression and fusion (ACDF) or posterior cervical decompression and fusion (PCDF). However, the resource demands of elective ACDF versus PCDF are still unclear. Prior studies have been limited to small single center studies.[1] The purpose of this study is to compare elective ACDF versus PCDF for DCSM on the hospital episode of care for in terms of 1) cost 2) length of hospital stay and 3) discharge destination in a large Medicare patient population.

Materials and Methods: This is a retrospective case-control analysis of the 2019 Medicare Provider Analysis and Review (MedPAR) Limited Data Set (LDS) and Centers for Medicare and Medicaid Services (CMS) 2019 Impact File. Patients undergoing elective ACDF and PCDF surgery were included. Combined anterior and posterior cervical fusions, revision cases, thoracic extension, disc replacements, fractures, traumatic cord injuries, and epidural abscess were excluded. Univariate analysis of potential demographic, comorbidity, surgical, perioperative, and hospital confounders was performed. Multivariate models in the form of linear regression analyses for hospital cost of care and length of stay and a binary logistic regression analysis for discharge destination were performed including surgical approach and potential confounders with $p<0.05$ on univariate analysis.

Results: There were 21,350 patients that met inclusion criteria. There were 14,126 cases of ACDF (66.2%) and 7,224 elective PCDF (33.8%) cases. There were 10,859 males (50.9%) and 10,491 females (49.1%). The majority of patients were age 65-74 (n=11,155, p=52.2%). The mean cost of elective cervical fusion for myelopathy was $23,663.330±13,810.527 and mean length of stay was 2.86±3.01 days. The majority of patients were discharged home (78.5%).

On univariate analysis, elective ACDF was associated with decreased cost ($20,991.692±11,872.223 vs. $28,887.522±15,771.514, $p<0.001$), length of stay (2.32±2.76 vs. 3.90±3.20 days, $p<0.001$), and lower incidence of non-home discharge (13.9% vs. 36.3%, $p<0.001$) compared to elective PCDF.

On multivariate analysis, ACDF was independently associated with decreased cost of $5,613.255 (95% confidence interval [CI]: $4,211.709-7,014.800, $p<0.001$), shorter length of stay by 1.145 days (95% CI:0.776-1.514 days, $p<0.001$), and nonhome discharge destination by 65.7% (adjusted odds ratio: 0.343, 95% CI: 0.276-0.425).

Conclusion: Elective primary ACDF for DCSM was independently associated with decreased cost of $5,613 (24% lower from mean cost), decreased hospital length of stay of 1.145 days, and 65.7% lower rate of nonhome discharge compared to PCDF. These findings may inform value-based care of DCSM. Patient-specific anatomic and clinical factors should always be considered in surgical decision-making for treatment of DCSM.

PAPER 78

Vitamin K Supplementation Reduces Spinal Hyperostosis and Ameliorates Locomotor Impairment in a Mouse Model of Cervical Ossification of the Posterior Longitudinal Ligament

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Introduction: Ossification of the posterior longitudinal ligament (OPLL) is a multifactorial disease with various interacting genetic and environment factors. Research has identified a number of genes that may be involved in the pathogenesis of OPLL; however, there is currently no pharmacotherapy available to slow or arrest the progression of OPLL in the clinical setting. As a candidate target for modulating the progression of OPLL, we focused on the role of vitamin K-dependent proteins, particularly Gla-rich protein (GRP), which acts as a potent inhibitor of ectopic calcification in various soft tissues.[1] The purpose of this study was to investigate the effect of vitamin K modulation on spinal hyperostosis and its association with GRP in a mouse model of cervical OPLL.

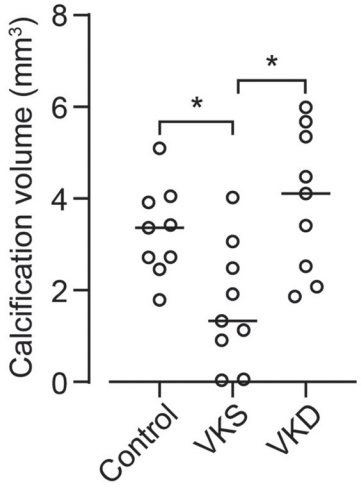
Materials and Methods: We used tip-toe walking Yoshimura (twy) mice as an animal model of cervical OPLL. These mice exhibit ectopic calcification/ossification of various soft tissues, including ligaments in the upper cervical spine, which mimics the pathological conditions in human OPLL. Thirty twy mice aged 5 weeks were divided into three groups based on vitamin K intake. The control group received vitamin K from a normal diet; the vitamin K supplementation (VKS) group received a normal diet supplemented with an intraperitoneal injection of vitamin K2 (menaquinone-4; 50 mg/kg, twice a week); and the vitamin K deficiency (VKD) group received a gamma-irradiated vitamin K-deficient diet. The modulations of vitamin K intake were continued for 6 weeks. At the endpoint, a footprint analysis was conducted to assess locomotor functions, and the serum concentration of GRP was measured using an ELISA kit. The mice were then euthanized before undergoing imaging studies. Three-dimensional micro-computed tomography (3D micro-CT) was performed to quantify the volume of ectopic calcifications in the cervical spine. Immunostaining for GRP was conducted on paraffin-embedded mid-sagittal sections of the cervical spine. One-way ANOVA followed by Tukey's post-test was performed for group comparisons.

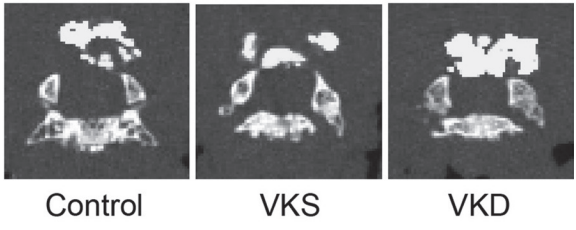
Results: The volume of ectopic calcification assessed by 3D micro-CT was significantly smaller in the VKD group than the other groups (Fig. 1). In the footprint analysis, the VKS group showed significantly longer stride lengths both in the fore- and hindlimbs compared with the other groups (Fig. 2). Serum GRP concentrations were significantly higher in the VKS group than the VKD group. Immunostaining for GRP revealed accumulation of GRP-positive cells in the vicinity of ectopic calcifications (Fig. 3). The VKD group had the least number of GRP-positive cells around the calcified lesions.

Conclusion: Vitamin K supplementation significantly reduced ectopic calcification of the cervical ligament and ameliorated locomotor impairment in twy mice. Vitamin K-supplemented mice also had increased levels of GRP both in serum and pathological tissue. These results indicate that GRP acts as a molecular link between vitamin K modulation and calcification/ossification of spinal ligaments. Vitamin K supplementation may be a novel therapeutic approach for patients with OPLL.

PAPER 78 continued

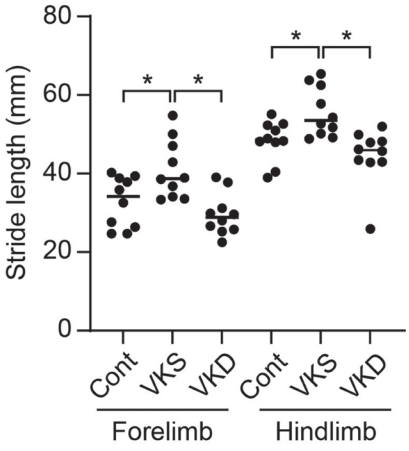
Fig. 1. Volume of ectopic calcification

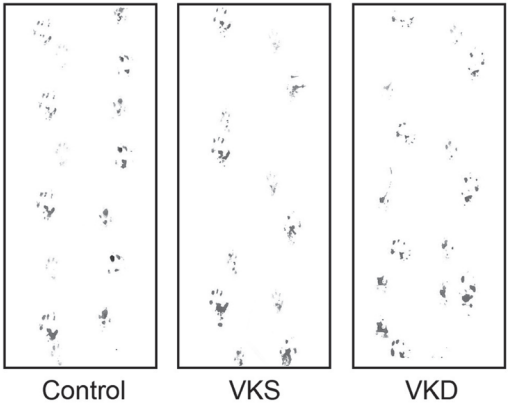




Ectopic calcification: yellow

Fig. 2. Footprint analysis

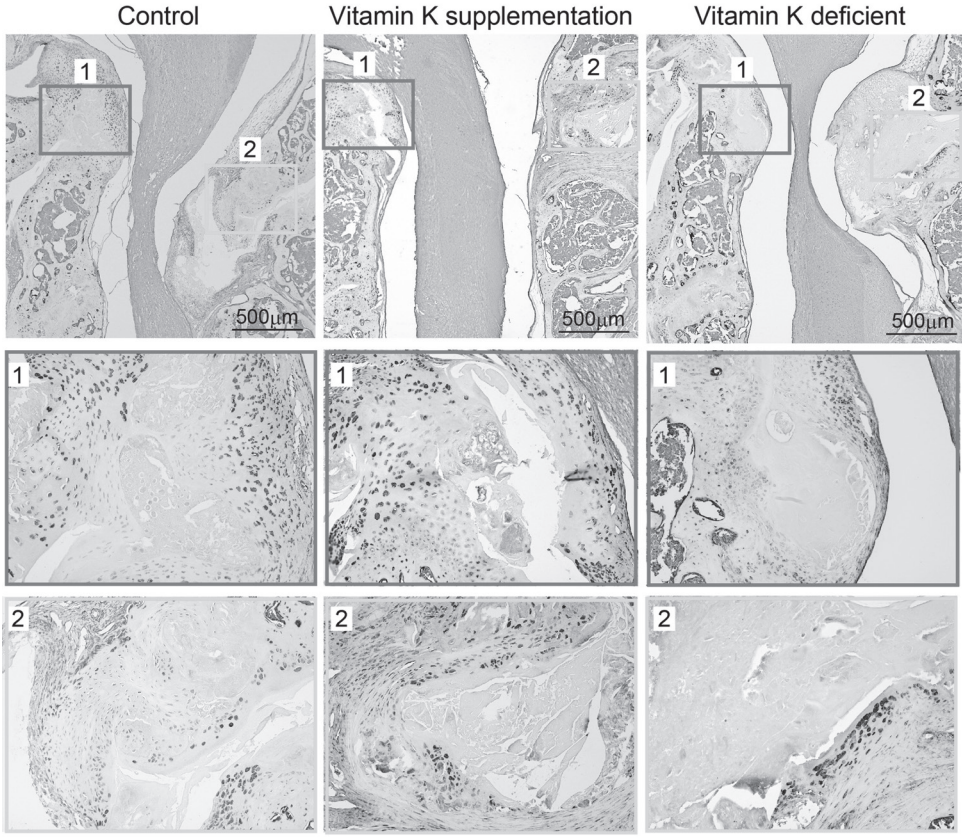




Green: forelimb prints, red: hindlimb prints

PAPER 78 continued

Fig. 3. Immunostaining for GRP



GRP: Brown, counterstained with hematoxylin

PAPER 79

Reducing Opioid Prescriptions for 707 Patients following Cervical Spine Surgery Using a Novel, Patient-Centric, Individualized Calculation Tool

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University of California, San Francisco[1] Medical College of Wisconsin[2]

Introduction: Opioids are commonly prescribed to patients postoperatively; however, data to inform appropriate opioid prescriptions following cervical spine surgery are still lacking. This study proposes a patient-centric, individualized opioid prescribing protocol that effectively reduces opioid usage in the outpatient settings following cervical spine surgery via increased physician awareness of individual patient pain management requirements.

Materials and Methods: A retrospective, observational analysis of 707 opioid-naïve, adult cervical spine surgery patients from June 2012 to December 2019 was conducted at a large, quaternary care institute. 227 (32%) patients underwent an anterior cervical spine surgery and 480 (68%) underwent a posterior cervical spine surgery. From 2012-2018, there was no standardized method for prescribing opioids in the inpatient or outpatient setting. However, in 2019, a new protocol was implemented whereby each patient's total opioid consumption in the 24 hours prior to discharge was standardized to oral morphine equivalents (OMEs). Discharge opioids were matched to inpatient 24-hour predischarge opioid usage. The effects of the intervention were assessed by stratifying patients into two cohorts of 2012-2018 and 2019. Efficacy of the opioid calculation tool was evaluated via outpatient opioid dosages and outpatient opioid refill rates.

Results: After the implementation of the novel opioid prescription strategy in 2018, there was an overall reduction in median daily discharge OME (90 vs. 60 OMEs, $p < 0.001$). In anterior surgery, inpatient and outpatient opioid doses did not significantly change following the implementation of the protocol ($p > 0.05$). However, for patients undergoing a posterior surgery, inpatient (60 vs. 45 OME, $p = 0.027$) and outpatient (90 vs. 60 OME, $p < 0.001$) opioid doses were reduced significantly following the implementation of the novel protocol. In multivariable analysis, reduced inpatient opioid requirement (OR 0.96 per 10-unit OME decrease, 95% CI 0.93-0.99), an anterior surgical approach (OR 0.62, 95% CI 0.42 – 0.89), reduced surgical case time (OR 0.83 per 1-hour decrease, 95% CI 0.71-0.97), and lack of inpatient gabapentinoid usage (OR 0.56, 95% CI 0.39-0.79) reduced the likelihood of outpatient opioid refills. Importantly, there was no increase in long-term (>30-day) outpatient opioid refills following the implementation of this protocol in 2019 ($p > 0.05$).

Conclusion: This study proposes an easy-to-use, individualized opioid prescription protocol for cervical spine patients that effectively manages acute postoperative pain. This protocol resulted in significantly reduced inpatient and outpatient opioid use for patients undergoing a posterior cervical spine surgery. A variety of factors, including an anterior surgical approach, are associated with a reduced risk of outpatient opioid refills. Utilizing this novel protocol to alert prescribers to individual opioid requirements may help reduce opioid prescriptions.

PAPER 80

Glutamate activates a proliferative and astrogliogenic program in spinal cord ependymal stem cells: implications for regenerative therapeutic translation

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Introduction: The adult spinal cord contains a population of multi-potent ependymal-derived neural stem/progenitor cells (epNSPCs) which are normally quiescent but are acutely activated to proliferate, differentiate, and migrate after cervical spinal cord injury (SCI). Once activated, epNSPCs serve as critical players in promoting endogenous regeneration and baseline functional recovery. However, activation of epNSPCs remains limited to the acute injury period and thus, strategies that harness their regenerative potential after subacute or chronic SCI hold great promise in enhancing endogenous repair and regeneration. A major barrier to unlocking the therapeutic benefits of epNSPCs has been a limited understanding of the mechanisms that regulate their activation in response to SCI. Recently, we discovered that excitotoxic levels of glutamate, a hallmark in the pathophysiology of acute SCI, promote epNSPC proliferation and survival *in vitro*. In this study, we characterize the downstream signaling pathways involved in this response and examine a therapeutic strategy targeting this mechanism to harness the endogenous regenerative capacity of the injured cervical spinal cord.

Materials and Methods: epNSPCs were isolated from the central canal region of the adult spinal cord, cultured, and treated with glutamate in the presence or absence of pharmacological inhibitors of glutamate receptors *in vitro*. Cell proliferation, differentiation and pathway analysis were conducted using a combination of immunohistochemistry, RNA sequencing and Western Blot. *In vivo*, cervical SCI was induced in adult rats using a clinically relevant compression-contusion model of SCI. One week post-SCI (subacute period), animals were randomized to receive one of the following treatments (n=7/group): 1) CX546 (a positive allosteric AMPA receptor modulator), or 2) vehicle control. Animals underwent weekly behavioural testing and spinal cords were extracted for histological analysis.

Results: Glutamate leads to calcium influx in spinal cord epNSPCs via AMPA receptors and this change in calcium in concert with Notch signaling serve to increase the proliferation of epNSPCs via phosphorylated CREB, and induce astrocytic cell fate specification through Hes1 upregulation *in vitro*. Furthermore, positive allosteric modulation of AMPA receptors subacutely after cervical SCI *in vivo* significantly enhances epNSPC proliferation, astrogliogenesis, increases neurotrophic factor production and promotes neuronal survival and early functional recovery.

Conclusion: Our study uncovers an important mechanism by which glutamatergic signaling via AMPA receptors alters the proliferation and phenotype of spinal cord epNSPCs. Pharmacological modulation of AMPA receptor signaling offers a novel and highly translational therapeutic strategy to regulate the fate of epNSPCs and harness their regenerative potential after cervical SCI.

PAPER 81

Assessing Correlations Between NASS Patient Satisfaction Index and Patient-Reported Outcomes (PROs) at 3-month, 12-month, and 24-month Timepoints in Patients Undergoing Cervical Spine Surgery Using the QOD Registry

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Introduction: In the era of value-based healthcare, it is increasingly important to understand and measure appropriate outcomes to accurately assess value. Tracked outcomes should therefore reflect the desires of patients undergoing those interventions. We thus sought to determine which patient reported outcomes (PROs) were most correlated with satisfaction in patients treated for cervical spondylotic myelopathy.

Materials and Methods: The Quality Outcomes Database (QOD), a prospectively collected multi-institutional database, was used to analyze demographic, PRO, and satisfaction data among patients undergoing surgery. We assessed North American Spine Society (NASS) satisfaction, Neck Disability Index (NDI), Visual analog scale for neck pain (NP-VAS) and arm pain (AP- VAS), EuroQoL-Visual Analog Scale (EQ-VAS), and modified Japanese Orthopedic Association (mJOA) at 3, 12, and 24 month follow up.

Results: 1141 patients were surgically treated for cervical spondylotic myelopathy. The average age was 60.5, 52.6% were male, 92.4% were non-Hispanic, average BMI was 30.2, and average length of stay was 2.1 days. All patients had an indication for surgery of myelopathy, of which 1107 (98%) also had an indication of neck pain, and 379 (33%) had an indication of radiculopathy. 785 (69%) had an anterior approach surgery, while 356 (31%) had a posterior approach.

At 3 month follow up, satisfaction was positively correlated with NP-VAS (R=0.298, p<.001), AP-VAS (R=0.315, p<.001), NDI (R=0.362, p <.001), and negatively correlated with EQ-VAS (R= -0.294, p<.001) and mJOA (R=-0.287, p <.001). At 12 month follow up, satisfaction was positively correlated with NP-VAS (R=0.442, p<.001), AP-VAS (R=0.384, p<.001), NDI (R=0.459, p <.001), and negatively correlated with EQ-VAS (R= -0.357, p<.001) and mJOA (R= -0.363, p <.001). At 24 month follow up, satisfaction was positively correlated with NP-VAS (R=0.490, p<.001), AP-VAS (R=0.358, p<.001), NDI (R=0.491, p <.001), and negatively correlated with EQ-VAS (R= -0.310, p<.001) and mJOA (R= -0.378, p <.001).

Conclusion: NDI was the PRO most correlated with patient satisfaction at 3, 12 and 24 month follow up. Among the PROs assessed, mJOA was the least correlated with patient satisfaction at 3 month follow up, whereas EQ-VAS was the least correlated with patient satisfaction at 12 and 24 month follow up. These findings may better guide outcome selection in patient follow up and help clinicians appropriately counsel patients on expected outcomes.

PAPER 82

Therapeutic effects of combined hiPSC-NS/PCs transplantation and rehabilitative training in chronic spinal cord injury.

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Keio University School of Medicine[1]

Introduction: Cell transplantation therapy using human-induced pluripotent stem cell-derived neural stem/progenitor cells (hiPSC-NS/PCs) is a new therapeutic strategy for spinal cord injury (SCI). The efficacy of hiPSC-NS/PCs transplantation was reported by a number of preclinical studies which targeted sub-acute phase as a timing of therapeutic intervention, but no functional recovery was observed when transplanted at chronic phase.

Rehabilitative training is another type of SCI therapy that should be considered as an important strategy for recovering motor function after SCI, and its effectiveness has been clinically proven. However, rehabilitative training was known to be less effective when applied in the chronic phase.

A combined therapy with hiPSC-NS/PCs transplantation and rehabilitative training is attracting attention as a therapeutic option for chronic SCI because they could produce synergistic effects. In this study, we investigated the therapeutic effect of the combined therapy of hiPSC-NS/PCs transplantation and rehabilitative training.

Materials and Methods: Contusive SCI was induced in NOD-SCID mice, and hiPSC-NS/PCs were transplanted into the injured spinal cord of mice at 49 days post injury. The animals were divided into the treadmill training (TMT (+)) group and the non-treadmill training (TMT (-)) group. After transplantation, the TMT (+) group was subjected to treadmill training based on the overload principles for 8 weeks. Hindlimb locomotor function of each animal was evaluated weekly using the Basso Mouse Scale (BMS) scores up to 105 days post injury. The rotarod test and quadrupedal gait analysis using the DigiGait system were also performed before sacrificing the animals. Their spinal cords were removed and used for histological analyses or protein quantifications by capillary electrophoresis.

Results: The survival rate of grafted hiPSC-NS/PCs was significantly larger in the TMT (+) group than in the TMT (-) group. Moreover, the cell differentiation assay of grafted hiPSC-NS/PCs revealed that the proportion of NeuN positive neurons were significantly higher in the TMT (+) group than in the TMT (-) group, and the axons of the engrafted neural cells extended widely from epicenter to rostral and caudal. At the lumber spinal cord, Syn1 positive area and 5HT positive fibers were increased in the TMT (+) group. Capillary electrophoresis revealed that expressions of BDNF and NT3 proteins in spinal cord tissue were significantly enhanced in the TMT (+) group.

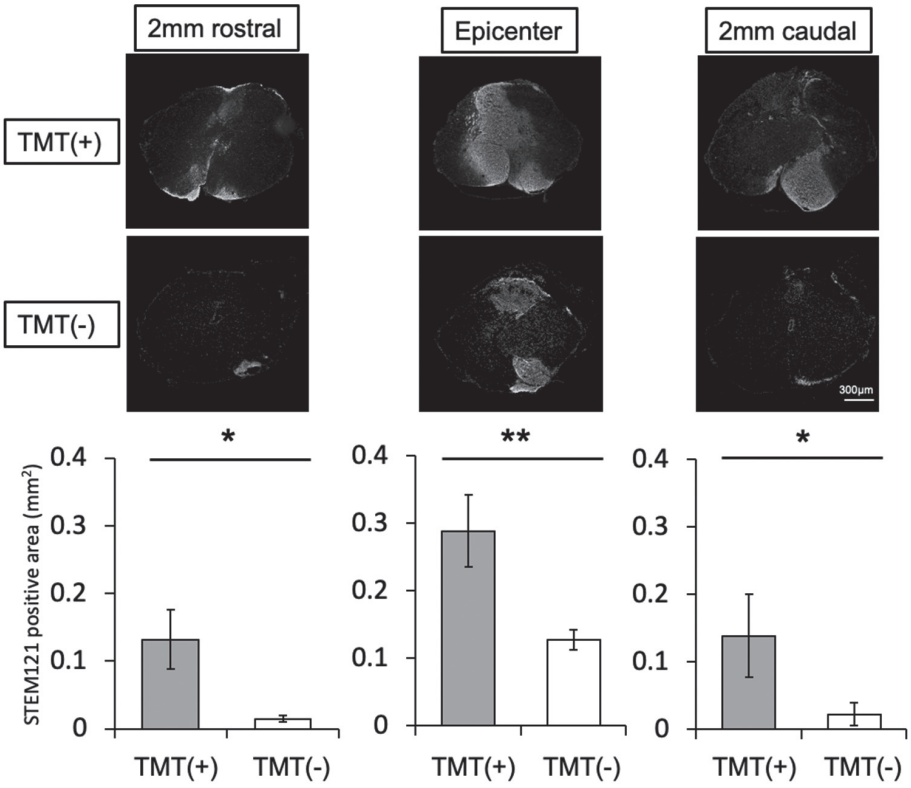
The BMS scores indicated significantly better recovery in the TMT (+) group than in the TMT (-) group. Quadrupedal gait analysis revealed that stride length and coordination of the limb pairs were improved in the TMT (+) group.

Conclusion: Rehabilitative training not only enhanced synaptic activity in the lumber spinal cord, but also promoted survival rate and neural differentiation of transplanted hiPSC-NS/

PAPER 82 continued

PCs. Consequently, motor functions significantly improved in the TMT (+) group. Therefore, a combined therapy of hiPSC-NS/PCs transplantation and rehabilitative training has the potential to promote functional recovery even when starting this intervention at chronic spinal cord injury.

Fig.1 Survival of grafted hiPSC-NS/PCs



PAPER 82 continued

Fig.2 Protein quantification of BDNF and NT-3

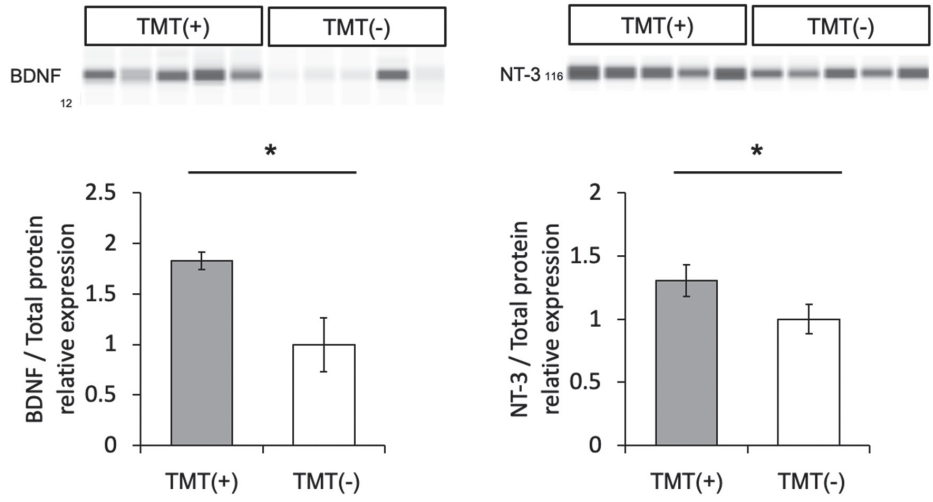
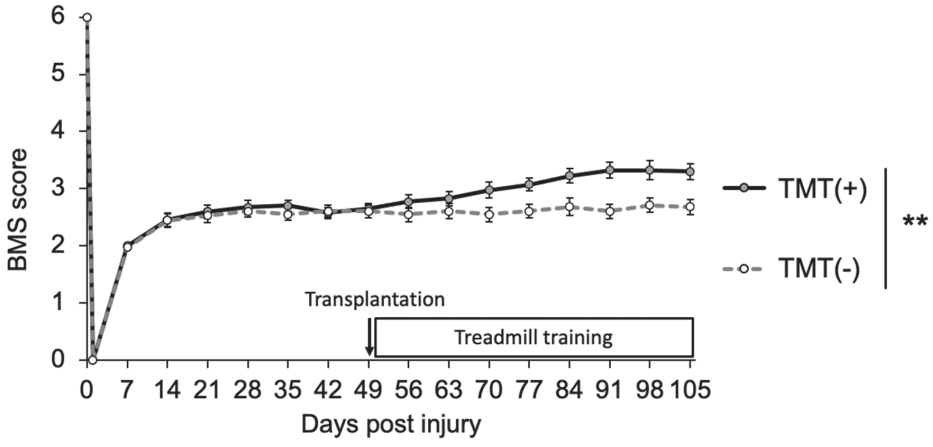


Fig.3 Time-course hindlimb locomotor rating



PAPER 83

The effect of posterior cervical laminoplasty with dome laminotomy on cervical alignment and disability in patients with cervical spondylotic myelopathy patients

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Introduction: Posterior cervical laminoplasty is an effective procedure that can induce multi-level decompression through posterior cord shifting. However, complications such as cord kinking, C5 palsy, and loss of sagittal alignment have also been reported after laminoplasty. To prevent static or dynamic kinking of the spinal cord, dome laminotomy at the upper and/or lower segments can be performed, however, the clinical and radiological results have not been reported yet.

Materials and Methods: For 155 patients who underwent posterior laminoplasty, the clinical and radiological parameters were analyzed. Open-door type laminoplasty was performed in all patients. The decision on the opening side of laminoplasty and whether dome laminotomy was needed was decided by the surgeon's decision in consideration of the degree of cord compression and the patient's symptoms.

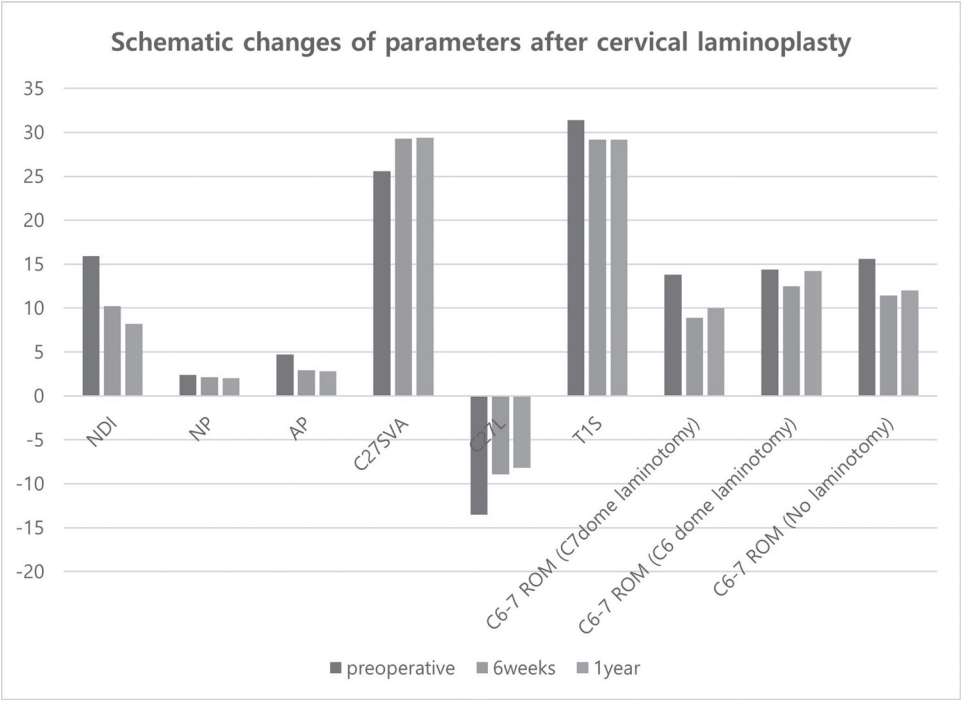
Results: Among 155 patients, the proportion of men who underwent laminoplasty (72.8%) was significantly higher than women (M: F= 113: 42, $p<0.05$). Compared to the preoperative period, at 6 weeks follow-up after laminoplasty, C2-C7 lordosis (C2-7L, -13.5° vs. -8.9°) and T1 slope (T1S, 31.4° vs. 29.2°) decreased and C2-7 sagittal vertical axis (C2-7SVA, 25.6 mm vs. 29.3 mm) was increased significantly ($p<0.01$). However, there was no statistical difference between all parameters from 6 weeks to 1 year (C2-7L: -8.9° vs. -8.2°, T1S: 29.2° vs. 29.2°, and C2-7 SVA: 29.3mm vs. 29.4mm). Neck pain did not differ between pre- and postoperative 6 weeks (2.4 vs. 2.1), however, decreased significantly at 1-year postoperative follow-up (2.4 vs. 2.0, $p<0.05$). The neck disability index decreased steadily from preoperatively to 6 weeks and 1-year postoperatively (15.7 vs. 10.2 vs. 8.4, $p<0.01$). Arm pain was significantly decreased at postoperative 6 weeks compared to preoperatively (4.7 vs. 2.9, $p<0.01$), and was maintained until postoperative1-year (2.9 vs. 2.8, Table 1).

Patients who underwent C2 dome laminotomy showed longer decompression levels than those without dome laminotomy (5.0 vs 3.7, $p<0.01$) and increased preoperative C2-7 SVA (30.5 mm vs. 21.1 mm, $p< 0.01$). However, C2-7 SVA did not differ at 1-year postoperatively (32.4mm vs. 30.6mm vs. 28.4mm vs. 25.7 mm, $p=0.16$) whether laminotomy was performed. Patients who underwent C7 dome laminotomy showed longer decompression levels than those without dome laminotomy (4.8 vs. 3.7, $p<0.01$), but there was no difference in preoperative C2-7 SVA and C6-7 segmental motion. However, in patients who underwent C7 laminotomy, C6-7 segmental motion significantly decreased at 6-weeks and 1-year after surgery (6 weeks: 8.9° vs. 11.4°; 1 year: 10.0° vs. 12.0°, $p<0.05$).

Conclusion: After laminoplasty, C2-7L and T1S decreased, and C2-7 SVA increased, however, clinical symptoms improved steadily. C2-7L, T1S, and C2-7SVA at 6-weeks postoperatively can be early parameters for predicting the cervical alignment at 1-year follow-up. Even though patients requiring C2 or C7 dome laminotomy showed longer decompression levels and an increased preoperative C27SVA, however, there was no additional C2-7 SVA loss. Therefore,

PAPER 83 continued

laminoplasty with dome laminotomy could be an effective procedure for inducing spinal cord decompression without additional loss of cervical sagittal alignment if being careful when performing C7 dome laminotomy for the further loss of segmental motion.



PAPER 83 continued

Table 1. Radiological and clinical results after posterior laminoplasty with additional upper dome laminotomy

	C3 total laminectomy (N=54)	C2 dome laminotomy (N=26)	C3 dome laminotomy (N=41)	No laminotomy (N=28)	p-value
Age	64.6	62.8	61.4	60.3	.394
No. of levels	**4.3**	**5.0**	**4.5**	**3.7**	**<.01**
Preop C2-7L (°)	-13.6	-12.7	-14.5	-11.3	.564
Postop C2-7L (6wks, °)	-7.6	-10.7	-10.1	-6.3	.238
Postop C2-7L (1yr, °)	-8.2	-5.4	-9.4	-7.8	.431
Preop C2-7 SVA (mm)	**28.5**	**30.5**	**23.7**	**21.1**	**<.01**
Postop C2-7 SVA (6wks, mm)	**33.9**	**31.7**	**26.2**	**24.6**	**<.01**
Postop C2-7 SVA (1yr, mm)	32.4	30.6	28.4	25.7	.164
Preop T1 slope (°)	**32.4**	**32.7**	**32.0**	**27.7**	**<.05**
Postop T1 slope (6wks, °)	29.5	32.0	29.0	26.7	.098
Postop T1 slope (1yr, °)	30.5	29.2	29.6	26.5	.253
Preop NP	2.6	3.0	2.3	2.1	.549
Postop NP (6wks)	2.4	1.7	2.5	1.7	.284
Postop NP (1yr)	2.1	2.0	1.7	2.1	.850
Preop NDI	14.8	16.3	16.7	15.9	.661
Postop NDI (6wks)	10.3	10.2	10.2	9.7	.990
Postop NDI (1yr)	8.9	9.5	8.5	5.8	.360
Preop AP	4.2	5.1	5.1	4.9	.267
Postop AP (6wks)	3.0	2.3	2.9	3.4	.484
Postop AP (1yr)	2.8	3.1	2.8	2.6	.939

C2-7L represents C2-C7 lordosis; SVA, sagittal vertical axis; ROM, range of motion; NDI, neck disability index; NP, neck pain; AP, arm pain.

PAPER 83 continued

Table 2. Radiological and clinical results after posterior laminoplasty with additional lower dome laminotomy

Parameters	C6 dome laminotomy (N=27)	C7 dome laminotomy (N=80)	No laminotomy (N=41)	p-value
Age	66.0	60.7	63.3	0.118
No. of levels	**4.3**	**4.8**	**3.7**	**<0.01**
Preop C2-7L (°)	-13.2	-13.3	-14.0	.932
Postop C2-7L (6wks, °)	-10.6	-9.0	-7.7	.517
Postop C2-7L (1yr, °)	-7.8	-8.9	-7.5	.727
Preop C6-7 ROM (°)	**14.4**	**13.8**	**15.6**	**.407**
Postop C6-7 ROM (6wks, °)	**12.5**	**8.9**	**11.4**	**<.05**
Postop C6-7 ROM (1yr, °)	**14.2**	**10.0**	**12.0**	**<.05**
Preop C2-7 SVA (mm)	23.5	25.6	25.8	.668
Postop C2-7 SVA (6wks, mm)	25.4	28.5	32.6	.083
Postop C2-7 SVA (1yr, mm)	28.0	29.0	31.0	.616
Preop T1 slope (°)	29.6	31.6	31.5	.474
Postop T1 slope (6wks, °)	28.9	28.9	29.9	.781
Postop T1 slope (1yr, °)	29.1	29.4	29.0	.955
Preop NP	2.5	2.4	2.3	.952
Postop NP (6wks)	1.6	2.1	2.3	.401
Postop NP (1yr)	1.7	2.3	1.7	.245
Preop NDI	16.5	15.6	14.9	.676
Postop NDI (6wks)	10.8	9.7	9.8	.800
Postop NDI (1yr)	8.3	8.1	8.0	.988
Preop AP	4.8	4.7	4.5	.842
Postop AP (6wks)	3.1	2.8	3.1	.786
Postop AP (1yr)	2.9	2.9	2.8	.949

C2-7L represents C2-C7 lordosis; SVA, sagittal vertical axis; ROM, range of motion; NDI, neck disability index; NP, neck pain; AP, arm pain.

PAPER 84

Long-Term Survivorship of Cervical Spine Procedures; a Survivorship Meta-Analysis and Meta-Regression

Mohamed Sarraj, MD[1], Phil Hache, MD, Colby Oitment, MD, Daipayan Guha, MD, Travis Marion, MD, Markian Pahuta, MD
McMaster University[1]

Introduction: Surgeons are increasingly recommending surgery to patients with degenerative conditions of the cervical spine. This is reflected in the fact that cervical surgery rates are accelerating in the United States and increased 206% between 1992 and 2005. Generally, surgical approaches to manage DCM and/or radiculopathy can be divided into anterior and posterior. Anterior approaches include anterior cervical discectomy and fusion (ACDF), and cervical disc replacement (CDR). Surgeries utilizing posterior approach include laminoplasty and posterior spinal instrumented fusion (PSIF). Though there are some indications and preferences for certain approaches over others depending on the pathology; the choice of implant is commonly dependent on surgeon preference. The purpose of this study was to synthesize available data on long-term survivorship for commonly performed cervical spine procedures and to compute summary survival curves for both second surgery at index level, and adjacent level surgery.

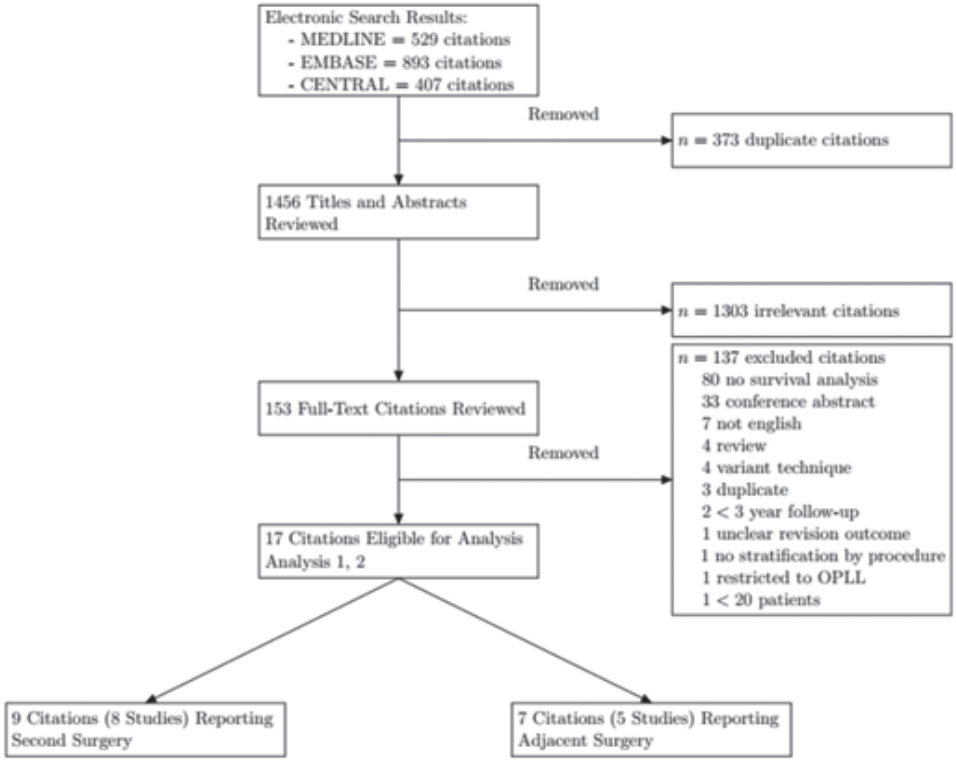
Materials and Methods: A systematic review of OVID MEDLINE, EMBASE, and CENTRAL databases was conducted following the PRISMA guidelines. Title, abstract, and full text screening was done in duplicate with Kappa scores used to measure agreement. Only articles with cohorts of greater than 20 patients followed for a minimum of 36 months and with available survival data were included. Procedures included were anterior cervical discectomy and fusion (ACDF), cervical disc replacement (CDR), laminoplasty and posterior laminectomy and fusion. Reconstructed individual patient data were pooled across studies using a Bayesian random-effects meta-regression. Survival curves were pooled using a fixed effect approach using the framework outlined by Ishak et. Al. We considered exponential, Weibull, Gompertz, Log-logistic, and Log-normal probability density functions in model building.

Results: Our search identified a total of 1456 citations after exclusion of duplicates. After a full text review of 156 titles, we included 20 studies including eight randomized controlled trials. Our analysis of second surgery included 49,950 ACDF, 357 CDR, 6,800 laminoplasty, and 16,704 PDIF patients. Our second analysis of adjacent segment surgery included 1,710 ACDF patients and 1148 CDR patients. Relative to ACDF, the risk of second surgery was higher with ADR and PDIF with acceleration factors 1.73 (95% CrI: 1.04, 2.80) and 1.35 (95% CrI: 1.25, 1.46) respectively. Relative to ACDF, the risk of second surgery was lower with laminoplasty with deceleration factor 0.06 (95% CrI: 0.05, 0.07). Despite statistically significant acceleration factors, survival estimates for ACDF, ADR and PDIF were not significantly different from each other, indicating a lack of clinical significance. CDR decreased the risk of adjacent level surgery with hazard ratio 0.43 (95% CrI: 0.33, 0.55).

Conclusion: This is the first quantitative synthesis of published data on the long-term survivorship of the most common surgeries for degenerative cervical spine pathologies. We found that CDR decreased the incidence of adjacent level surgery. We also found posterior laminectomy and fusion to have a significantly higher risk of secondary surgery when

PAPER 84 continued

compared to ventral approaches or posterior laminoplasty. In cases of clinical equipoise between fusion procedures, particularly between single or two level ACDF and posterior laminectomy and fusion, our analysis suggests superior survivorship with the anterior procedure.



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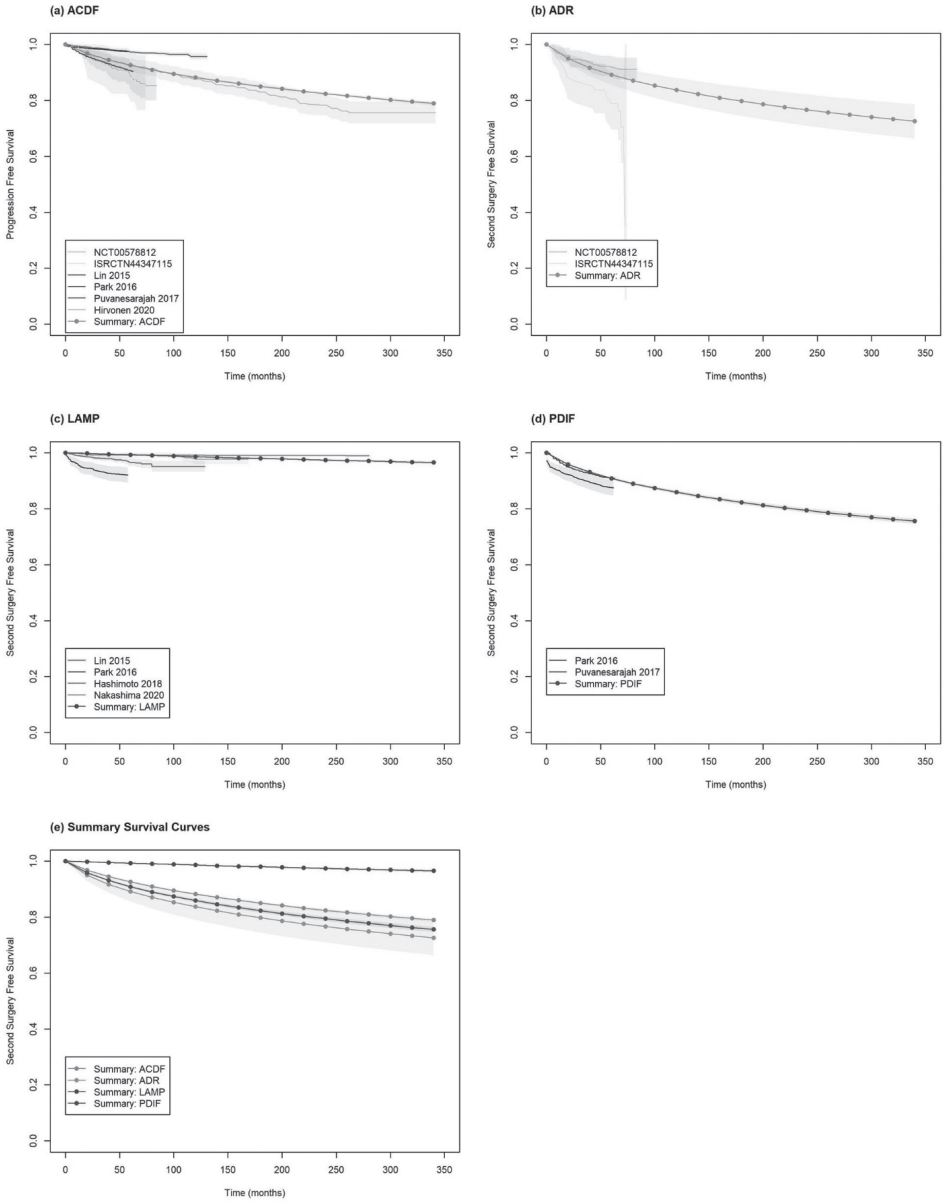

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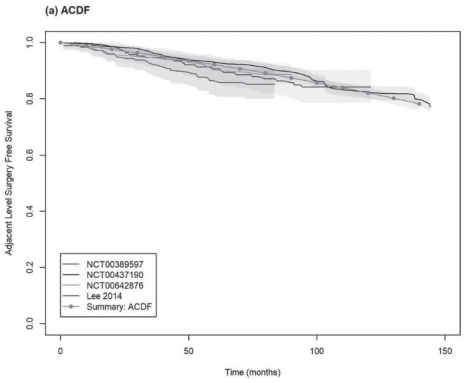
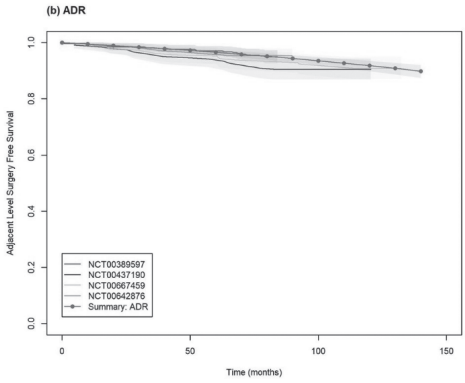
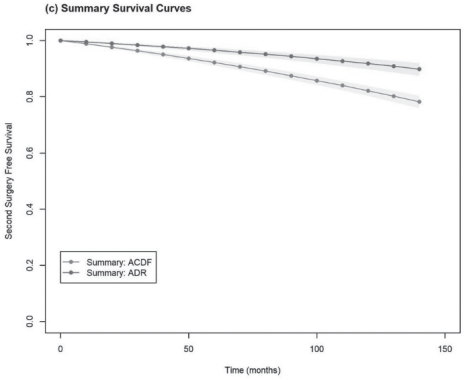






The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

E-POSTER 1

Comparison of Intraoperative Positioning with Mayfield Skull Clamp vs. Dual-Vector Cervical Traction with Gardener-Wells Tongs in Long-segment Posterior Cervical Fusion

Alysha Jamieson, BA, Saman Shabani, MD[1], Parishkrita Srivastava,, Kian Niknam, BS, Jeff Zheng,, Joshua Rivera, BA, Vivian Le, MPH, Nitin Agarwal, MD, Dean Chou, MD, Praveen Mummaneni, MD, Lee Tan, MD
Medical College of Wisconsin[1]

Introduction: Intraoperative positioning for posterior cervical fusion (PCF) surgery may have implications on cervical alignment and deformity correction. Two commonly used methods of cranial stabilization in PCF include Mayfield skull clamp versus dual-vector cervical traction with Gardener-Wells Tongs (GWT). However, there is a paucity of existing literature directly comparing the radiographic outcome of using GWT versus Mayfield skull clamp during PCF. In this retrospective study, we aim to determine the radiographic outcome differences between the Mayfield and GWT groups in the setting of long-segment posterior cervical fusion.

Materials and Methods: We reviewed all PCF cases performed by three senior authors (DC, PVM, LAT) between February 2012 and February 2020. Patients with prior history of a spinal tumor, infection, or trauma were excluded. All fusions crossed the cervicothoracic junction and included at least four levels. Patients were split into Mayfield and GWT groups based on which intraoperative cranial fixation method was used during surgery (Figure 1). Patient demographics and surgical details were recorded. Radiographic measurements were performed on pre- and post-operative standing, neutral lateral cervical x-rays for each patient including cervical sagittal vertical axis (cSVA), C2-7 cervical lordosis (CL), and T1 slope. Mann-Whitney U test and Fisher's Exact test were used for the continuous and binary variables, respectively.

Results: A total of 90 patients (M = 48, F = 42) met the inclusion criteria. 37 patients were in the GWT group, while 53 patients used Mayfield group. The mean age was 63.4 +/- 8.93 years. The demographic characteristic were similar between the two groups (Table 1). The preoperative T1 slope was the only pre-op radiographic measurement found to have a statistically significant difference with the GWT group having a higher mean preoperative T1 slope than Mayfield group (28.1 vs 22.7 degrees, p = 0.041). There was no statistically significant difference found in the postoperative, and change in cSVA, CL or T1 slope (Table 2). However, there was a trend of post-op T1 slope increase in the Mayfield group postoperatively by 4.4 +/- 8.4 degrees, while the T1 slope stayed relatively stable in GWT patients.

Conclusion: Intraoperative positioning with Mayfield skull clamp and dual-vector traction using GWT can achieve comparably similar cervical alignment for long-segment PCF crossing the CTJ.

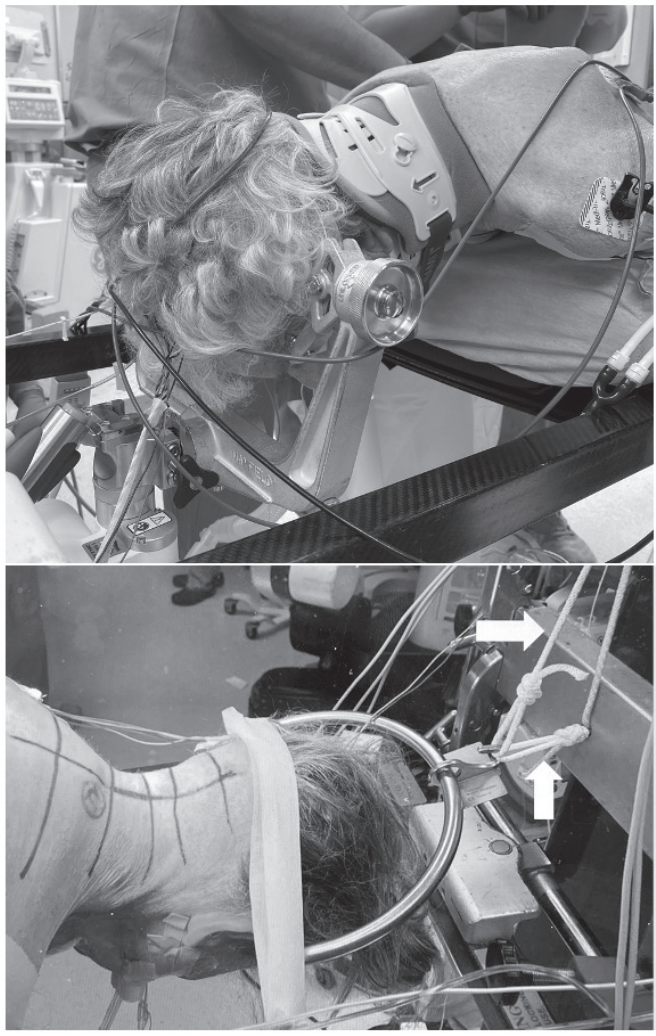
E-POSTER 1 continued

Figures

Figure 1. A representative case of long-segment PCF with intraoperative positioning using Mayfield skull clamp (A) and dual-vector traction using Gardner-Wells tongs (B).

A.

B.



E-POSTER 1 continued

Table 1: Demographic data for all included patients

Demographic	Gardner-Wells Tong	Mayfield Skull Clamp	Odds Ratio	p value
Total Number of Patients N	37	53	---	---
Sex (Male) (N, %)	17 (45.9%)	31 (58.5%)	0.835	0.829
Age at Surgery Mean (SD)	63.5 (8.4)	63.3 (9.3)	---	0.610
BMI Mean (SD)	26.8 (6.9)	28.3 (6.4)	---	0.203
Diabetes (N, %)	8 (21.6%)	13 (24.5%)	1.178	0.805
Coronary Artery Disease (N, %)	4 (10.8%)	6 (11.3%)	1.053	1
Anxiety (N, %)	11 (29.7%)	13 (24.5%)	0.768	0.583
Depression (N, %)	9 (24.3%)	18 (34.0%)	1.600	0.359
Arthritis (N, %)	3 (8.1%)	8 (15.1%)	2.015	0.515
Chronic Renal Disease (N, %)	2 (5.4%)	4 (7.6%)	1.428	1.000
Chronic Pulmonary Disease (N, %)	8 (21.6%)	8 (15.1%)	0.644	0.576
Osteoporosis (N, %)	2 (5.4%)	6 (11.3%)	2.234	0.463
Smoking History *(not current smoker, current some days, current everyday)*	29, 3, 5	49, 1, 3	0.142	Pearson chi2(2) = 3.9072

Table 1: Mann-Whitney U test was used for the continuous variables, and Fisher's Exact test was used for the binary variables. No significance was found for any demographic variables.

E-POSTER 1 continued

Table 2: Radiographic measurement analysis

Measurement	Gardner-Wells Tong [Mean (SD)]	Mayfield Skull Clamp [Mean (SD)]	Whitney U test	p-value
Pre-op cSVA	31.6 (15.0)	31.0 (15.6)	962.5	0.825
Post-op cSVA	40.5 (13.4)	36.9 (12.8)	1066.5	0.270
Delta cSVA	8.9 (12.6)	5.8 (15.1)	1021.5	0.471
Pre-op C2-7 CL	12.3 (10.6)	12.0 (10.5)	933.5	0.986
Post-op C2-7 CL	8.1 (10.6)	8.6 (6.8)	793	0.225
Delta C2-7 CL	-4.25 (11.7)	-3.3 (11.0)	821	0.331
Pre-op T1 slope	28.1 (12.2)	22.7 (9.2)	1177.5	**0.041**
Post-op T1 slope	29.0 (8.9)	27.1 (8.0)	1102	0.160
Delta T1 slope	0.83 (11.8)	4.4 (8.4)	821.5	0.333

Table 2: Mean and standard deviation were calculated for each measurement pre and postoperatively. The change in each measurement was calculated. Only preoperative T1 slope was found to be significant between GWT and Mayfield skull clamp.

E-POSTER 2

Atrophy of the Posterior Cricoarytenoid Muscle as an Indicator of a recurrent laryngeal nerve injury history before revision anterior cervical surgery

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Seoul Asan Hospital[1]

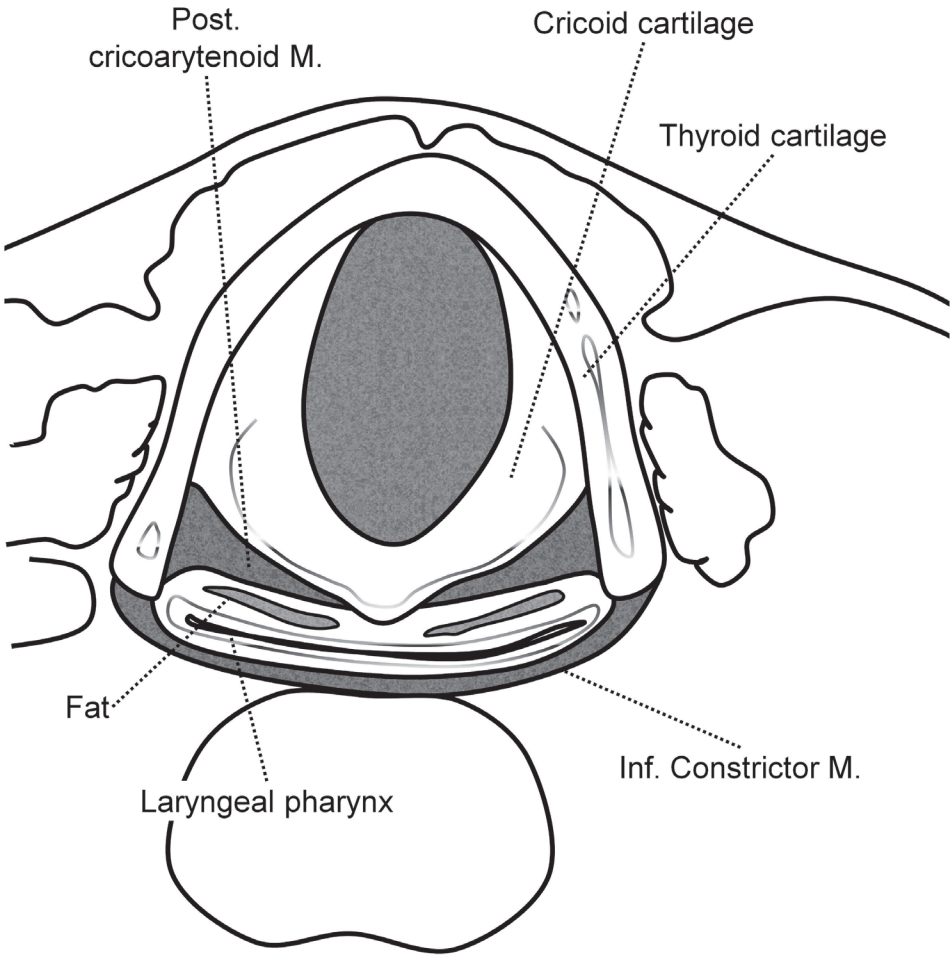
Introduction: Previous studies have reported that asymptomatic vocal cord palsy (VCP) arises in 8-10% of patients who have received a preoperative laryngoscopic screening before revision anterior cervical spine surgery (ACSS). We however in our recent another study observed more cases of symptomatic normal vocal cord motility than asymptomatic VCP in preoperative larynogoscopic examinations of a revision ACSS cohort. Therefore, we assumed that the intrinsic muscle atrophy caused by recurrent laryngeal nerve injury could cause vocal cord-related symptoms. Radiological examinations made prior to revision ACSS were reviewed in this present study in relation to the posterior cricoarytenoid (PCA) muscle, one of the intrinsic muscles.

Materials and Methods: We retrospectively analyzed 68 patients who underwent a revision ACSS for cervical pathology. Patients in this group with vocal cord-related symptoms were classified as a symptomatic group (group S, n=11), and those without symptoms as asymptomatic (group AS, n=57). The bilateral size and luminosity of the PCA muscles in these patients were measured in the axial view with a Picture Archiving and Communication System using preoperative vertebral arteriography computed tomography (CT) and magnetic resonance imaging (MRI) evaluations. Since the size and luminosity values were different on each image, the ratios of the ipsilateral and contralateral muscle values were determined for each modality.

Results: There was no abnormal findings of VCP on laryngoscopy study. However, the mean ratio of the PCA muscle size on CT was 1.40 ± 0.37 in group S and 1.02 ± 0.12 in group AS (P=0.007). These values on the MRI were 1.49 ± 0.45 in group S and 1.02 ± 0.14 in group AS, which was also a significant difference (P= 0.008). The PCA muscle luminosity on the MRI was 1.03 ± 0.16 in group S and 0.97 ± 0.18 in Group AS, which was not a significant difference (P=0.608).

Conclusion: Surgeons who are aimming to minimize the onset of complications, and select the most appropriate approach, when planning a revision ACSS needs to be cautious of any differences in the cricoarytenoid muscle between the two sides evident on a preoperative CT or MRI scan in patinets with a vocal cord related-symptom. This evidence may indicate a previous recurrent laryngeal nerve injury.

E-POSTER 2 continued



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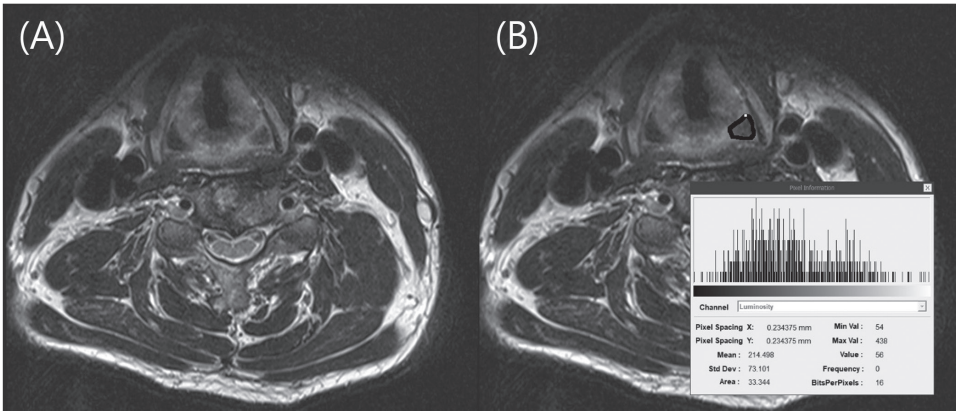

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E-POSTER 3

Preoperative Serum Calcium is Predictive of Postoperative Complications in Patients Undergoing PCDF

Anitesh Bajaj, BS[1], Rushmin Khazanchi, BA, Rohan Shah, BA, Steven Kurapaty, BS[2], Samuel Reyes, BS[1], Wellington Hsu, MD, Alpesh Patel, MD, MBA, FACS[2], Srikanth Divi, MD[3]
Feinberg School of Medicine[1] Northwestern University[2] Northwestern University Feinberg School of Medicine[3]

Introduction: Calcium and vitamin D are essential micronutrients with important roles in human bone physiology and maintenance.[1] As many as 43% of patients undergoing orthopaedic surgery may have hypovitaminosis D, which has been shown to be associated with increased odds of adverse events postoperatively.[2] Our understanding of the effects of serum calcium on perioperative outcomes is uncertain. This study aims to evaluate the effects of preoperative serum calcium and vitamin D levels on postoperative medical complications and the reutilization of healthcare resources in patients undergoing posterior cervical decompression and fusion (PCDF). A secondary intent is to identify specific calcium and vitamin D threshold values that predict poor postoperative outcomes following PCDF.

Materials and Methods: Patients ≥18 years who underwent PCDF from 2002 - 2021 were included in our study. Demographics, medical and surgical history, and preoperative serum vitamin D and calcium lab values within 3 months of surgery were recorded. Primary outcomes included major medical complications within 90 days (acute myocardial infarction, cardiac arrest, deep vein thrombosis, pulmonary embolism, respiratory distress, pneumonia, sepsis, and stroke), minor medical complications within 90 days (anemia, delirium, dysphagia, nausea, vomiting, and urinary retention), surgical site infections, 90-day readmissions, 90- and 365-day reoperation, and emergency department/urgent care utilization rates. Analyses were performed separately for vitamin D and calcium in a staged approach. Univariate analyses were performed using independent, two-tailed Welch's t-tests. Outcome variables significant on univariate analyses were then evaluated using multivariable binomial logistic regression. Receiver Operating Characteristic (ROC) curves were used to identify predictive cutoff values for outcomes of interest. Youden's Index was used to identify optimal cutoffs. ROC curves were assessed using Area under the ROC Curve (AUC) measurements and Mann Whitney U tests.

Results: A total of 775 patients with preoperative serum calcium levels and 276 individuals with vitamin D measurements were included (Table 1). Univariate analysis found significantly lower calcium levels in patients with major medical complications ($p=0.001$), minor medical complications ($p<0.001$), 90-day reoperations ($p=0.002$), and 90-day readmissions ($p=0.026$) (Table 2). Higher vitamin D levels were found in patients without 90-day reoperations ($p=0.003$). Using multivariate regression, each unit increase in calcium levels (mg/dL) yielded lower odds for major medical complications (OR: 0.730; 95% CI: 0.554 - 0.963, $p=0.026$), minor medical complications (OR: 0.712; CI: 0.561 - 0.904, $p=0.005$), and 90-day reoperations (OR: 0.355; 95% CI: 0.144 - 0.873, $p=0.024$). ROC curve analysis revealed serum calcium cutoffs of ≤9.2 mg/dL predictive of major medical complications (AUC: 0.58 ± 0.05, $p<0.001$), ≤8.8 mg/dL predictive of minor medical complications (AUC: 0.58 ± 0.04, $p<0.001$), and ≤9.0 mg/dL predictive of 90-day reoperations (AUC: 0.70 ± 0.14, $p=0.004$) (Figure 3).

Conclusion: A decrease in preoperative serum calcium levels independently predicted

E-POSTER 3 continued

increased odds of postoperative major and minor medical complications along with 90-day reoperations in a cohort of patients undergoing PCDF. Several cutoff laboratory calcium values were calculated to identify patients with increased perioperative risk for complications.

Table 1: PCDF Sample - Calcium and Vitamin D

Characteristic	Calcium, *N = 775*	Vitamin D, *N = 276*
Age	63.5 (13.2)**	53.9 (12.1)**
BMI	28.6 (7.7)**	28.5 (5.6)**
Gender:		
Male	441 (56.9%)	154 (55.8%)
Female	334 (43.1%)	122 (44.2%)
Fusion Type:		
Single Level	57 (7.4%)	14 (5.1%)
Multi Level	718 (92.6%)	262 (94.9%)
Serum Value	9.0 mg/dL (0.7)**	34.4 mg/dL (15.6)**
ASA Class:		
Class 1	9 (1.2%)	6 (1.3%)
Class 2	204 (26.3%)	215 (47.5%)
Class 3	510 (65.8%)	225 (49.7%)
Class 4	52 (6.7%)	7 (1.5%)

Values shown as N (%).
** denotes Mean (Standard Deviation)

E-POSTER 3 continued

Table 2: PCDF Univariate and Multivariate Results - Calcium and Vitamin D

Outcome Variable	Calcium			Vitamin D		
	Univariate	Multivariate		Univariate	Multivariate	
	P-value	Adjusted OR (95% CI)	P-value	P-value	Adjusted OR (95% CI)	P-value
ED/UC Visit	0.648	–	–	0.833	–	–
Major Medical Complication	0.001*	0.730 (0.554, 0.963)	0.026*	0.051	–	–
Minor Medical Complication	<0.001*	0.712 (0.561, 0.904)	0.005*	0.644	–	–
Surgical Site Infection	0.389	–	–	0.783	–	–
Reoperation:						
within 90 days	0.002*	0.355 (0.144, 0.873)	0.024*	0.003*	0.336 (0.000, inf)	1.000
within 1 year	0.235	–	–	0.162	–	–
Readmission within 90 days	0.026*	0.803 (0.579, 1.081)	0.148	0.674	–	–

* denotes statistical significance as defined by p<0.05.
Abbreviations: Emergency Department (ED), Urgent Care (UC)

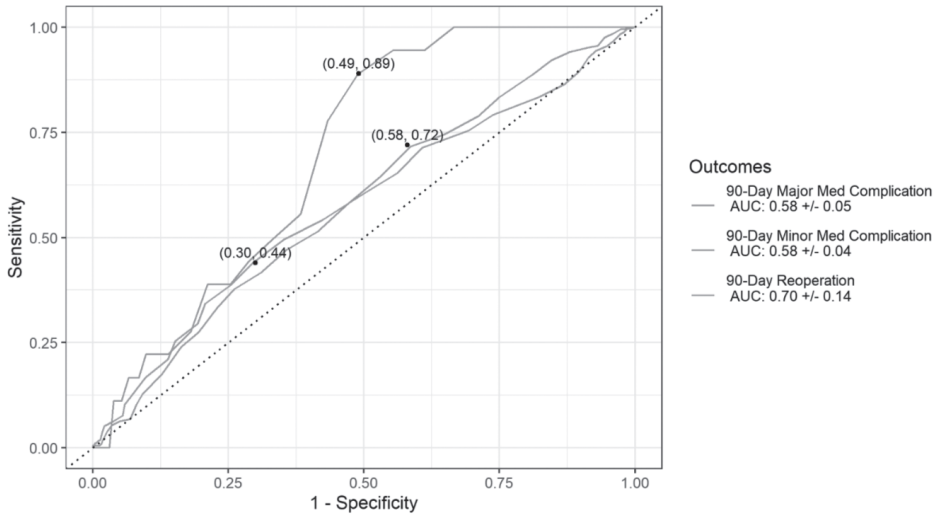

Figure 3. Receiver Operating Characteristic Curves for Predicting Medical Complications and Postoperative Healthcare Utilization Using Preoperative Calcium Levels. The AUC for 90-day major medical complications was 0.58 with an optimal cutoff value of 9.2 mg/dL. The AUC for minor medical complications was 0.58 with an optimal cutoff value of 8.8 mg/dL. The AUC for 90-day reoperations was 0.70 and the optimal cutoff value was 9.0 mg/dL.

Abbreviations: AUC: Area Under the ROC Curve

E-POSTER 4

Brain imaging using resting-state functional magnetic resonance imaging (rs-fMRI) can predict electrophysiological dysfunction in degenerative cervical myelopathy (DCM) as a functional brain biomarker.

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Yamaguchi university Orthopedics[1] Orthopedic Surgery, Yamaguchi University[2]

Introduction: Degenerative cervical myelopathy (DCM) is a spectrum of disorders that involve extrinsic spinal cord compression leading to neurologic dysfunction. The symptoms of DCM are broad and includes multiple conditions that can cause and mimic myelopathy. Previous studies reported that accurate assessment of neurological severity of DCM by conventional magnetic resonance imaging (MRI) is still difficult. Meanwhile, resting-state function MRI (rs-fMRI) and functional connectivity (FC) analysis have recently gathered much attention as a tool to evaluate functional brain alterations in patients with neurological diseases. In this study, therefore, to evaluate the possibility that they can assess the neurological severity of DCM, we investigated the relationship between FC strength and electrophysiological features of DCM, that is, latencies of motor evoked potentials (MEPs) and amplitudes of somatosensory evoked potentials (SEPs).

Materials and Methods: Preoperative 34 patients with DCM and 21 age- and sex-matched healthy controls (HCs) underwent a 30-min rs-fMRI scan (Table 1). MRI scans were performed using a 3T MRI (Siemens MAGNETOM Prisma). Participants were simply instructed to rest with their eyes opened, look at one point, not think of anything, and not fall asleep during an rs-fMRI scan. We performed fractional amplitude of low-frequency fluctuations (fALFF) and FC analysis to detect differences in the strength and synchronicity of spontaneous brain activity between patients with DCM and HCs. Moreover, we performed a multiple regression analysis to investigate the relationship between FC strengths and latency of MEPs or SEP amplitudes in patients with DCM. Stimulation of SEPs was delivered to the posterior tibial nerve at the ankle. The scalp recording electrode was placed at the Cz with a reference electrode located. Motor-evoked potentials (MEPs) were recorded from bilateral abductor digit minim and abductor halluces muscles. Transcranial magnetic stimulation was delivered with a circular coil having an outer diameter of 140 mm.

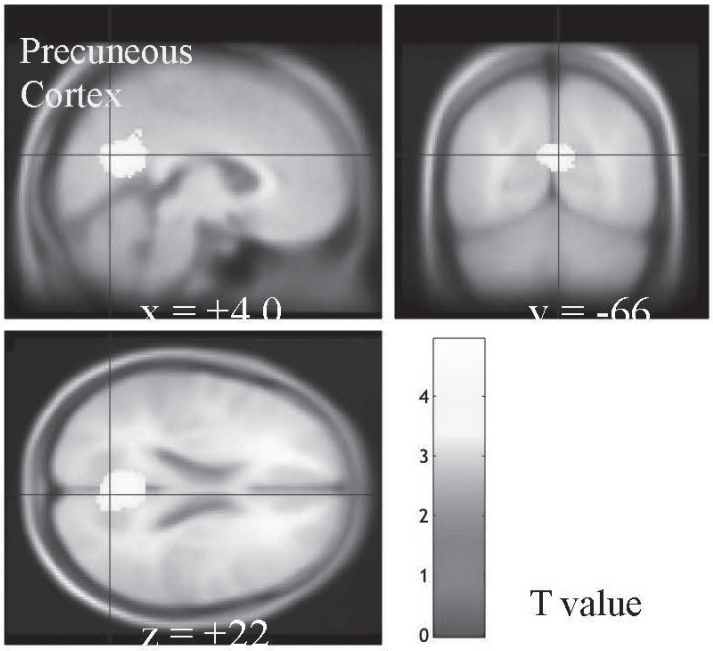
Results: fALFF analysis revealed that spontaneous activity strength in the occipital cortex differed between patients with DCM and HCs. FC analysis showed that FC between the primary motor cortex and the precuneus in patients with DCM were significantly stronger. The strength of this FC significantly correlated with the latency of MEPs relating to the motor disability (Fig 1). Furthermore, FC between the sensorimotor cortex and the lateral occipital cortex was significantly stronger in patients with DCM, and the strength of this FC significantly correlated with SEPs amplitude relating to the sensory disability (Fig 2).

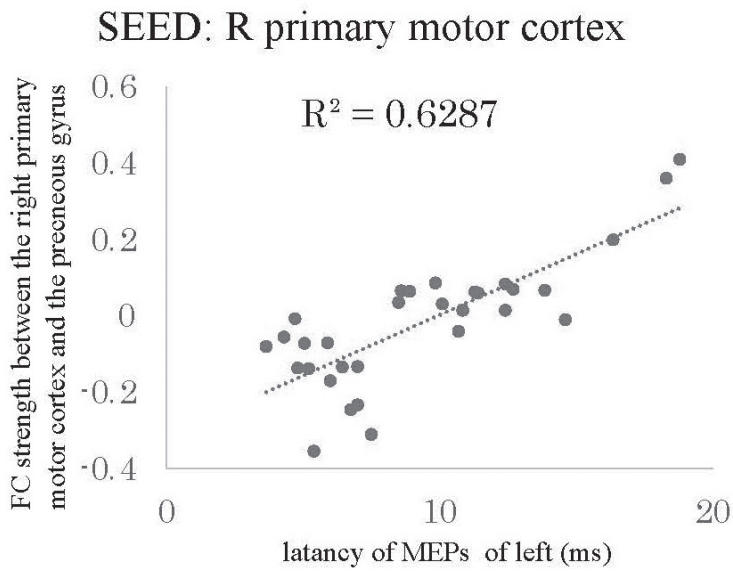
Conclusion: We demonstrated that several FC strengths correlated with electrophysiological measures of severity of DCM in preoperative patients with DCM. Even though our findings are preliminary, they suggest that rs-fMRI and FC analysis is a promising approach to evaluate the neurological severity of DCM.

E-POSTER 4 continued

Variable	DCM	HC
Participants	34	21
Sex (m/f)	23/11	14/7
Age, years	66 ± 12	66 ±9.5
Handedness (right/left)	30/0	21/0
Medication		
NSAIDs	12	0
Pregabalin	6	0
Tramadol/acetaminophen	5	0
Sedative-hypnotics	0	NA
Disease duration (month)	27.0±38.6 (1-180)	NA

E-POSTER 4 continued





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Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

E-POSTER 5

Comparison between the bone union rates using auto-iliac bone and bone morphogenetic protein without auto bone in a posterior atlantoaxial fusion procedure: Results from a minimum 1-year follow-up

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Seoul Asan Hospital[1]

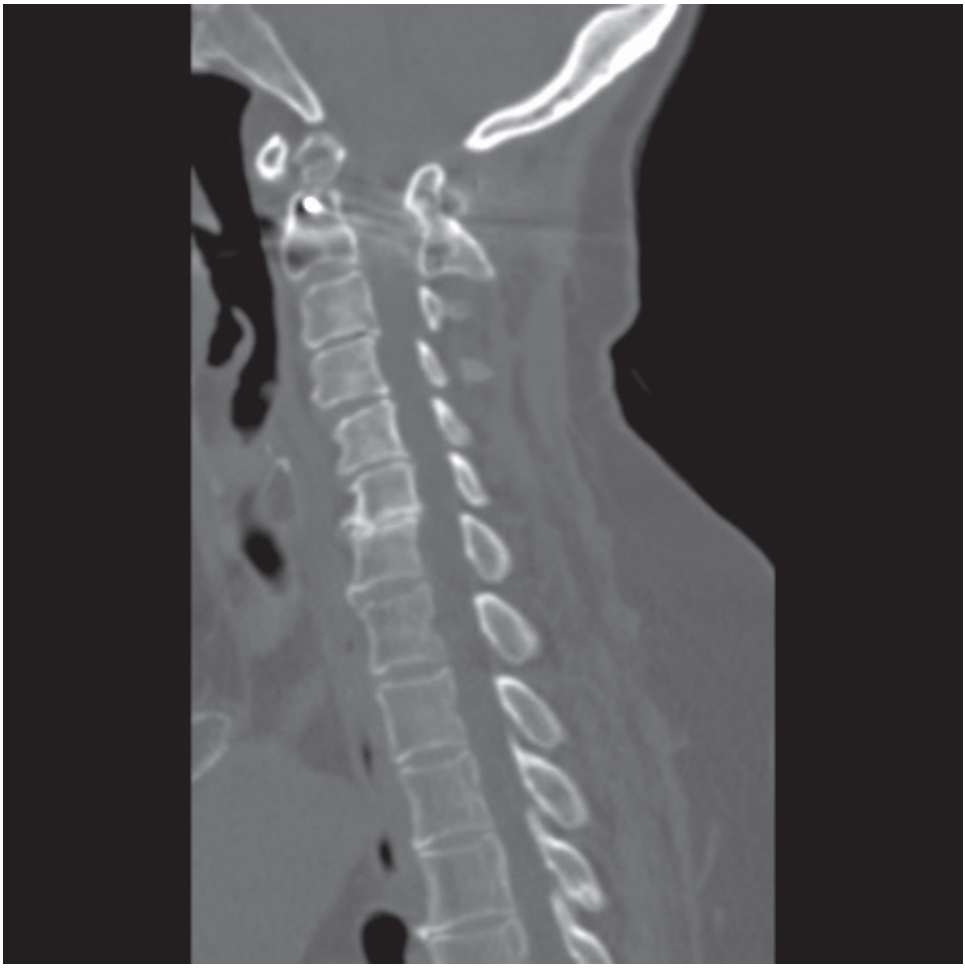
Introduction: Traditionally, auto-iliac bone has traditionally been the gold standard for bone grafting in spinal fusion but has been replaced recently by recombinant human bone morphogenetic protein-2 (rhBMP-2) in several operations. Atlantoaxial bone fusions are challenging due to the biomechanical stress that arises at this level. Therefore, some concerns have been raised regarding bone fusion using rhBMP-2 without auto bone in a posterior atlantoaxial fusion procedure. This study was conduct to 1) compare the bone union rates achieved with an auto-iliac bone graft and rhBMP-2 without auto bone 2) check to potential advantage and disadvantage of rhBMP-2 as bone graft material in posterior atlantoaxial fusion procedures.

Materials and Methods: The study included 103 patients who underwent a posterior atlantoaxial fusion due to a C1-2 pathology. As bone graft material, using an auto-iliac bone graft were assigned to the iliac bone graft group (group I, n=68), while cases involving rhBMP-2 without auto bone were assigned to a rhBMP-2 group (group B, n=35). We evaluated the bone unions in these cases using postoperative 1-year dynamic radiographs (flexion and extension position) and computed tomography(CT). To check atlantoaxial bone fusion, we analyzed pseudomotion in postoperative dynamic radiographs and bone bridge formation, facet joint fusion, and metal loosening in postoperative CT, respectively. Additionally, we analyzed and compared the demographic, operative, and clinical factors between the two groups of patients.

Results: No significant differences were evident between the bone union rates using 1-year dynamic radiographs in group I and B (66/68, 97.0%, vs 34/35, 97.1%, respectively; P=1.000). However, the bone union rates using 1-year CT in group I is higher than group B (59/68, 86.7% vs 18/35, 51.4%, repectively; P<0.001). Additionally, the operation time is longer in group I than group B (189.4±39.0 min vs 102.6±20.9 min, p<0.001). And, the hospital stay length also is longer in group I than group B (9.8±4.1 vs 7.7±4.8, p=0.048) . A persistent pain at the graft site during at 1 year was reported in 20.6% (14/68) of patients in group I. Although clinical outcomes improved postoperatively in both group, no inter-group differences were observed.

Conclusion: There was no significant difference in the bone union rate on dynamic radiographs between two auto-iliac bone graft and rhBMP-2 without auto bone. Additionally, there was no differnece in the clinical outcomes. Considering the advantages including decreased operative times, shorter hospital stay and donor site morbidity, rhBMP-2 has advantages as grafting choice for posterior atlantoaxial fusion procedure. But, this study also demonstrated that definite bone bridge formation and facet joint fusion on postoperative CT were lessly checked in the rhBMP-2 without auto bone group. Therefore, a long term follow-up is also required in posterior atalntoaxial bone fusion using rhBMP-2 without auto bone.

E-POSTER 5 continued



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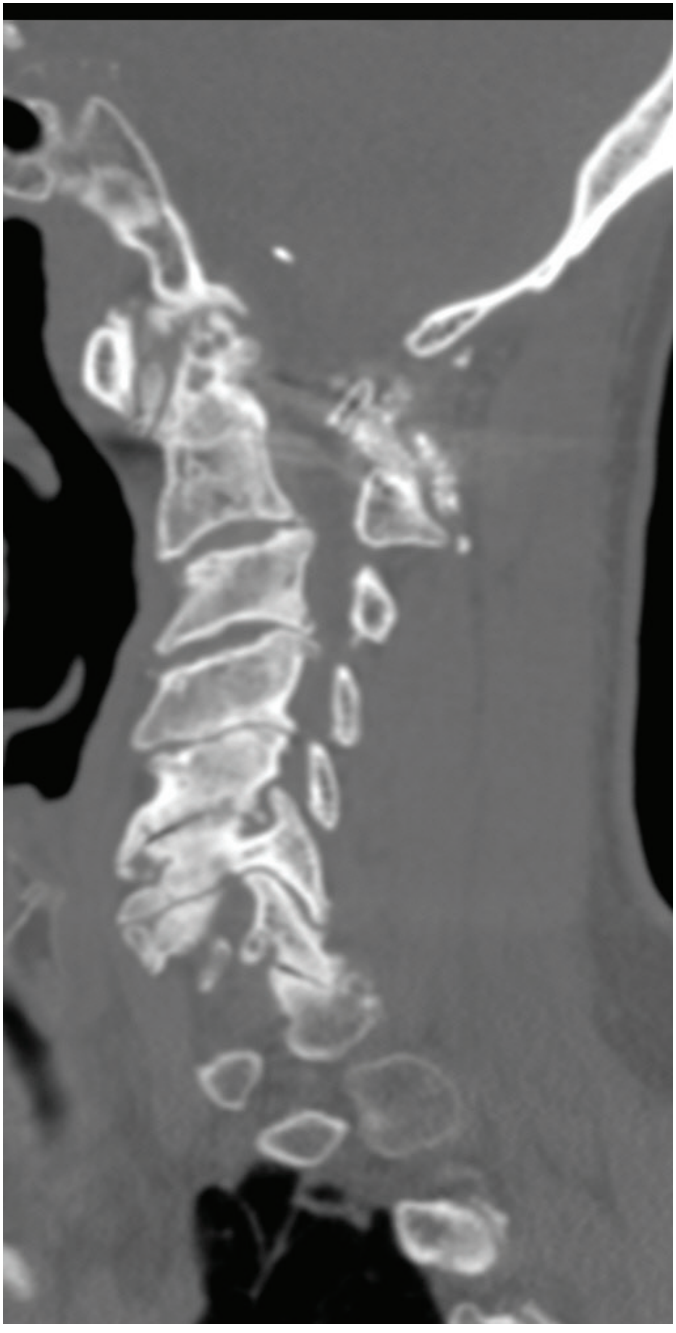

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

E-POSTER 6

A Clinical Prediction Rule for Upper Limb Functional Outcomes after Traumatic Cervical Spinal Cord Injury

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Washington University School of Medicine[1] Washington University in St. Louis[2]

Introduction: Traumatic cervical spinal cord injury (SCI) can result in debilitating paralysis. Recovery of upper limb function can have a profound impact on patients' quality-of-life.[1] SCI results in time-dependent degeneration of the nerves/muscles. Various reconstructive therapies i.e., nerve transfers are time-sensitive such that earlier surgeries (within 12 months of SCI) have better treatment outcomes.[2] Following cervical SCI, early prediction of upper extremity function is important to counsel patients and plan for reconstructive therapies.[3] Our objective with this study was to develop a simple and clinically applicable prediction rule to prognosticate upper limb functional recovery after cervical SCI.

Materials and Methods: A longitudinal cohort of traumatic cervical SCI patients admitted to one of 29 North American centers in SCI model systems (SCIMS) from 2011 to 2016 was included.[4] Eligible patients were >=15 years of age with tetraplegia (neurological level of injury C2-C8, American Spinal Injury Association [ASIA] grade A-D), with early (within one-month of SCI) and late (1-year follow-up) clinical examinations.[3] The primary outcome was the composite of dependency in major activities of daily living (ADLs) including mobility, transfers, eating, and bladder management measured by functional independence measure. Data were split into training (2011-2014) and testing (2015-2016) cohorts. Multivariable logistic regression was used to predict the outcome based on early neurological variables. Discrimination was quantified using the c-statistic [AUC] and model performance was internally validated with 10-fold cross-validation. The training cohort was used to derive the prediction score and the testing cohort was used for temporal validation. The AUC of the prediction score was compared with the current gold standard (i.e., ASIA grading).

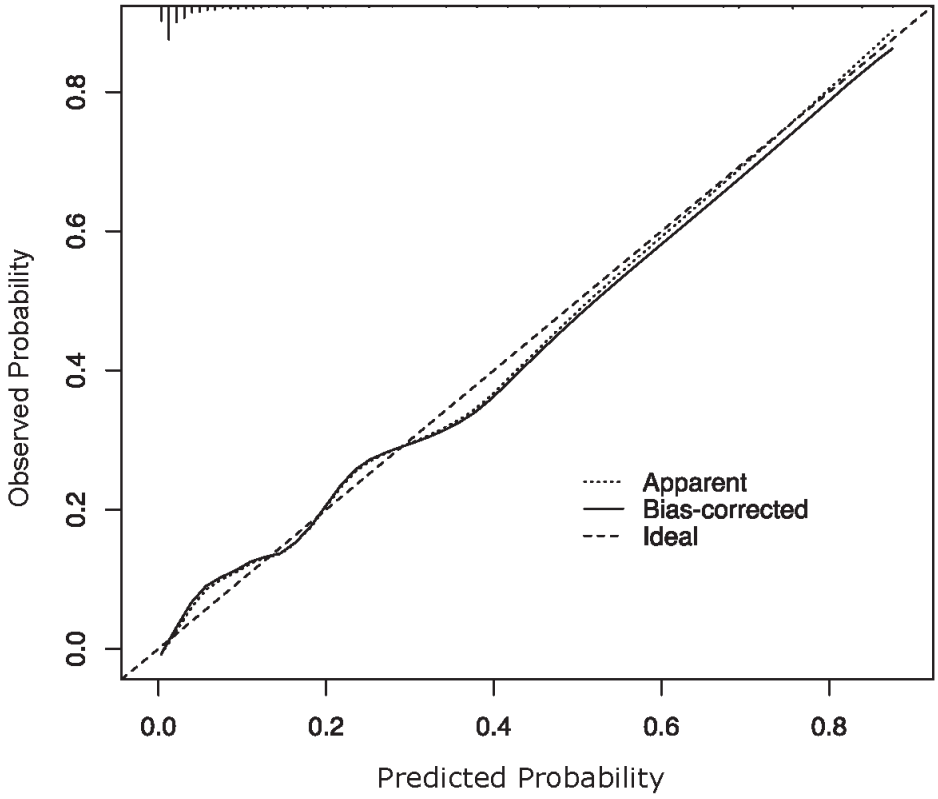
Results: Among 14,780 traumatic cervical SCI patients, 940 had complete one-year outcome data. 133 (14%) patients had primary outcome (dependency in ADLs) at 1-year follow-up. Dependent patients had complete SCI (ASIA A-B) in 78% as compared to 35% in independent patients ($p<0.001$). The variables significantly associated with the outcome were age (>60 ***vs.*** <60 years), sex, surgical-decompression after SCI, light touch sensation at C5 and C8 dermatomes (absent: 0, impaired: 1, normal: 2), and motor scores of the elbow flexors (C5) and wrist extensors (C6) (manual motor testing grades 0-5). A multivariate model including age, sex, surgical-decompression, and these four neurological tests had excellent discrimination in distinguishing dependent tetraplegic patients from independent patients at one year (bias-corrected c-statistic: 0.90, 95% CI, 0.88-0.93) with good calibration **(**Figure 1). A clinical prediction score ranging from 0 to 47 points was developed based on these measures, with higher scores increasing the risk of dependency (Figure 2). The training cohort had a median SCI-score of 12 (IQR: 5-23). The negative predictive value of a cut-off of 21 points in score was 98% (95% CI, 96%-99%). The discrimination of the prediction score was significantly higher (change in AUC: 0.14, $p<0.001$, 95% CI, 0.10-0.18) than the ASIA grading (Figure 3).

Conclusion: This data-driven prediction rule may help prognosticate an individual's ability to

E-POSTER 6 continued

perform ADLs independently following cervical SCI. This prognostic tool can be used to set patient expectations, rehabilitation goals, and inform plans for time-sensitive reconstructive surgeries.

Calibration plot showing observed *vs.* predicted probability of composite dependency in ADL



E-POSTER 6 continued

A Point values for each variable

Age	Points
≤ 60	0
≥ 60	4

Sex	Points
Men	0
Women	2

Spinal surgery	Points
Yes	0
No	2

C5 motor score	Points
0	10
1	8
2	6
3	4
4	2
5	0

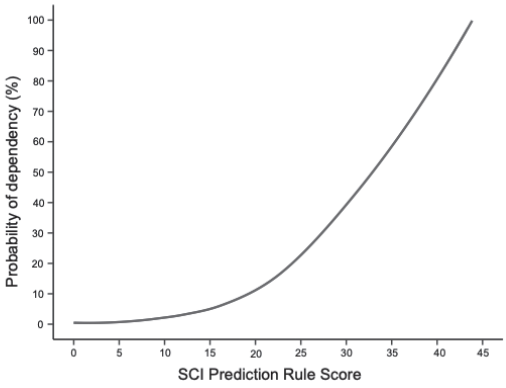
C5 light touch	Points
0	4
1	2
2	0

C8 light touch	Points
0	10
1	5
2	0

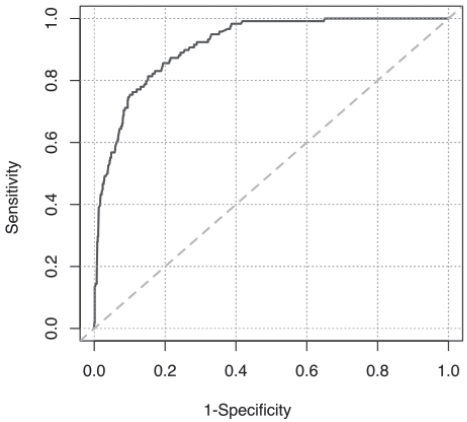
C6 motor score	Points
0	15
1	12
2	9
3	6
4	3
5	0

Sum of points	
Age	+
Sex	+
Spinal Surgery	+
C5 light touch	+
C8 light touch	+
C5 motor score	+
C6 motor score	+
Total Score =	

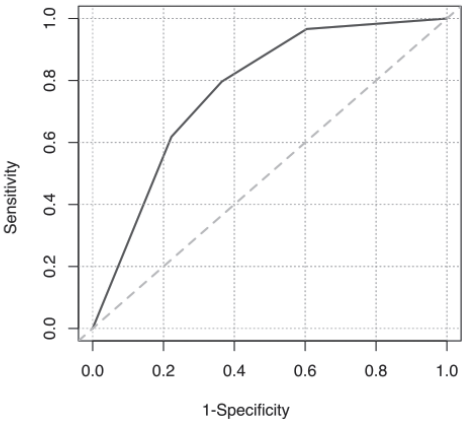
B Probability of dependency based on prediction score



A ROC curve for SCI prediction rule



B ROC curve for ASIA grading system



E-POSTER 7

Factors Influencing the Development of and Recovery from C5 Palsy

Nicholas O'Malley, BS, Zoran Budimlija, DrMed, PhD, Aleksandar Berić, MD, PhD, Athena Lollis, MD, Anna Shor, MD, Sinthema Roy, BS, Carolyn Stickley, BS, Robert Brenner, MD, Nikolas Baksh, MD, Constance Maglaras, PhD, Tina Raman, MD

Introduction: C5 palsy is a serious and pervasive sequela of cervical spine surgery. Currently, there is a dearth of literature detailing risk factors for developing C5 palsy or factors influencing recovery from this debilitating condition.

Materials and Methods: This was a single center retrospective cohort review of patients undergoing cervical spine surgery from 2012-2019. Included patients were greater than or equal to 18 years of age, underwent cervical spinal surgery including the C4/C5 level, and had minimum 2 years follow-up (F/U). C5 palsy was defined as deltoid +/- bicep weakness with Modified Rankin Score grading at least 1 point below baseline (BL). Characteristics studied included demographics, surgical procedure and approach (anterior/posterior, decompression and/or fusion). Radiographic analysis and MRI and CT measurements of foramen dimensions and spinal cord drift at BL and F/U were performed. Intraoperative Neuro-monitoring data (IONM) was collected including differences in Somatosensory Evoked Potential (SSEP) amplitude and latency. In addition all events where latency was above >10% of BL, and amplitude was within 75-100% of BL, 50-75% of BL, and <50% of BL, and when amplitude or latency were "not recorded" were tracked. Finally, factors influencing recovery were defined as muscle relaxer use, steroid use, discharge to acute rehab, and use of physical therapy (PT). Statistical analysis included t-tests, chi-square analysis. Significance set at $p<0.05$.

Results: 232 patients met inclusion, revealing a 6.7% rate of C5 Palsy development. Those who developed C5 Palsy were significantly older, had more levels fused, more levels decompressed. Analysis of IONM data showed that pts who developed C5 palsy had significantly larger differences in Right Median amplitude, Left Median amplitude, and Left Ulnar amplitude. No differences were noted in BMI, Op time, EBL, gender, smoking status, or inclusion of ACDF approach (Table 1). No differences in instances where latency or amplitude fell into defined IONM thresholds were noted.

Among the 15 pts who developed C5 palsy, 14 (93.33%) had recovered within 2 years, and had a mean time to recovery of 210.07±139.50 days. Regarding IONM data, the mode of R Median amplitude change was 1.48 μV, the mode of L Median amplitude change was 1.27 μV, and the mode of L Ulnar amplitude change was 0.41μV. No differences in recovery time were noted in pts who used steroids, muscle relaxers, were discharged to acute rehab, or went to PT.

Conclusion: The addition of IONM data provides new insight into the development of C5 Palsy. Namely, larger fluctuations in Median n. amplitude intraoperatively, on average 1.56 μV on the right and 1.20 μV on the left, were associated with the development of C5 palsy. This analysis on amplitude demonstrates that there is potential for intraoperative monitoring to detect irritation or possibly injury to the C5 nerve root during surgery. The vast majority of patients recover within 1 year and there is no defined treatment protocol that hastened recovery time.

E-POSTER 7 continued

Table 1. Comparison of Demographic, Intraoperative, IONM, and Radiographic Data in Patients with and without C5 Palsy

			N	Mean	Std. Dev	p
Demographics	Age (yr)	C5 Palsy	15	64.67	8.61	**0.016**
		No	216	57.32	11.52	
	BMI (kg/m2)	C5 Palsy	15	28.57	4.97	0.739
		No	216	29.10	6.00	
	Gender (% female)	C5 Palsy	41			1.00
		No	40			
	Smoking Status (% smokers)	C5 Palsy	18			0.170
		No	33			
Intraoperative	Levels Fused	C5 Palsy	15	4.27	1.10	**0.003**
		No	216	3.10	1.47	
	Levels Decompressed	C5 Palsy	12	4.00	0.85	**0.011**
		No	216	3.20	1.25	
	Op Time (min)	C5 Palsy	15	243.07	99.58	0.352
		No	214	216.99	105.09	
	EBL (mL)	C5 Palsy	15	318.57	215.33	0.417
		No	216	233.83	385.27	
	ACDF (%)	C5 Palsy	50			0.107
		No	57			
IONM Data	R Median Amplitude diff	C5 Palsy	9	1.56	0.62	0.024
		No	9	0.91	0.48	
	R Median Latency diff	C5 Palsy	9	2.21	0.45	0.744
		No	9	2.38	1.43	
	L Median amplitude diff	C5 Palsy	9	1.20	0.34	0.077
		No	9	0.75	0.29	
	L Median Latency diff	C5 Palsy	9	7.77	17.68	0.516
		No	9	3.79	3.34	
	R Ulnar Amplitude diff	C5 Palsy	9	1.96	0.53	0.672
		No	9	2.20	1.62	
	R Ulnar Latency diff	C5 Palsy	9	1.00	0.00	0.176
		No	9	0.82	0.39	
	L Ulnar Amplitude diff	C5 Palsy	9	1.13	0.70	0.021
		No	9	0.52	0.15	
	L Ulnar Latency diff	C5 Palsy	9	3.79	3.15	0.241
		No	9	2.43	1.09	
Radiographic data	Change in R Foramen Width	C5 Palsy	40	0.6175	1.53	**<0.001**
		No	8	4.5875	2.85	
	Change in L Foramen Width	C5 Palsy	40	0.4175	1.37	0.111
		No	7	-0.4857	1.29	
	Change in L Nerve Width	C5 Palsy	40	0.4875	1.22	0.128
		No	7	-0.4571	1.38	
	Change in R Nerve Width	C5 Palsy	40	0.2300	0.78	0.320
		No	12	4.5167	14.27	
	Change in Spinal Cord Position	C5 Palsy	40	1.2500	1.71	**<0.001**
		No	1	-5.7000		
	Change in Lordosis	C5 Palsy	150	3.1593	11.45	**0.001**
		No	7	-12.3143	16.06	

Individual Disclosures can be found in the Disclosure Index pages 20-33.
Papers are numbered based on their presentation date and time, which may be found on pages 8-19. E-posters are listed after podium presentations

E-POSTER 8

Severe Semispinalis Cervicis Sarcopenia is Associated with Worse Patient Reported Outcomes following Laminoplasty for Myelopathy

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Mayo Clinic, Rochester, MN[1] Mayo Clinic[2]

Introduction: Paraspinal sarcopenia is known to have a detrimental effect on postoperative outcomes following posterior cervical fusion and decompression. However, the impact of qualitative paraspinal sarcopenia on outcomes following laminoplasty remains unknown. The purpose of the present study was to determine whether paraspinal sarcopenia impacts patient reported outcome measures (PROMs) following laminoplasty for cervical spondylotic myelopathy (CSM).

Materials and Methods: We retrospectively reviewed a cohort of consecutive patients undergoing laminoplasty between the years 2010-2021 at a single academic institution. Patients were included if they underwent laminoplasty for cervical spondylotic myelopathy with or without radiculopathy and had neck disability index (NDI) scores, visual analog scale (VAS) neck scores, and VAS arm scores recorded both preoperatively and at 1 year postoperatively. Patient demographics and surgical variables were collected. Two independent reviewers blinded to the clinical outcomes performed Goutalier grading of the bilateral semispinalis cervicis muscles at C5-6. The two reviewers' scores were then averaged, and patients were classified into mild, moderate, and severe sarcopenia subgroups based upon the Fuchs Modification of the Goutalier grading system. PROMs were then compared between subgroups. The number of patients within each subgroup achieving a minimal clinically important difference (MCID) and substantial clinical benefit (SCB) was determined using accepted criteria in the literature. Multivariate analysis was performed to determine independent predictors of PROMs.

Results: We identified 114 patients for inclusion in this study. Patients with severe sarcopenia (Goutalier 2.5-4) were older and had a higher proportion of female patients than the mild and moderate sarcopenia subgroups (Table 1). No differences were identified in preoperative PROMs between subgroups. The mild and moderate sarcopenia subgroups demonstrated a significant improvement in NDI from preoperative to postoperative (-8.3 and -4.7, respectively; P<0.001), while the severe sarcopenia cohort failed to demonstrate a significant improvement (-0.3; P=0.76). The severe sarcopenia subgroup was also significantly less likely to achieve MCID or SCB in NDI and had a higher proportion of patients who reported worsening of their NDI from preoperative to 1 year postoperatively. Multivariate analysis demonstrated sarcopenia to be an independent predictor of postoperative NDI (P=0.008), likelihood of achieving MCID (OR 0.07; P=0.003), and likelihood of reporting worse postoperative NDI (OR 21.6; P<0.001). All sarcopenia subgroups demonstrated an improvement in VAS neck from preoperative to 1 year postoperative, but the mild sarcopenia subgroup had a significantly lower VAS neck (0.7) than the moderate (1.7) or severe (1.9; P=0.03) sarcopenia subgroups. Patients with mild and moderate sarcopenia demonstrated a significant improvement in VAS arm, while those with severe sarcopenia failed to demonstrate an improvement and were more likely to report

E-POSTER 8 continued

worsening of their arm pain postoperatively (P=0.03).

Conclusion: Patients with severe paraspinal sarcopenia are less likely to improve in terms of neck disability, neck pain, and arm pain at 1 year postoperatively following laminoplasty for CSM. Additional studies are needed to determine the mechanism by which paraspinal sarcopenia drives worse PROMs following laminoplasty.

Table 1: Demographics

	Goutalier 0-1 (n=35)	Goutalier 1.5-2 (n=49)	Goutalier 2.5-4 (n=30)	All Patients (n=114)	P Value
Age	51.4 (13.6)	61.1 (10.9)	68.9 (11.4)	60.2 (13.6)	**<0.001**
Sex (Female)	15 (42.9%)	10 (20.4%)	14 (46.7%)	39 (34.2%)	**0.03**
BMI*	29.2 (5.2)	29.0 (5.8)	28.6 (5.3)	29.0 (5.4)	0.89
<25	6 (17.1%)	13 (26.5%)	8 (26.7%)	27 (23.7%)	0.91
25-35	25 (71.4%)	29 (59.2%)	17 (56.7%)	71 (62.3%)	
>35	4 (11.4%)	7 (14.3%)	5 (16.7%)	16 (14.0%)	
Diabetes	2 (5.7%)	9 (18.4%)	8 (26.7%)	19 (16.7%)	0.07
Active Tobacco Use	4 (11.4%)	5 (10.2%)	4 (13.3%)	13 (11.4%)	0.91
Chronic Steroid Use	1 (2.9%)	1 (2.0%)	0 (0.0%)	2 (1.8%)	0.67
Inflammatory Arthritis	2 (5.7%)	3 (6.1%)	4 (13.3%)	9 (7.9%)	0.44

Continuous variables are displayed as mean (standard deviation), categorical variables are displayed as number (percent).
*Abbreviations: BMI (body mass index)

Table 2: Neck Disability Index Scores Based on Fuchs Modification of the Goutalier Grade

Goutalier Grade	# of Patients	Mean Preoperative NDI	Mean Postoperative NDI	Patients Reporting Worse NDI After Surgery (%)	Patients Achieving MCID (%)	Patients Achieving SCB (%)	Perioperative Change	P Value
Goutalier 0-1	35	14.5 (7.8)	6.2 (6.9)	4 (11.4%)	31 (88.6%)	29 (82.9%)	-8.3 (7.6)	**<0.001**
Goutalier 1.5-2	49	13.8 (9.7)	9.1 (7.5)	3 (6.1%)	45 (91.8%)	24 (49.0%)	-4.7 (6.6)	**<0.001**
Goutalier 2.5-4.0	30	13.2 (8.4)	12.9 (6.7)	13 (43.3%)	16 (53.3%)	4 (13.3%)	-0.3 (6.0)	0.76
		0.87	**0.01**	**0.002**	**<0.001**	**0.006**	**0.001**	

Table 3: VAS Neck Scores Based on Fuchs Modification of the Goutalier Grade

Goutalier Grade	# of Patients	Mean Preoperative VAS	Mean Postoperative VAS	Patients Reporting Worse VAS After Surgery (%)	Patients Achieving MCID (%)	Patients Achieving SCB (%)	Perioperative Change	P Value
Goutalier 0-1	35	3.6 (2.6)	0.7 (1.5)	3 (8.6%)	25 (71.4%)	16 (45.7%)	-2.9 (3.0)	**<0.001**
Goutalier 1.5-2	49	4.2 (3.2)	1.7 (2.1)	6 (12.2%)	30 (61.2%)	16 (32.7%)	-2.5 (3.0)	**<0.001**
Goutalier 2.5-4.0	30	3.7 (2.4)	1.9 (2.2)	7 (23.3%)	18 (60.0%)	5 (16.7%)	-1.8 (2.9)	**0.01**
		0.60	**0.03**	0.41	0.63	0.10	0.31	

E-POSTER 9

Development of new postoperative neck pain at 12 and 24 months after surgery for cervical spondylotic myelopathy: a Quality Outcomes Database study

Brandon Sherrod, MD[1], Georgios Michalopoulos, MD, Graham Mulvaney, MD, Nitin Agarwal, MD, Anthony Asher, MD, Domagoj Coric, MD, Kai-Ming Fu, MD, Kevin Foley, MD, Paul Park, MD, Cheerag Upadhyaya, MD, John Knightly, MD, Mark Shaffrey, MD, Eric Potts, MD, Christopher Shaffrey, MD[2], Michael Wang, MD, Luis Tumialan, MD, Praveen Mummaneni, MD, Khoi Than, MD, Mohamad Bydon, MD, Erica Bisson, MD, MPH[1]
University of Utah[1] Duke Clinics (South)[2]

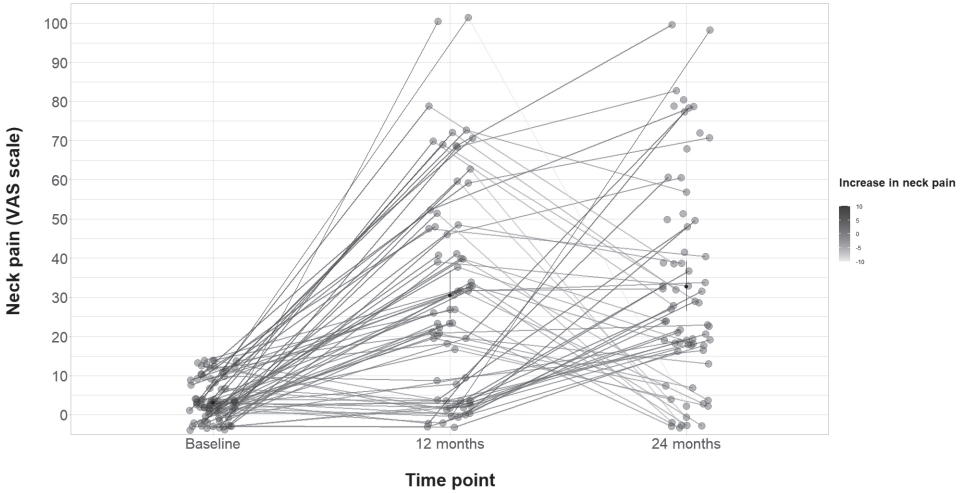
Introduction: Patients who undergo surgery for cervical spondylotic myelopathy (CSM) will occasionally develop postoperative neck pain that was not present preoperatively, yet the incidence of this phenomenon is unclear. The authors aimed to elucidate patient and surgical factors associated with new sustained pain onset after CSM surgery.

Materials and Methods: The authors reviewed prospectively collected data from the CSM Quality Outcomes Database (QOD) module. The presence of neck pain was defined using the neck pain Numeric Rating Scale (NRS). Patients with no neck pain at baseline (neck pain NRS ≤1) were then stratified based on presence of new postoperative pain development (neck pain NRS of ≥2) at 12 and 24 months postoperatively.

Results: Of the 1,141 patients in the CSM QOD registry, 224 (19.6%) reported no neck pain at baseline. Among 170 patients with no baseline neck pain and available 12-month follow-up, 46 (27.1%) reported new postoperative pain at 12 months. Among 184 patients with no baseline neck pain and available 24-month follow-up, 53 (28.8%) reported new postoperative pain at 24 months. The mean neck pain NRS difference was 4.3 for those with new postoperative pain vs. those without at 12 months (4.4±2.2 vs. 1.0±3.0, p<0.001) and 3.9 at 24 months (4.1±2.4 vs. 2.0±4.0, p<0.001). The majority of patients reporting new-onset neck pain reported being satisfied with surgery, but satisfaction was significantly lower compared to patients without neck pain at 12-month (66.7% versus 94.3%, p<0.001) and 24-month (65.4% versus 90.8%, p<0.001) follow-ups. Twenty patients (43.5%) who had new pain at 12 months had sustained pain at 24 months, and 21 patients (16.9%) who had no new pain at 12 months reported pain at 24 months. Baseline NDI was an independent predictor of new postoperative neck pain at both 12-month and 24-month time points (aOR 1.03, 95% CI 1.07-2.13, p=0.014; aOR 1.02, 95% CI 1–1.05, p=0.04, respectively). Total number of levels treated was associated with new-onset neck pain at 12 months (aOR 1.51, 95% CI 1.07-2.13, p=0.021), and duration of symptoms more than 3 months was a predictor of 24-month neck pain (aOR 3.27, 95% CI 1.02-10.45, p=0.046).

Conclusion: Patient disability at baseline (NDI), number of levels treated surgically (51% increased risk of new onset pain per additional level treated), and greater than 3 month preoperative symptom duration correlate positively with the risk of new-onset neck pain following CSM surgery. The majority of patients with new-onset neck pain still report satisfaction from surgery, suggesting that the risk of new-onset neck pain should not hinder indicated operations from being performed.

E-POSTER 9 continued



E-POSTER 10

Predictors of Patient Satisfaction Following Laminoplasty and Posterior Cervical Fusion for Degenerative Cervical Myelopathy

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Introduction: Degenerative cervical myelopathy (DCM) is the most common cause of spinal cord dysfunction (1). Symptom onset is usually insidious in nature and can vary widely in clinical severity (2). Surgical management options include decompression through either an anterior or posterior approach (1). The two most common posterior operations are laminectomy and fusion (LF) and laminoplasty (LP). While both LF and LP are appropriate treatments for DCM, there is a paucity of data to identify patient characteristics associated with patient satisfaction following these procedures. To improve this knowledge gap, we conducted a retrospective review of a large multi-center prospective spine outcomes registry investigating which patient characteristics accurately predict patient satisfaction following either LF or LP for DCM.

Materials and Methods: The Quality Outcomes Database, a national prospective spine surgery registry, was queried for patients who underwent LF or LP for DCM. Included were 88 LP and 976 LF patients who received surgery between 04/2013 and 07/2019. The primary outcome was the North American Spine Surgery patient satisfaction ordinal questionnaire, which is measured on a 4-point scale (1= surgery met my expectations and 4= I am the same or worse as compared to before surgery) but converted the dichotomous outcome of being satisfied (1 & 2) or not (3 & 4). Pearson chi-square tests, unpaired t-test, and Mann Whitney U test were used to assess initial differences in demographics, clinical characteristics and satisfaction based on surgical technique. A multivariate logistic regression model was conducted to assess the association of surgical technique (LF vs LP) with patient satisfaction, controlling for baseline demographics and clinical characteristics.

Results: No statistically significance differences in patient satisfaction were found between LF and LP (78.3% vs 76.1%, p=0.642) at 12 month follow-up (Table 1). LP patients had significantly higher proportions of advanced education, worse myelopathic symptoms, private insurance, absence of depression/anxiety, and absence of adjacent segment disease. Length of stay (LOS), neck disability index (NDI), and baseline arm/neck pain were significantly worse in LF patients. In the regression model, procedure type was not significantly associated with patient satisfaction when adjusting for demographic and clinical characteristics. Symptom duration >3 months, increasing LOS, and race (non-white) were significant predictors of decreased patient satisfaction in both groups (Table 2).

Conclusion: Posterior surgical options for DCM include both LP and LF. Our present study found that patients achieve equal satisfaction following either procedure at 12-month follow-up. Symptom duration of less than 3 months, decreased length of hospital stay, and identifying as white race were all significant positive predictors of patient satisfaction. LP patients were better educated, less anxious/depressed, and were more commonly privately insured than LF patients, which highlights an important inequity in the socioeconomic access to LP. In addition, further research investigating the satisfaction disparity between white and non-white patients

E-POSTER 10 continued

is a critical area of future research. As with all elective spine surgeries, proper surgical indication and establishing post-operative expectations is critical to successful outcomes. The data from our study will aid surgeons when counseling patients regarding satisfaction following LP and LF.

Table 1. Outcome (satisfaction) summary for laminoplasty and PCF patients with 12 month outcome (satisfaction)

	Total		Laminoplasty (n=88)		PCF (n=976)			
	N	%	N	%	N	%	Statistic	p-value
Patient satisfaction (12mo)							χ^2=0.77	0.856
Surgery met my expectations.	576	54.1%	49	55.7%	527	54.0%		
I did not improve as much as I had hoped but I would undergo the same operation for the sar	255	24.0%	18	20.5%	237	24.3%		
Surgery helped but I would not undergo the same operation for the same results.	116	10.9%	11	12.5%	105	10.8%		
I am the same or worse as compared to before surgery.	117	11.0%	10	11.4%	107	11.0%		
Patient satisfaction (12mo)							χ^2=0.22	0.642
Not satisfied	233	21.9%	21	23.9%	212	21.7%		
Satisfied	831	78.1%	67	76.1%	764	78.3%		

Table 2. Logistic regression model predicting 12mo satisfaction (n=1064)

				95% CI		
	B	Wald Chi-Square	OR	Lower	Upper	*p*
Symptom duration=3-12 months (ref:< 3months)	-1.287	11.682	0.276	0.13	0.58	<0.001
Length of stay	-0.109	11.122	0.897	0.84	0.96	<0.001
Symptom duration=>12 months (ref:< 3months)	-1.226	10.793	0.293	0.14	0.61	0.001
Race=White (ref:Non-white)	0.580	8.631	1.786	1.21	2.63	0.003
Baseline NDI	-0.007	2.645	0.993	0.98	1.00	0.104
Diabetes=Yes (ref:No)	-0.246	1.895	0.782	0.55	1.11	0.169
Ambulation=Independent (Not independent)	-0.267	1.843	0.766	0.52	1.13	0.175
Gender=Female (ref:male)	0.212	1.812	1.236	0.91	1.68	0.178
Procedure type=PCF (ref:Laminoplasty)	0.284	1.066	1.329	0.78	2.28	0.302
Education=>high school (ref:High school or <)	0.160	1.020	1.173	0.86	1.60	0.313
Current smoker=Yes (ref:No)	-0.176	0.729	0.838	0.56	1.26	0.393
Insurance=Private (ref: Public)	-0.138	0.534	0.871	0.60	1.26	0.465
Age	-0.007	0.494	0.993	0.98	1.01	0.482
BMI	0.007	0.300	1.007	0.98	1.03	0.584
Depression or Anxiety=Yes (ref:No)	-0.082	0.232	0.921	0.66	1.29	0.630
Employment status=Employed (ref: Unemployed)	0.067	0.111	1.069	0.72	1.59	0.739

Note. χ^2 *(16)=47.82, p<0.001, Nagelkerke* R^2 *=0.068*

Controlling for other predictors, type of procedure (laminoplasty vs PCF) was not a significant predictor of 12-month satisfaction.

Symptom duration, length of stay, and race were significant and most important predictors of 12-month patient satisfaction. Having symptoms 3+ months at baseline (vs <3-months) was associated

E-POSTER 11

The Influence of Race, Education, and Net Worth on Short-term Cervical Spinal Fusion Outcomes

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Introduction: There has been a steady increase in cervical spinal fusion procedures performed each year in the United States.[1] Previous studies have demonstrated the effects of patient race and income on outcomes following cervical fusion procedures; however, no study to date has comprehensively examined the impact of multiple socioeconomic (SES) variables on postoperative outcomes.[2-3] Our study aims to analyze how SES variables including race, education, and net worth influence postsurgical outcomes after cervical spinal fusion.

Materials and Methods: The Optum Database was used to extract all patients between 2003 and 2021 who underwent a cervical spinal fusion procedure. CPT and ICD-9/10 codes were used to identify patients. Demographic characteristics, socioeconomic variables, and clinical outcome variables were identified, and univariate analysis was performed using Student's t-test and chi-squared tests for continuous and categorical variables, respectively. Statistically significant findings are defined as a p-value of 0.05.

Results: Between 2003-2021, 111,914 patients in the database underwent cervical spinal fusion. In our cohort, Black patients had the highest mean hospital length of stay (LOS) (4.9 days, $p < 0.001$), the highest rates of 30-day readmission (8.1%, $p < 0.001$), 30-day emergency room (ER) visit (7.0%, $p = 0.021$), and the highest out-of-pocket charges ($412.7, $p < 0.001$) (Table 1). Patients with less than a 12th grade education had the highest rates of 30-day readmission (9.0%, $p = 0.002$), 30-day reoperation (1.6%, $p = 0.043$), 30-day ER visit (7.7%, $p < 0.001$) and the highest median hospital charges ($83,654.5, $p < 0.001$) (Table 2). Patients in the highest net worth bracket (>$500K) had lower mean LOS (7.6 days, $p < 0.001$) and 30-day readmission rate (5.9%, $p = 0.002$), compared with patients in lower net worth brackets (Table 3). Interestingly, patients with the highest net worth had the highest median hospital charges ($68,337.3, $p < 0.001$), but the lowest median out-of-pocket charges ($250.0, $p < 0.001$).

Conclusion: Socioeconomic variables influence postoperative outcomes in cervical spinal fusion surgery. Patient racial characteristics, education, and net worth describe modifiable risk factors that should be noted by surgeons considering candidates for cervical spinal fusion surgery. Future studies should focus on tangible interventions in response to these findings, as socioeconomic status should not, and need not be a hindrance to excellent postoperative outcome. Future focus on increased preoperative education in at-risk patient populations, and related targeted interventions would likely improve postoperative outcomes in this population, ultimately reducing total healthcare utilization and costs.

E-POSTER 11 continued

Table 1. Comparison of cervical fusion patients by race.

	Asian (N=1,902)	Black (N=12,691)	Hispanic (N=8,332)	White (N=86,441)	p-value
Patient Characteristics					
Age, y, mean (SD)	58.2 (14.7)	58.8 (12.7)	58.4 (13.6)	57.5 (13.1)	<0.001*
Female, n (%)	889 (46.7)	6911 (54.5)	4325 (51.9)	43574 (50.4)	<0.001*
CCI, mean (SD)	3.8 (4.2)	5.1 (4.5)	4.9 (4.5)	4.5 (4.3)	<0.001*
Hospitalization Characteristics					
Length of stay, days, mean (SD)	4.7 (7.9)	4.9 (8.8)	4.4 (7.8)	3.5 (8.4)	<0.001*
30-day readmission, n (%)	137 (7.2)	1022 (8.1)	589 (7.1)	5206 (6.0)	<0.001*
30-day reoperation, n (%)	13 (0.7)	65 (0.5)	51 (0.6)	469 (0.5)	0.752
30-day ER visit, n (%)	110 (5.8)	883 (7.0)	502 (6.0)	5580 (6.5)	0.021*
Discharge to home, n (%)	1377 (72.4)	9340 (73.6)	6092 (73.1)	70533 (81.6)	<0.001*
30-Day complications					
Any complication, n (%)	218 (11.5)	1609 (12.7)	925 (11.1)	10113 (11.7)	0.006*
Stroke, n (%)	17 (0.9)	115 (0.9)	53 (0.6)	654 (0.8)	0.152
Cardiac complication, n (%)	33 (1.7)	214 (1.7)	128 (1.5)	1554 (1.8)	0.122
Pulmonary complication, n (%)	102 (5.4)	768 (6.1)	481 (5.8)	5606 (6.5)	0.015*
PE, n (%)	<10	65 (0.5)	26 (0.3)	281 (0.3)	0.014*
AKI, n (%)	26 (1.4)	243 (1.9)	111 (1.3)	911 (1.1)	<0.001*
Sepsis, n (%)	17 (0.9)	73 (0.6)	58 (0.7)	380 (0.4)	<0.001*
UTI, n (%)	33 (1.7)	241 (1.9)	143 (1.7)	1106 (1.3)	<0.001*
DVT, n (%)	<10	37 (0.3)	12 (0.1)	163 (0.2)	0.007*
Bleeding, n (%)	<10	17 (0.1)	10 (0.1)	104 (0.1)	0.814
Wound infection, n (%)	11 (0.6)	48 (0.4)	28 (0.3)	300 (0.3)	0.518
CSF leak, n (%)	<10	47 (0.4)	23 (0.3)	283 (0.3)	0.755
Neurologic deficit n (%)	<10	48 (0.4)	22 (0.3)	230 (0.3)	0.231
Hardware failure, n (%)	<10	<10	12 (0.1)	72 (0.1)	0.318
Procedure Payment					
Hospital charge, median [IQR]	80027.2 [43352.4, 155795.2]	67401.1 [40153.6, 126538.9]	85161.8 [49580.4, 155841.7]	59855.7 [35185.5, 108948.1]	<0.001*
Out of pocket cost, median [IQR]	267.8 [0.0, 1204.2]	412.7 [0.0, 1300.0]	250.0 [0.0, 1196.0]	295.0 [0.0, 1168.9]	<0.001*

E-POSTER 11 continued

Table 2. Comparison of cervical fusion patients by education level.

	Less than 12th Grade (N=431)	High School Diploma (N=33.414)	Less than Bachelor's (N=61,458)	Bachelor's Degree or higher (N=16,253)	p-value
Patient Characteristics					
Age, y, mean (SD)	60.3 (13.3)	57.7 (12.6)	57.8 (13.2)	57.3 (13.8)	<0.001*
Female, n (%)	196 (45.5)	17165 (51.4)	31619 (51.4)	7823 (48.1)	<0.001*
CCI, mean (SD)	5.2 (4.8)	4.8 (4.4)	4.5 (4.3)	4.1 (4.2)	<0.001*
Hospitalization Characteristics					
Length of stay, days, mean (SD)	4.6 (7.5)	4.0 (9.8)	3.6 (7.8)	3.6 (7.5)	<0.001*
30-day readmission, n (%)	39 (9.0)	2237 (6.7)	3864 (6.3)	963 (5.9)	0.002*
30-day reoperation, n (%)	<10	183 (0.5)	330 (0.5)	91 (0.6)	0.043*
30-day ER visit, n (%)	33 (7.7)	2305 (6.9)	3971 (6.5)	917 (5.6)	<0.001*
Discharge to home, n (%)	292 (67.7)	26349 (78.9)	49430 (80.4)	13037 (80.2)	<0.001*
30-Day complications					
Any complication, n (%)	50 (11.6)	3978 (11.9)	7184 (11.7)	1907 (11.7)	0.836
Stroke, n (%)	<10	279 (0.8)	457 (0.7)	117 (0.7)	0.119
Cardiac complication, n (%)	<10	544 (1.6)	1132 (1.8)	275 (1.7)	0.119
Pulmonary complication, n (%)	34 (7.9)	2110 (6.3)	3887 (6.3)	1072 (6.6)	0.391
PE, n (%)	<10	109 (0.3)	207 (0.3)	69 (0.4)	0.289
AKI, n (%)	<10	446 (1.3)	688 (1.1)	172 (1.1)	0.026*
Sepsis, n (%)	<10	176 (0.5)	282 (0.5)	74 (0.5)	0.039*
UTI, n (%)	<10	498 (1.5)	835 (1.4)	217 (1.3)	0.378
DVT, n (%)	<10	68 (0.2)	108 (0.2)	44 (0.3)	0.11
Bleeding, n (%)	0 (0.0)	40 (0.1)	80 (0.1)	18 (0.1)	0.791
Wound infection, n (%)	<10	133 (0.4)	211 (0.3)	47 (0.3)	0.336
CSF leak, n (%)	<10	97 (0.3)	221 (0.4)	49 (0.3)	0.42
Neurologic deficit n (%)	<10	107 (0.3)	161 (0.3)	44 (0.3)	0.525
Hardware failure, n (%)	0 (0.0)	25 (0.1)	59 (0.1)	13 (0.1)	0.54
Procedure Charges					
Hospital charge, median [IQR]	83654.53 [44057.32, 153354.80]	62627.77 [36297.30, 117090.56]	61890.24 [36296.12, 113150.57]	64774.68 [37588.22, 116725.50]	<0.001*
Out of pocket cost, median [IQR]	200.00 [0.00, 1132.00]	336.65 [0.00, 1243.24]	295.00 [0.00, 1176.14]	250.00 [0.00, 1153.35]	<0.001*

E-POSTER 11 continued

Table 3. Comparison of cervical fusion patient outcomes by net worth range.

	<$25K (N=25,184)	$25K-$149K (N=21,842)	$150K-$249K (N=12,052)	$250K-$499K (N=18,762)	$500K+ (N=25,480)	p-value
Patient Characteristics						
Age, y, mean (SD)	56.4 (13.1)	56.3 (13.0)	57.7 (12.9)	58.6 (12.9)	60.9 (12.8)	<0.001*
Female, n (%)	14645 (58.2)	11065 (50.7)	5997 (49.8)	9085 (48.4)	11739 (46.1)	<0.001*
CCI, mean (SD)	5.1 (4.4)	4.5 (4.2)	4.4 (4.3)	4.3 (4.3)	4.3 (4.3)	<0.001*
Hospitalization Characteristics						
Length of stay, days, mean (SD)	4.1 (8.2)	3.7 (8.7)	3.6 (9.7)	3.5 (6.8)	3.6 (7.6)	<0.001*
30-day readmission, n (%)	1844 (7.3)	1319 (6.0)	755 (6.3)	1068 (5.7)	1497 (5.9)	<0.001*
30-day reoperation, n (%)	143 (0.6)	120 (0.5)	79 (0.7)	86 (0.5)	137 (0.5)	0.345
30-day ER visit, n (%)	1783 (7.1)	1417 (6.5)	773 (6.4)	1194 (6.4)	1304 (5.1)	<0.001*
Discharge to home, n (%)	19349 (76.8)	17712 (81.1)	9794 (81.3)	15359 (81.9)	20271 (79.6)	<0.001*
30-Day complications						
Any complication, n (%)	3164 (12.6)	2475 (11.3)	1381 (11.5)	2151 (11.5)	2838 (11.1)	<0.001*
Stroke, n (%)	213 (0.8)	161 (0.7)	92 (0.8)	137 (0.7)	184 (0.7)	0.649
Cardiac complication, n (%)	393 (1.6)	328 (1.5)	195 (1.6)	359 (1.9)	547 (2.1)	<0.001*
Pulmonary complication, n (%)	1742 (6.9)	1366 (6.3)	741 (6.1)	1185 (6.3)	1413 (5.5)	<0.001*
PE, n (%)	104 (0.4)	64 (0.3)	40 (0.3)	59 (0.3)	89 (0.3)	0.307
AKI, n (%)	353 (1.4)	251 (1.1)	125 (1.0)	209 (1.1)	276 (1.1)	0.008*
Sepsis, n (%)	133 (0.5)	104 (0.5)	53 (0.4)	74 (0.4)	133 (0.5)	0.364
UTI, n (%)	396 (1.6)	282 (1.3)	169 (1.4)	249 (1.3)	318 (1.2)	0.002*
DVT, n (%)	38 (0.2)	46 (0.2)	25 (0.2)	44 (0.2)	51 (0.2)	0.477
Bleeding, n (%)	32 (0.1)	28 (0.1)	21 (0.2)	14 (0.1)	32 (0.1)	0.272
Wound infection, n (%)	98 (0.4)	77 (0.4)	57 (0.5)	55 (0.3)	66 (0.3)	0.002*
CSF leak, n (%)	99 (0.4)	65 (0.3)	44 (0.4)	54 (0.3)	79 (0.3)	0.355
Neurologic deficit n (%)	81 (0.3)	54 (0.2)	37 (0.3)	43 (0.2)	71 (0.3)	0.365
Hardware failure, n (%)	22 (0.1)	22 (0.1)	<10	15 (0.1)	25 (0.1)	0.833
Procedure Payment						
Hospital charge, median [IQR]	67754.5 [39148.4, 124726.8]	59347.4 [35226.8, 108533.0]	57074.1 [33988.0, 105369.3]	57579.5 [34019.4, 105849.2]	68337.3 [39237.4, 123718.1]	<0.001*
Out of pocket cost, median [IQR]	395.0 [0.0, 1300.0]	323.9 [0.0, 1241.8]	295.0 [0.0, 1153.9]	275.0 [0.0, 1059.3]	250.0 [0.0, 1000.0]	<0.001*

E-POSTER 12

Surgeon preferences: decompression for incidental cervical spine stenosis

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Introduction: Spine surgeons frequently encounter asymptomatic cervical stenosis. Given the challenges inherent to incidentally discovered conditions, there is insufficient evidence available to guide clinical decision-making. Practice patterns have not been reported.

This study was conducted to investigate surgeon practice patterns regarding surgical intervention for incidentally discovered cervical stenosis. We sought to investigate the importance of factors including spinal canal diameter, neurologic symptoms, and imaging findings suggestive of cord compression on surgical decision making.

Materials and Methods: After pilot testing was performed, a 13-question online survey was sent to the membership of the Cervical Spine Research Society; 61 surgeons completed the entire survey. 59 surgeons (98%) practice in North America, 55 (90%) are fellowship trained, and 44 (72%) have been in practice for 10+ years. Responding surgeons practice in the following settings: academic/university affiliated (44%), combined academic/private ("privademic") (34%), private practice (13%), hospital employee (5%), and individual practice (4%).

Results: 48 of 61 surgeons (78%) do not offer decompression for incidentally discovered cervical stenosis in asymptomatic patients; 13 of 61 surgeons (22%) would offer decompression based on a small canal diameter. Regarding the role of EMGs, 35/61 surgeons (58%) would not offer decompression for incidental cervical stenosis without symptoms but with abnormal EMG findings.

If incidentally discovered cervical stenosis is accompanied by neurologic signs/symptoms or concerning imaging findings, most surgeons offer surgery. Surgical decompression is preferred in cases with hyper-reflexia (80% operate), myelomalacia with normal exam (82% operate), and myelomalacia with hyper-reflexia (98% operate).

45% of respondents indicated age does not influence their surgical decision-making in incidentally discovered cervical stenosis; of the remaining surgeons, 34% are less likely to recommend surgical decompression for patients older than 75 years of age.

Conclusion: Incidentally discovered cervical stenosis is frequently encountered by spine surgeons, yet practice patterns are largely unknown. We surveyed practice patterns among spine surgeons in the CSRS. Among asymptomatic patients, most spine surgeons surveyed do not offer surgical decompression. However, in the presence of myelomalacia or neurological deficits, most surgeons offer surgery. Additionally, roughly half of respondents indicated age does not factor into clinical decision making and 1/3 indicated they would be less likely to offer surgery in the elderly. This is the first survey assessing surgical decision making for asymptomatic cervical stenosis. Larger studies are needed to more fully understand practice patterns.

E-POSTER 13

Risk factors for unplanned readmission after cervical spine surgery for metastatic disease

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Introduction: Patients undergoing surgery for cervical spine metastases have a high rate of unplanned readmission due to medical comorbidities and concomitant chemotherapy and radiation.[1] However, which patients require unplanned readmission remains understudied. In a cohort of patients undergoing cervical spine surgery for metastatic disease, we sought to: 1) identify risk factors associated with unplanned readmission, and 2) determine the impact of an unplanned readmission on long-term outcomes.

Materials and Methods: A single-center, retrospective, case-control study was undertaken of all patients undergoing cervical spine surgery for metastatic disease between 02/2010-01/2021. The primary outcome of interest was unplanned readmission within 6-months of the index surgery. The exposure variables of interest were grouped into three categories: 1) Preoperative data: demographics, comorbidities, symptoms, and Karnofsky Performance Sore (KPS), 2) Operative data: type of surgery, operative time, estimated blood loss (EBL), length of stay (LOS) and discharge disposition, and 3) Tumor specific variables: chemotherapy, radiotherapy (RT), and immediate postoperative KPS and *McCormick Scale (MMS). Bivariate comparison was made with* t-test and Chi-square. Kaplan-Meier survival curves for readmission probability was plotted.

Results: A total of 64 patients underwent cervical spine surgery for metastatic disease with the following approaches: 11(17.1%) anterior, 31(48.4%) posterior, and 22(34.3%) combined. Mean age at surgery was 61.2±11.1 years, 40 (62.5%) were males, and 39 (60.9%) had other organ metastases. A total of 11/64 (17.1%) patients had an unplanned readmission within 6-months of the index surgery, 3 for surgical reasons and 8 for medical reasons. No difference was found in age (p>0.999), gender (p=0.734), BMI (p=0.307), preoperative KPS (p=0.745), motor strength (p=0.495) or comorbidities (p=0.417) between those who were readmitted versus not (Table 1). Readmitted patients had a higher rate of preoperative RT (p=0.014), postoperative RT (p=0.014), and postoperative chemotherapy (p=0.037). No statistical differences were found in the following areas: operative time (p=0.871), EBL (p=0.593), LOS (p=0.667), discharge disposition (p=0.528), and operative approach (p=0.450). Furthermore, no difference was found regarding complications (p=0.144), postoperative KPS (p=0.666), and postoperative MMS (p=0.275) (Table 2). Regarding the impact of unplanned readmission on long-term tumor control, Kaplan-Meier analysis and log-rank test showed that an unplanned readmission was associated with reduced overall survival (p=0.047) (Fig. 1) but not local recurrence (p=0.170).

Conclusion: In a cohort of patients undergoing cervical spine surgery for metastatic disease, undergoing preoperative RT, postoperative RT, and postoperative chemotherapy were significantly associated with unplanned readmission within 6-months. Furthermore, patients readmitted within 6-months had reduced overall survival compared to those without readmission. Though these risk factors may represent patients with worse overall disease

E-POSTER 13 continued

burden, these results underscore the importance of avoiding unplanned readmissions after cervical spine surgery for metastatic disease.

Table 1. Demographics

	Total N= 64	No Readmission N=53	Yes Readmission N=11	p-value
Age	61.2 ± 11.1	61.0 ± 11.5	62.1 ± 9.7	>0.999
BMI	26.4 ± 6.9	26.2 ± 7.1	27.5 ± 6.0	0.307
Gender				0.734
Female	24 (37.5%)	19 (35.8%)	5 (45.5%)	
Male	40 (62.5%)	34 (64.2%)	6 (54.5%)	
Symptomatic duration	1.9 ± 2.0	1.9 ± 2.1	2.2 ± 1.8	0.574
Smoke				0.364
Never	33 (51.6%)	25 (47.2%)	8 (72.7%)	
Prior	12 (18.8%)	11 (20.8%)	1 (9.1%)	
Current	19 (29.7%)	17 (32.1%)	2 (18.2%)	
Other organ metastasis	39 (60.9%)	31 (56.4%)	8 (88.9%)	0.078
Motor Deficit	38 (59.4%)	32 (60.4%)	6 (54.5%)	0.746
Preop KPS	65.2 ± 17.1	65.5 ± 17.3	63.6 ± 16.9	0.745
Cord Compression	26 (40.6%)	22 (41.5%)	4 (36.4%)	>0.999
Preop Chemo	21 (32.8%)	15 (28.3%)	6 (54.5%)	0.155
Postop Chemo	22 (34.4%)	15 (28.3%)	7 (63.6%)	**0.037**
Preop RT	4 (6.2%)	1 (1.9%)	3 (27.3%)	**0.014**
Postop RT	14 (21.9%)	7 (13.2%)	7 (63.6%)	**0.001**

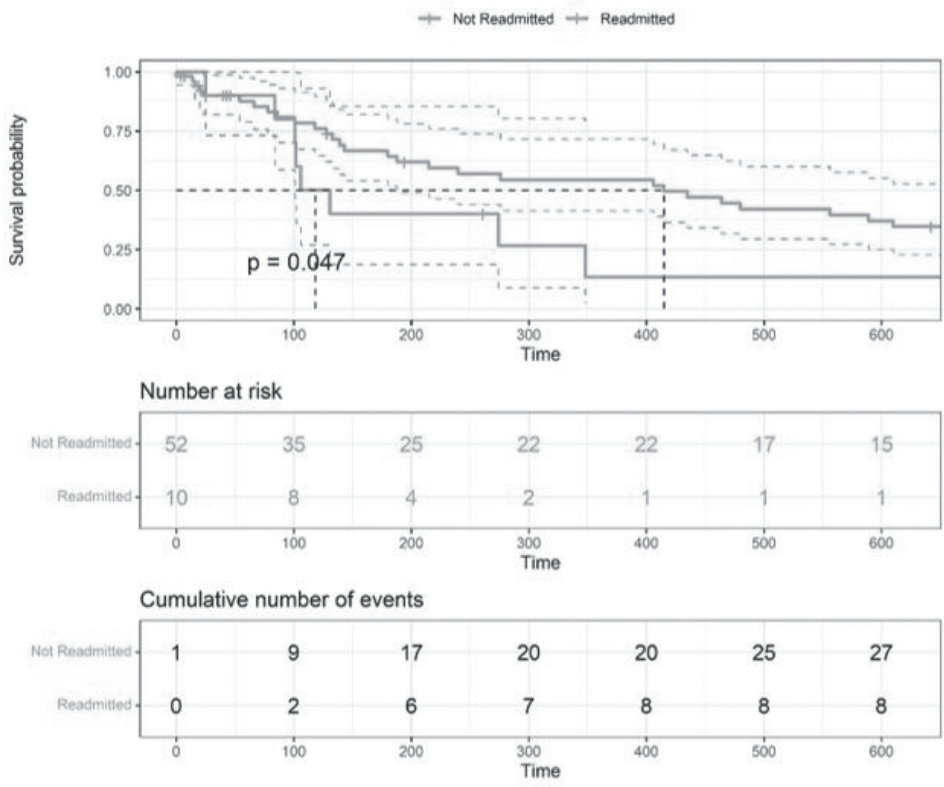
E-POSTER 13 continued

Table 2. Intraoperative and long-term outcome variables.

	Total N=64	No Readmission N= 53	Yes Readmission N=11	p-value
Instrumented	61 (95.3%)	51 (96.2%)	10 (90.9%)	0.438
Decompressed	55 (85.9%)	46 (86.8%)	9 (81.8%)	0.646
Total Decompressed Levels	2.4 ± 1.3	2.4 ± 1.3	2.1 ± 1.4	0.555
Total Instrumented Levels	5.0 ± 2.7	5.1 ± 2.7	4.8 ± 2.4	0.964
Transpedicular decompression	6 (9.4%)	4 (7.5%)	2 (18.2%)	0.273
Corpectomy/Vertebrectomy	34 (53.1%)	29 (54.7%)	5 (45.5%)	0.575
Operative Time	305.3 ± 118.7	304.8 ± 123.3	307.8 ± 99.3	0.871
EBL (mL)	496.3 ± 471.5	497.9 ± 451.2	488.2 ± 584.7	0.593
Approach				0.450
Anterior	11 (17.1%)	9 (17.0%)	2 (18.2%)	
Combined	22 (34.3%)	20 (17.0%)	2 (18.2%)	
Posterior	31 (48.4%)	24 (45.3%)	7 (63.6%)	
New Neurologic Deficit	3 (4.7%)	2 (3.8%)	1 (9.1%)	
Dysphagia	19 (29.7%)	16 (30.2%)	3 (27.3%)	>0.999
DHT/NG placed	12 (18.8%)	11 (20.8%)	1 (9.1%)	0.673
LOS (days)	5.9 ± 6.0	6.1 ± 6.4	5.0 ± 2.7	0.667
Discharge Home	41 (64.1%)	33 (62.3%)	8 (72.7%)	0.732
Local recurrence	7 (10.9%)	5 (9.4%)	2 (18.2%)	0.593
Recurrence	18 (28.1%)	13 (24.5%)	5 (45.5%)	0.267
Reoperation	6 (9.4%)	2 (3.8%)	4 (36.4%)	**0.006**
Postop KPS	74.7 ± 16.2	74.0 ± 16.8	77.8 ± 13.9	0.666
Last KPS	63.5 ± 16.6	65.6 ± 16.8	56.9 ± 14.9	0.184
Postop MMS	1.6 ± 0.9	1.7 ± 0.9	1.4 ± 1.0	0.275
Last MMS	2.1 ± 1.1	2.0 ± 1.1	2.6 ± 1.2	0.155
Time to Last F/U	554.8 ± 656.2	620.6 ± 713.3	316.2 ± 310.7	0.393
Deceased status	45 (72.6%)	36 (69.2%)	9 (90.0%)	0.260
Time to Death	438.8 ± 597.9	493.0 ± 648.2	222.1 ± 248.6	0.281

E-POSTER 13 continued

Figure 1. Overall Survival by Readmission Status



E-POSTER 14

A Comparison of Postoperative Clinical Improvement for Pain, Disability, and Physical Function in Primary ACDF vs Revision ACDF for Adjacent Segment Degeneration

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Introduction: Limited literature exists evaluating expected postoperative clinical improvement in patients undergoing revision anterior cervical discectomy and fusion (ACDF) for adjacent segment disease following index operation. Our study compares perioperative and postoperative clinical outcomes between Primary ACDF and Revision ACDF secondary to adjacent segment disease.

Materials and Methods: A retrospective review of a surgical database was performed for primary or revision (performed for symptomatic adjacent segment disease (ASD)), elective, single level or multilevel ACDF. Patient demographics, perioperative characteristics, postoperative complications, and patient-Reported Outcome Measures (PROMs) were collected preoperatively and postoperatively. PROMs utilized included Visual Analog Scale (VAS) neck/arm, Neck Disability Index (NDI), and Short-Form 12 Item Physical Composite Score (SF-12 PCS). Patients were divided into two cohorts: primary procedure at index level and revision ACDF operation at adjacent level. A 1:4 propensity match was conducted. Following propensity score matching, groups were evaluated for differences in demographics, perioperative characteristics using chi-square test and an unpaired Student's t-test for categorical and continuous variables, respectively. Paired samples t-test evaluated differences in PROM score improvements from their respective baseline value. Unpaired Student's t-test evaluated differences in PROM scores between groups. Minimum Clinical Important Difference (MCID) achievement rates were compared between groups with chi-squared analysis.

Results: Following propensity score match, 183 patients were included - 138 patients in primary ACDF cohort and 45 patients in revision ACDF cohort. Patients in the primary ACDF cohort reported reduced operative duration, EBL, postoperative LOS, and postoperative narcotic consumption on POD1 ($p<0.031$, all)(Table 2). A significantly greater percentage of patients in revision cohort reported postoperative dysphagia. Mean preoperative PROM scores were different between groups for NDI with revision cohort demonstrating increased preoperative disability ($p<0.022$)(Table 4). Differences in mean PROM scores were demonstrated for the following PROMs: VAS neck at 6-weeks, 12-weeks, 6-months, and 1-year, NDI at 12-weeks, 6-months, and 1-year, SF-12 MCS at 6-months and 1-year, and SF-12 PCS at 6-months and 1-year with primary cohort demonstrating superior outcomes for all aforementioned mean differences($p<0.046$, all)(Table 4). Primary ACDF cohort only did not improve SF-12 PCS at 6-weeks and SF-12 MCS from 12-weeks to 1-year ($p<0.025$, all)(Table 4). Revision ACDF patient cohort demonstrated improvement from preoperative baseline for VAS arm up-to 12-weeks, VAS neck upto 6-months, NDI at 12-weeks and 6-months timepoints, and SF-12 PCS at 12-week timepoint (Table 4). Patients in both cohorts reported greater than 50% rate of overall MCID achievement for VAS neck and NDI. Revision ACDF cohort reported significantly inferior MCID achievement rate for VAS neck at 12-weeks, 6-months, and Overall VAS neck ($p<0.042$, all)(Table 5).

E-POSTER 14 continued

Conclusion: Patients undergoing primary ACDF demonstrated improved ability to maintain long term postoperative progress for arm pain, neck pain, and neck disability. Following revision surgery for ASD patients demonstrated significantly inferior neck pain scores from 6-weeks to 1-year, worsened neck disability from 12-weeks to 1-year, and worsened physical function at 6-month and 1-year. The results of our study may help surgeons set expectations for patients undergoing revision ACDF for adjacent segment disease for post-operative improvement across physical function, disability, and neck/arm pain.

Table 2. Perioperative Characteristics

	Total (n=183)	Primary ACDF (n=138)	Revision ACDF (n=45)	*p-value
Spinal Pathology				
Central Stenosis	60.7% (111)	60.1% (83)	62.2% (28)	0.804
Foraminal Stenosis	6.6% (12)	5.1% (7)	11.1% (5)	0.155
Herniated Nucleus Pulposus	67.2% (123)	78.3% (108)	33.3% (15)	**<0.001**
Degenerative Disc Disease	19.1% (35)	10.9% (15)	44.4% (20)	**<0.001**
Degenerative Spondylolisthesis	2.7% (5)	2.9% (1)	2.2% (4)	0.809
Neuropathy				0.660
None	6.0% (11)	5.8% (8)	6.7% (3)	
Radiculopathy	19.1% (35)	17.4% (24)	24.4% (11)	
Myelopathy	3.3% (6)	2.9% (4)	4.4% (2)	
Myeloradiculopathy	71.6% (131)	73.9% (102)	64.4% (29)	
Number of Operative Levels				
Single-Level	74.3% (136)	73.2% (101)	77.8% (35)	0.633
Two-Level	22.4% (41)	23.9% (33)	17.8%(8)	
Three-Level	3.3% (6)	2.9% (4)	4.4%(2)	
Operative Time (Mean±SD; min)	73.0 ± 62.2	64.1 ± 19.2	100.2 ± 117.3	**<0.001**
Estimated Blood Loss (Mean±SD; mL)	43.3 ± 24.6	40.8 ± 18.7	50.6 ± 36.3	**0.021**
Adjacent Segment Disease within 5 years	7.9%	9.8%	0.0%	0.258
1-year arthrodesis	94.5%	93.7%	97.4%	0.378
Pseudoarthrosis at 6m	3.7%	4.1%	2.6%	0.660
Length of Stay (Mean±SD; hours)	25.4 ± 21.2	23.1 ± 15.9	32.5 ± 31.6	**0.009**
Post-operative Day of Discharge (POD)				
POD0	34.1% (62)	35.8% (49)	28.9% (13)	0.066
POD1	52.2% (95)	53.3% (73)	48.9% (22)	
POD2	8.8% (16)	8.0% (11)	11.1% (5)	
POD3	3.3% (6)	1.5% (2)	8.9% (4)	
POD4	1.1% (2)	1.5% (2)	0.0% (0)	
Postoperative VAS Pain Score				
POD0	4.8 ± 1.8	4.8 ± 1.8	4.9 ± 1.7	0.547
POD1	3.9 ± 1.7	3.9 ± 1.7	4.1 ± 1.9	0.563
Postoperative Narcotic Consumption (OME)				
POD0	50.7 ± 40.4	49.1 ± 38.7	55.6 ± 45.4	0.352
POD1	24.9 ± 31.7	22.0 ± 27.4	33.8 ± 41.5	**0.031**

OME = Oral Morphine Equivalents;
POD = Postoperative Day

E-POSTER 14 continued

Table 4. Patient Reported Outcome Measures

	Primary ACDF Mean±SD	Primary ACDF Post-operative PROM Improvement	Revision ACDF Mean±SD	Revision ACDF Post-operative PROM Improvement	*p-value
VAS Arm					
Preoperative	5.8 ± 2.9	-	5.9 ± 2.7	-	0.815
6-weeks	2.6 ± 2.4	**<0.001**	3.2 ± 2.8	**0.008**	0.320
12-weeks	3.2 ± 2.9	**<0.001**	3.2 ± 2.8	**0.025**	0.965
6-months	2.7 ± 2.9	**<0.001**	3.9 ± 2.6	0.127	0.100
1-year	2.8 ± 3.1	**0.008**	3.2 ± 3.7	0.231	0.779
VAS Neck					
Preoperative	6.4 ± 2.5	-	6.9 ± 1.6	-	0.361
6-weeks	3.6 ± 2.3	**<0.001**	4.9 ± 2.2	**0.005**	**0.021**
12-weeks	2.9 ± 2.4	**<0.001**	4.4 ± 2.7	**<0.001**	**0.028**
6-months	2.6 ± 2.6	**<0.001**	4.8 ± 2.6	**0.003**	**0.003**
1-year	3.5 ± 2.6	**0.003**	4.5 ± 3.2	0.274	**0.035**
NDI					
Preoperative	39.8 ± 17.7	-	49.8 ± 16.6	-	**0.022**
6-weeks	31.6 ± 17.6	**0.002**	38.5 ± 19.7	0.107	0.121
12-weeks	25.5 ± 17.5	**<0.001**	36.0 ± 22.9	**0.024**	**0.046**
6-months	21.0 ± 17.3	**<0.001**	35.6 ± 19.1	**0.003**	**0.005**
1-year	23.2 ± 19.6	**<0.001**	41.3 ± 25.7	0.348	**0.044**
SF-12 MCS					
Preoperative	46.3 ± 12.8	-	44.0 ± 11.6	-	0.423
6-weeks	51.8 ± 9.2	**0.025**	47.5 ± 11.9	0.349	0.151
12-weeks	48.1 ± 9.9	0.088	45.2 ± 7.5	0.405	0.254
6-months	53.2 ± 11.4	0.083	44.1 ± 10.4	0.823	**0.027**
1-year	49.9 ± 10.3	0.694	37.9 ± 11.9	0.292	**0.007**
SF-12 PCS					
Preoperative	36.5 ± 9.7	-	35.5 ± 10.9	-	0.657
6-weeks	36.6 ± 8.7	0.796	37.1 ± 10.7	0.119	0.094
12-weeks	44.2 ± 11.2	**<0.001**	42.7 ± 11.8	**0.005**	0.623
6-months	40.4 ± 11.1	**0.002**	38.6 ± 8.0	0.054	**0.037**
1-year	43.6 ± 9.4	**0.002**	39.5 ± 4.7	0.702	**<0.001**

*p-values calculated using paired samples t-test to determine postoperative improvement

E-POSTER 14 continued

Table 5. MCID Achievement

PROM	Primary ACDF	Revision ACDF	p-value
VAS Arm			
6-weeks	38.6%	35.0%	0.775
12-weeks	30.6%	37.5%	0.609
6-months	36.4%	17.7%	0.157
1-year	43.5%	28.6%	0.481
Overall	46.0% (29)	56.5% (13)	0.389
VAS Neck			
6-weeks	47.5%	28.6%	0.130
12-weeks	65.5%	29.4%	**0.009**
6-months	61.2%	33.3%	**0.042**
1-year	54.6%	50.0%	0.825
Overall	72.1% (36)	54.2% (21)	**0.012**
NDI			
6-weeks	41.1%	50.0%	0.489
12-weeks	62.5%	56.3%	0.657
6-months	73.8%	52.9%	0.120
1-year	57.1%	37.5%	0.344
Overall	72.1% (44)	65.2% (15)	0.537
SF-12 PCS			
6-weeks	17.8%	42.9%	0.054
12-weeks	42.6%	37.5%	0.723
6-months	54.2%	30.0%	0.198
1-year	52.6%	16.7%	0.122
Overall	49.2% (32)	45.8% (11)	0.776
SF-12 MCS			
6-weeks	37.8%	35.7%	0.889
12-weeks	31.9%	37.5%	0.682
6-months	37.5%	30.0%	0.677
1-year	23.8%	16.7%	0.711
Overall	43.0% (28)	37.5% (9)	0.636

E-POSTER 15

Predicting Trajectories of Recovery after Surgery for Degenerative Cervical Myelopathy to Facilitate Improved Patient Counseling and Individualized Treatment Recommendations

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Introduction: There is a need to better understand, and predict, outcomes for operatively treated degenerative cervical myelopathy (DCM) patients (1). There is a particular need to help support improved treatment decision making for patients with mild DCM, for which operative or non-operative treatment can be reasonable initial management options (2). Using a novel analytic approach, we aimed to: 1) identify unique trajectories of post-operative outcomes up to 2 years from surgery, and; 2) develop, and internally validate, statistical models which predict trajectory assignment based on preoperative factors in the subset of patients with mild DCM.

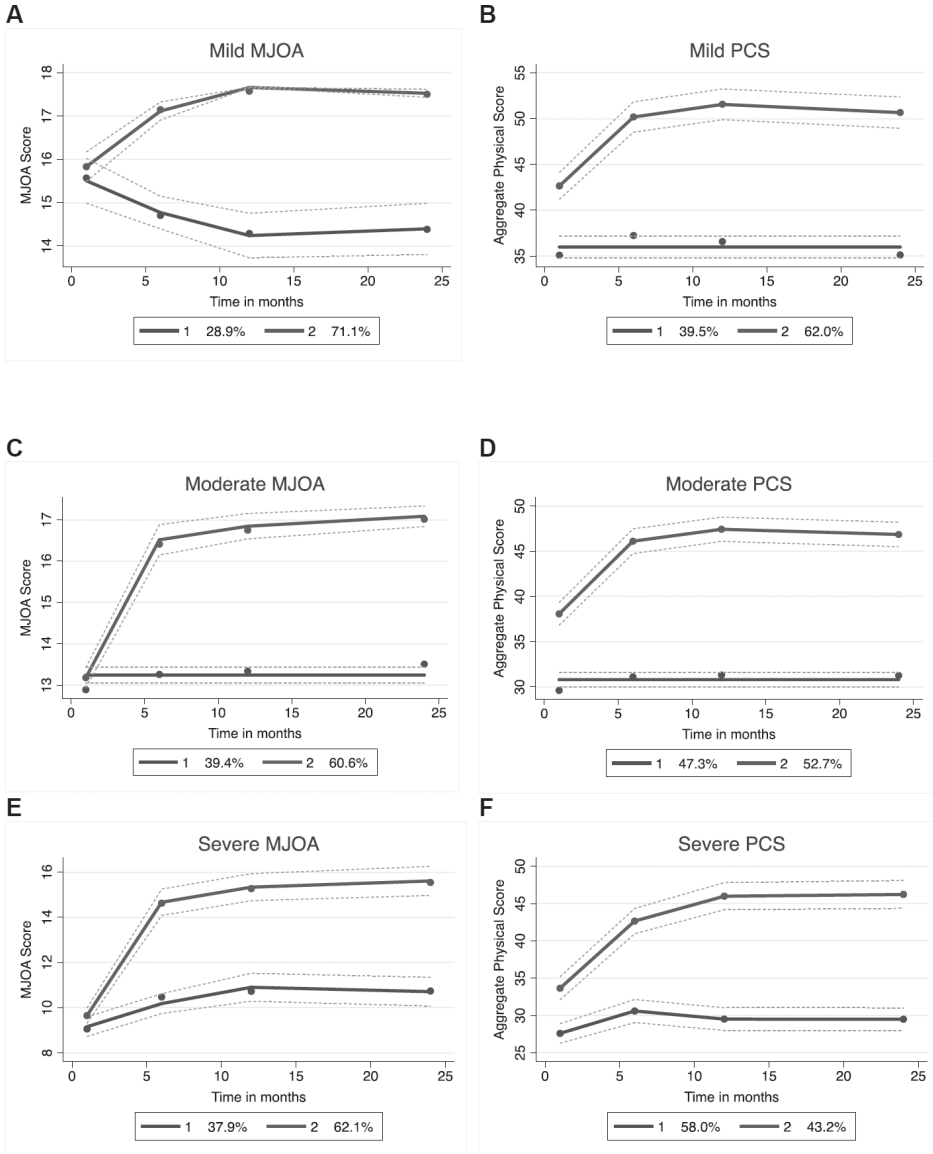
Materials and Methods: Analyses were based on a combined dataset comprised of two large North American multicenter prospective cervical myelopathy studies (N=755). Functional recovery and physical health component quality of life were assessed at baseline, 6 months, 1 year and 2 years postoperatively using modified Japanese Orthopedic Association (mJOA) score and the physical component summary (PCS) of the SF-36 respectively. Group based trajectory modeling was used to identify unique trajectories of mJOA and PCS recovery after surgery for mild (mJOA:15-17), moderate (mJOA:12-14) and severe (mJOA:<12) DCM. Logistic regression was applied to identify preoperative predictors of a poor recovery trajectory. Based on the subset of patients with mild DCM, prediction models of recovery trajectory were then developed and validated in bootstrap resamples. Predictive performance was assessed by discrimination (c-statistic) and calibration (agreement between observed and expected outcomes).

Results: Two unique trajectories of functional and physical component quality of life recovery were identified: good recovery and poor recovery (Figure 1). On average, ½ to ¾ (depending on outcome and myelopathy severity) of participants followed the good postoperative recovery trajectory characterized by improvement in mJOA and PCS scores over time, with most recovery occurring in the first few months. The remaining ½ to ¼ of patients followed the poor recovery trajectory experiencing little improvement, and in certain cases worsening, postoperatively. A prediction model for recovery trajectory in mild DCM patients demonstrated moderate discrimination (ROC=0.72, 95%CI:0.65-0.80), with significant preoperative neck pain (OR, 1.94, 95%CI: 1.38 – 2.74), smoking (OR, 1.56, 95%CI:0.78 – 3.13), and posterior surgical approach (OR,3.02, 95%CI:1.38 – 6.62) found to be the dominant predictors of poor recovery.

Conclusion: Surgically treated DCM patients follow two distinct recovery trajectories in the first two years postoperatively. While most experience substantial improvement (good recovery trajectory), a significant minority experience little improvement or worsening (poor recovery trajectory). Recovery trajectory can be predicted in the preoperative setting to facilitate individualized treatment recommendations for patients with mild symptoms.

E-POSTER 15 continued

Figure 1: Recovery trajectories with 95% confidence intervals
1=Poor recovery trajectory; 2= Good recovery trajectory



E-POSTER 16

Level-Specific Perioperative and Clinical Outcome Comparison: Cervical Disc Replacement versus Anterior Cervical Discectomy and Fusion for 2-Level Operations at C5-C7

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Introduction: While previous studies have compared cervical disc replacement (CDR) or anterior cervical discectomy and fusion (ACDF) procedures in aggregate, level-specific information comparing these procedures and their relationship to clinical outcomes is sparse in the literature. Additionally, multilevel outcome comparison studies are rarely reported. This study compares perioperative results and postoperative clinical outcomes in patients who received two-level CDR or ACDF at cervical level C5-C7.

Materials and Methods: Patients undergoing two-level CDR or ACDF at C5-C7 were identified from single surgeon registry. Patient demographics, perioperative characteristics, and postoperative complications were collected. Patient reported outcome measures (PROMs) were collected preoperatively and postoperatively (6-weeks/12-weeks/6-months/1-year) and included Visual Analog Scale (VAS) neck, VAS arm, Neck Disability Index (NDI), Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS PF), and Short-Form 12 Item Physical Composite Score (SF-12 PCS). Patients were categorized into: CDR and ACDF at C5-C7. Cohorts were assessed for differences in demographics/perioperative characteristics using chi-square test and unpaired Student's t-test for categorical and continuous variables, respectively. Groups were evaluated for differences in PROM score improvements from their respective baseline value using a paired samples t-test and any differences in PROM scores between groups were evaluated at each timepoint using an unpaired Student's t-test. Achievement of Minimum Clinical Important Difference (MCID) was determined by comparing ΔPROM scores to previously established threshold values. MCID achievement rates were compared between groups with chi-squared analysis.

Results: 188 patients met inclusion criteria with 30 patients undergoing two-level CDR at C5-C7 and 158 patients undergoing two-level ACDF at C5-C7. Significant demographic differences between cohorts were noted for mean age and smoking status with ACDF cohort being significantly older with greater percentage of smokers ($p<0.024$, all). Significant differences were demonstrated between groups for rates of both HNP and foraminal stenosis ($p<0.002$, all) (Table 2). Patients within the CDR cohort demonstrated significantly reduced operative times, EBL, rate of revision surgery, postoperative LOS, and postoperative narcotic consumption on both POD 0 and POD1 ($p<0.006$, all). Significant mean PROM differences were noted for the following PROMs at the following postoperative timepoints: VAS neck at 6-weeks and 12-weeks, NDI at 6-weeks and 12-weeks, SF-12 PCS at 6-weeks, 12-weeks, and 6-months, and PROMIS-PF at 6-weeks and 12-weeks (Table 4). CDR patient cohort only did not improve from baseline to 6-weeks PROMIS-PF (Table 4). ACDF patient cohort demonstrated improvement from preoperative baseline to 1-year time point for all PROMs collected at all individual postoperative timepoints with the exception of SF-12 PCS at 6-weeks and PROMIS-PF at 6-weeks and 12-weeks (Table 4). No differences were noted for rates of MCID achievement for

E-POSTER 16 continued

all PROMs at all follow up timepoints with exception for VAS neck at 6-weeks, 12-weeks, and overall, NDI at 6 and 12-weeks, and SF-12 PCS at 6-weeks, 12-weeks, and overall, all significantly favoring CDR cohort (Table 5).

Conclusion: The results of our study suggest patients undergoing 2-level CDR at C5-C7 may benefit from improved short and intermediate clinical outcomes for neck pain, neck disability, and physical function versus ACDF counterparts.

Table 2. Perioperative Characteristics

	Total (n=188)	ACDF at C5-C7 (n=158)	CDR at C5-C7 (n=30)	*p-value
Spinal Pathology				
Central Stenosis	54.3% (102)	51.9% (82)	66.7% (20)	0.137
Foraminal Stenosis	9.6% (18)	5.7% (9)	30.0% (9)	**<0.001**
Herniated Nucleus Pulposus	73.9% (139)	69.6% (110)	96.7% (29)	**0.002**
Degenerative Disc Disease	14.4% (27)	15.8% (25)	6.7% (2)	0.190
Neuropathy				0.116
None	6.9% (13)	8.2% (13)	0.0% (0)	
Radiculopathy	22.3% (42)	24.1% (38)	13.3% (4)	
Myelopathy	1.6% (3)	1.9% (3)	0.0% (0)	
Myeloradiculopathy	69.2% (160)	65.8% (104)	86.7% (26)	
Operative Levels				
C5-C7	100.0% (188)	100.0% (158)	100.0% (30)	-
Operative Time (Mean±SD; min)	87.5 ± 54.3	92.2 ± 57.7	61.6± 9.3	**0.006**
Estimated Blood Loss (Mean±SD; mL)	56.4 ± 57.5	61.3 ± 60.9	28.7 ± 9.1	**0.006**
Revision	3.2%(6)	3.8%(6)	0.0% (0)	**<0.001**
Adjacent Segment Disease within 5 years	4.8% (9)	5.7% (9)	-	-
1-year arthrodesis	95.1% (133)	95.0% (133)	-	-
Pseudoarthrosis at 6m	3.2% (6)	3.8% (6)	-	-
Length of Stay (Mean±SD; hours)	26.6 ± 23.1	28.8 ± 23.4	7.5 ± 5.3	**0.002**
Post-operative Day of Discharge (POD)				
POD0	34.7% (60)	27.3% (42)	98.7% (18)	**<0.001**
POD1	47.9% (83)	53.3% (82)	5.3% (1)	
POD2	13.3% (23)	14.9% (23)	0.0% (0)	
POD3	2.3% (4)	2.6% (4)	0.0% (0)	
POD4	0.6% (1)	0.7% (1)	0.0% (0)	
Postoperative VAS Pain Score				
POD0	4.9 ± 1.9	4.9 ± 1.9	4.5 ± 0.3	0.714
Postoperative Narcotic Consumption (OME)				
POD0	50.3 ± 51.9	55.9 ± 54.8	23.6 ± 19.6	**0.002**
POD1	19.5 ± 27.7	23.0 ± 28.8	1.1 ± 5.9	**<0.001**

OME = Oral Morphine Equivalents; POD = Postoperative Day
Re-hospitilization = Defined as returning to hospital within 6-weeks of surgery with a surgical related complaint.

E-POSTER 16 continued

Table 4. Patient Reported Outcome Measures

	ACDF at C5-C7 Mean±SD	ACDF at C5-C7 Post-operative PROM Improvement	CDR at C5-C7 Mean±SD	CDR at C5-C7 Post-operative PROM Improvement	*p-value
VAS Arm					
Preoperative	5.9 ± 2.6	-	5.7 ± 2.9	-	0.754
6-weeks	3.1 ± 2.6	**<0.001**	2.5 ± 3.2	**0.010**	0.424
12-weeks	3.3 ± 3.0	**<0.001**	1.7 ± 3.0	**0.010**	0.059
6-months	3.1 ± 2.7	**<0.001**	3.1 ± 2.6	**0.016**	0.968
1-year	2.2 ± 2.8	**<0.001**	0.5 ± 0.8	**<0.001**	0.113
VAS Neck					
Preoperative	6.0 ± 2.7	-	6.7 ± 2.3	-	0.295
6-weeks	3.8 ± 2.6	**<0.001**	2.4 ± 2.1	**<0.001**	**0.019**
12-weeks	3.5 ± 2.6	**<0.001**	1.1 ± 1.5	**<0.001**	**0.001**
6-months	3.5 ± 2.6	**<0.001**	2.4 ± 2.5	**0.008**	0.256
1-year	2.3 ± 2.1	**<0.001**	1.0 ± 1.1	**<0.001**	0.139
NDI					
Preoperative	39.8 ± 21.5	-	41.3 ± 20.5	-	0.770
6-weeks	31.3 ± 18.7	**0.008**	21.4 ± 18.2	**0.004**	**0.031**
12-weeks	29.5 ± 20.6	**<0.001**	10.3 ± 14.9	**0.002**	**<0.001**
6-months	24.9 ± 21.2	**<0.001**	20.0 ± 16.2	**0.007**	0.494
1-year	14.1 ± 13.7	**<0.001**	10.3 ± 10.2	**0.002**	0.501
SF-12 PCS					
Preoperative	35.5 ± 9.7	-	34.1 ± 9.4	-	0.529
6-weeks	35.1 ± 9.0	0.884	46.5 ± 8.5	**0.002**	**<0.001**
12-weeks	42.6 ± 10.1	**<0.001**	47.8 ± 9.6	**<0.001**	**0.047**
6-months	39.0 ± 12.1	**0.006**	55.4 ± 2.5	**0.009**	**0.011**
1-year	45.5 ± 44.7	**<0.001**	44.7 ± 11.2	**0.016**	0.877
PROMIS PF					
Preoperative	38.8 ± 6.7	-	43.4 ± 9.5	-	**0.044**
6-weeks	40.5 ± 7.1	0.084	50.4 ± 4.8	0.164	**<0.001**
12-weeks	40.8 ± 8.7	0.086	51.0 ± 9.9	**<0.001**	**0.003**
6-months	45.9 ± 9.4	**<0.001**	54.3 ± 13.1	**0.027**	0.075
1-year	50.2 ± 9.0	**<0.001**	56.8 ± 10.7	**0.030**	0.112

*p-values calculated using paired samples t-test to determine postoperative improvement

E-POSTER 16 continued

Table 5. MCID Achievement

PROM	ACDF at C5-C7	CDR at C5-C7	*p-value
VAS Arm			
6-weeks	31.5%	36.8%	0.669
12-weeks	38.0%	53.3%	0.291
6-months	35.0%	40.0%	0.826
1-year	45.0%	85.7%	0.062
Overall	49.2% (30)	56.5% (14)	0.548
VAS Neck			
6-weeks	38.8%	68.4%	**0.022**
12-weeks	51.7%	80.0%	**0.047**
6-months	57.5%	62.5%	0.789
1-year	65.0%	100.0%	0.069
Overall	61.6% (45)	83.3% (20)	**0.049**
NDI			
6-weeks	35.9%	63.2%	**0.039**
12-weeks	52.0%	80.0%	**0.045**
6-months	76.9%	75.0%	0.907
1-year	85.0%	85.7%	0.963
Overall	72.9% (43)	83.3% (20)	0.313
SF-12 PCS			
6-weeks	13.7%	60.0%	**<0.001**
12-weeks	34.8%	64.7%	**0.033**
6-months	37.9%	66.7%	0.335
1-year	55.0%	75.0%	0.459
Overall	44.6% (29)	70.0% (14)	**0.047**
PROMIS PF			
6-weeks	37.0%	41.7%	0.784
12-weeks	43.5%	75.0%	0.076
6-months	83.3%	83.3%	1.000
1-year	94.4%	83.3%	0.394
Overall	77.4% (20)	70.6% (14)	0.601

*p-value calculated with chi-squared analysis

E-POSTER 17

Differences in Risk Factors for Non-Home Discharge Across Number of Levels Fused in Anterior Cervical Discectomy and Fusion

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Introduction: Predictors of non-home discharge (NHD) have been elucidated in the spine surgery literature, and have previously been tied to poor outcomes and postdischarge adverse events after anterior cervical discectomy and fusion (ACDF). However, no study has compared differences in risk factors for NHD following ACDF based on the number of levels fused. The goal of this study was to elucidate and compare risk factors for non-home discharge in patients undergoing one/two-level ACDF versus three/four-level ACDF.

Materials and Methods: This was a retrospective study utilizing data from elective ACDFs performed between 2008-2019 at an urban, academic tertiary medical center. 2,227 cases of elective ACDF were identified from our institutional database. ACDFs were identified using CPT codes 22551, 22552, and 22554. Exclusion criteria included age < 18 and surgeries performed for cervical trauma, fracture, infection, or tumor. Surgeries that involved a posterior approach and non-cervical procedures were also excluded. Patients who had undergone ACDF were placed into two cohorts based on the number of levels fused (1-2 levels vs. 3-4 levels). Variables including patient demographics, perioperative characteristics, and rates of non-home discharge were compared between cohorts using chi-square analysis. Multivariate logistic regression analyses were then performed for both groups to determine risk factors for non-home discharge for 1-2 level ACDF and 3-4 level ACDF. Clinically relevant variables were used as predictors for the model.

Results: The 1-2 level and 3-4 level ACDF groups were well-matched in terms of sex (p=0.46) and BMI (p=0.94). Those who underwent 3-4 level ACDF were older (56.5 vs. 51.6 years, p<0.001). There was not a significant difference in the rates of NHD between 3-4 level (3.4%) and 1-2 level (2.5%) ACDFs (p=0.42). Within the 1-2 level ACDF group, American Society of Anesthesiologists (ASA) score > 2 (OR 2.14, 95% CI 1.09 - 4.22, p=0.028), all-cause complications (OR 2.94, 95% CI 1.13 - 7.65, p=0.027), and Medicare insurance status (OR 5.85, 95% CI 2.61 - 13.07, p=<0.001) were found to be independent predictors of NHD. Within the 3-4 level ACDF group, age (OR 1.09, 95% CI 1.01 - 1.18, p=0.029) and ASA > 2 (OR 6.36, 95% CI 1.14 - 35.38, p=0.035) were identified as risk factors for NHD.

Conclusion: High ASA score is associated with increased risk for NHD regardless of the number of levels fused in ACDF, and medicare patients within the 1-2 level ACDF population were at increased risk for NHD. These pre-operative factors should be taken into consideration as NHD is associated with greater costs to patients and longer hospital stays. Through the identification of patients undergoing ACDF procedures who may be at higher risk of NHD, physicians may be able to proactively plan discharge decisions to minimize hospital stays and costs.

E-POSTER 18

An Analysis of an Urban Single-Institution Dataset of the Impact of American Society of Anesthesiologists Score on Postoperative Outcomes following Anterior Cervical Discectomy and Fusion

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Introduction: The American Society of Anesthesiologists (ASA) Physical Status Classification has been shown to be an accurate determinant of morbidity and mortality index for patients undergoing spinal procedures. Higher ASA score has been described as a risk factor for poor outcomes in various spinal procedures, but little is known about its specific effect on patients that undergo ACDF. Greater understanding will assist with clinical decision making and perioperative management.

Materials and Methods: This was a retrospective study utilizing data from elective ACDFs performed between 2008-2019 at an urban, academic tertiary medical center. 1627 cases with ASA I/II and 559 cases with ASA III/IV who underwent ACDF were identified from our institutional database. Patients over 18 years old were retrospectively identified from our institutional database, using CPT codes 22551, 22552, and 22554. Patients undergoing the posterior approach, or non-elective ACDF excluded. They were then divided into two groups: low ASA score of I/II and high ASA score of III/IV. Patient demographics, perioperative variables, and postoperative outcomes were compared using chi-squared analysis and student's t-test. Multivariable logistic regression was performed controlling for age, sex, race, length of surgery, estimated blood loss (EBL), and segments fused.

Results: The high ASA cohort was older (57.3 years vs 50.7 years, $p<0.001$), had a higher mean BMI ($p<0.001$), and higher Elixhauser Comorbidity Index scores ($p<0.001$). The high ASA group also had longer operative times ($p<0.001$), more segments fused ($p<0.001$), higher EBL ($p<0.0001$), and longer LOS ($p<0.001$).

Unadjusted chi-square analysis showed that the high ASA group had more patients requiring ICU stays ($p<0.001$), complications ($p<0.001$), nonhome discharge ($p<0.001$), and both 30-day ($p<0.001$) and 90-day readmission ($p<0.001$). Multivariate logistic regression analysis revealed that high ASA patients were at increased risk for 30-day readmission (OR=2.2, 95% CI 1.0-4.7, p=0.041), 90-day readmission (OR=1.7, 95% CI 1.0-2.7, p=0.036), complication rates (OR=1.7, 95% CI 1.0-2.7 p=0.035), and nonhome discharges (OR=3.1, 95% CI 1.7-5.8, $p<0.001$) (Table 1).

Conclusion: High ASA status is significantly associated with increased risk for a range of intraoperative and postoperative outcomes, notably complications, readmission rates, and nonhome discharge, even after controlling for demographic variables. Preoperative risk assessment of these differences may help improve resource utilization and postoperative management of higher risk populations.

E-POSTER 18 continued

Table 1: Postoperative Outcomes

	Unadjusted $\chi 2$ Analysis			Multivariable Logistic Regression*	
	ASA I/II (n=1672)	ASA III/IV (n=559)	P-value	Odds Ratio (95% CI)	P-value
Delayed Extubation n(%)	15 (0.9)	5 (0.9)	.797	0.7 (0.2-2.0)	0.484
Required ICU Stay, n(%)	23 (1.4)	27 (4.8)	**<.0001**	2.6 (1.4-4.8)	**0.003**
Any Complication n(%)	56 (3.3)	40 (7.2)	**.0002**	1.8 (1.1-2.8)	**0.012**
Nonhome Discharge, n(%)	22 (1.3)	36 (6.4)	**<.0001**	3.1 (1.7-5.6)	**<0.001**
30-day readmission, n(%)	17 (1.0)	21 (3.8)	**<.0001**	2.5 (1.3-5.0)	**0.008**
90-day readmission, n(%)	50 (3.0)	43 (7.7)	**<.0001**	2.0 (1.3-3.0)	**0.036**

*Controlled for age, sex, race, BMI, length of surgery, estimated blood loss, and segments fused

E-POSTER 19

Pre-Operative Opioid Use Is Associated With Higher Rates of Healthcare Utilization After Elective Cervical Spine Surgery

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Introduction: There is a significant burden of preoperative opioid use in patients undergoing elective spine surgery. Prior literature has identified an association between preoperative opioid burden and poor legacy patient-reported outcome measures (PROMs). The purpose of this study is to investigate the impact of preoperative opioid use on short-term complications, PROMIS scores, and healthcare resource utilization at one year postoperatively.

Materials and Methods: Patients undergoing elective spine surgery between November 1, 2013 and September 30, 2018 at a single, tertiary academic center were prospectively followed for 12 months after surgery. Patients were split into two cohorts, those with and without pre-operative opioid use. Baseline patient demographics and underlying comorbidities, surgical variables, short-term (30 and 90 day) complications, PROMs and metrics of healthcare resource utilization were compared between these two groups. Two computer adaptive PROMs – physical function (PF) and pain interference (PI) – were assessed at 6 weeks, 3 months, and 12 months postoperatively. A minimally clinically important difference (MCID) of 8 was selected for PF and PI scores based on prior literature. Healthcare resource utilization included cervical imaging studies, emergency department visits, urgent care visits, postoperative opioid prescriptions, epidural or other spinal injections, and pain management referrals at 90-, 180-, and 365-days postoperatively.

Results: 151 patients undergoing elective cervical spine surgery were included in the final cohort. 105 patients were opioid naïve and 46 patients had opioid prescriptions within the 60 days prior to surgery. There were no significant differences in patient demographics or surgical factors between the two cohorts, including age, sex, BMI, Charlson Comorbidity Index (CCI), American Society of Anesthesiologists (ASA) class, surgical procedure, and number of levels fused (Table 1). Patients with preoperative opioid use were more likely to have an acute kidney injury (AKI) at 30 and 90 days postoperatively. Opioid users were more likely to have lower physical function (PF) scores at baseline (11.10 ± 7.24 vs. 8.83 ± 3.95, $p = 0.047$) and 3 months postoperatively (13.02 ± 10.08 vs. 10.26 ± 5.44, $p = 0.031$); However, there were no significant differences in the change from baseline for PF scores at 6 weeks, 3 months, and 12 months postoperatively between the two groups (Table 2). Preoperative opioid users had a greater decrease in PI at 12 months postoperatively (Table 2). However, the average change in PF and PI scores did not reach the pre-determined MCID at any timepoint in either group. Preoperative opioid users had higher rates of healthcare resource utilization, including 90-day cervical x-ray studies, 90- and 180- day emergency department visits, and number of opioid prescriptions at 90-, 180-, and 365- days postoperatively (Table 3).

Conclusion: Preoperative opioid use was associated with poor short-term outcomes, similar pain interference and physical function scores, and a significantly higher rate of healthcare resource utilization in the 12 months following elective cervical spine surgery. Patients using

E-POSTER 19 continued

opioids preoperatively should be counseled to prevent disproportionate utilization of the healthcare system, including costly emergency department visits, imaging studies, and chronic opioid use.

Table 1. Demographics, patient-, and surgical- variables

	Opioid Naïve [n = 105]	Opioid User [n = 46]	P
Sex			
Male	58.0%	60.9%	0.752
Female	42.0%	39.1%	
Age	56.12 ± 14.63	54.30 ± 16.59	0.501
Body Mass Index (BMI)	28.43 ± 5.41	29.99 ± 6.57	0.131
Charlson Comorbidity Index	2.31 ± 2.07	2.28 ± 2.79	0.938
ASA Class	2.23 ± 0.49	2.28 ± 0.66	0.645
Procedure			
ACDF	88.5%	84.7%	0.521
PSF	5.7%	8.6%	0.501
Other	5.8%	6.7%	0.813
Number of Levels Fused	1.33 ± 0.83	1.43 ± 1.09	0.531

E-POSTER 19 continued

Table 2. Patient-reported outcome measures (PROMIS scores)

	Opioid Naïve [n = 105]	Opioid User [n = 46]	P
Pain Interference (PI)			
Baseline	11.47 ± 6.71	13.48 ± 6.46	0.089
6 weeks	8.20 ± 5.79	8.26 ± 6.16	0.954
3 months	9.00 ± 4.63	10.00 ± 5.24	0.243
12 months	8.30 ± 5.11	7.50 ± 5.70	0.392
Physical Function (PF)			
Baseline	11.10 ± 7.24	8.83 ± 3.95	**0.047**
6 weeks	9.96 ± 8.88	8.30 ± 5.83	0.248
3 months	13.02 ± 10.08	10.26 ± 5.44	**0.031**
12 months	14.30 ± 11.68	11.02 ± 10.87	0.108
Δ PI from baseline			
6 weeks	-3.27 ± 7.69	-5.22 ± 8.37	0.165
3 months	-2.47 ± 7.06	-3.48 ± 6.50	0.408
12 months	-3.16 ± 6.91	-5.98 ± 7.28	**0.025**
Δ PF from baseline			
6 weeks	-1.14 ± 7.72	-0.52 ± 5.14	0.619
3 months	1.91 ± 8.96	1.43 ± 4.52	0.731
12 months	3.19 ± 11.69	2.20 ± 10.03	0.617

E-POSTER 19 continued

Table 3. Healthcare utilization measures

	Opioid Naïve [n = 105]	Opioid User [n = 46]	P
Cervical X-Rays			
90 days	1.83 ± 0.98	2.17 ± 1.02	**0.049**
180 days	2.51 ± 1.32	2.85 ± 1.17	0.143
365 days	3.42 ± 1.71	3.70 ± 1.56	0.350
Cervical Computed Tomography (CT)			
90 days	0.03 ± 0.17	0.04 ± 0.21	0.640
180 days	0.08 ± 0.30	0.09 ± 0.35	0.848
365 days	0.21 ± 0.63	0.20 ± 0.50	0.895
Cervical Magnetic Resonance Image (MRI)			
90 days	0.10 ± 0.34	0.07 ± 0.25	0.477
180 days	0.16 ± 0.40	0.09 ± 0.29	0.191
365 days	0.30 ± 0.54	0.13 ± 0.40	0.064
Emergency Department Visits			
90 days	0.04 ± 0.19	0.20 ± 0.46	**0.027**
180 days	0.08 ± 0.27	0.31 ± 0.73	**0.043**
365 days	0.15 ± 0.41	0.53 ± 1.31	0.057
Urgent Care Visits			
90 days	0.07 ± 0.32	0.07 ± 0.25	0.990
180 days	0.12 ± 0.43	0.13 ± 0.41	0.811
365 days	0.22 ± 0.68	0.20 ± 0.46	0.849
Opioid Prescriptions			
90 days	0.92 ± 0.66	3.76 ± 2.95	**<0.001**
180 days	1.05 ± 0.80	5.15 ± 5.30	**<0.001**
365 days	1.32 ± 1.19	7.24 ± 9.00	**<0.001**
Epidural/Other Spinal Injections			
90 days	0.01 ± 0.10	0.07 ± 0.33	0.262
180 days	0.05 ± 0.26	0.20 ± 0.65	0.143
365 days	0.11 ± 0.40	0.37 ± 0.93	0.078

E-POSTER 20

Impact of social deprivation on physical and mental health outcomes in patients following cervical spine fusion surgery

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Introduction: Degenerative cervical spine disease carries significant health and economic burdens and ranks amongst the most common indications for cervical spinal fusion surgery. Previous studies have demonstrated an association between individual socioeconomic factors and cervical fusion outcomes. However, the impact of neighborhood-level socioeconomic disadvantage on cervical spine disability and patient-reported outcomes is unknown. The area deprivation index (ADI) incorporates 17 markers of socioeconomic status from the 1990 US Census data. This geographic based measurement for social deprivation not only reflects individual social health, but also serves as a surrogate to measure community-level social deprivation. In this study, we evaluate the impact of the area deprivation index on both preoperative patient-reported outcomes and change in these domains after cervical spine fusion.

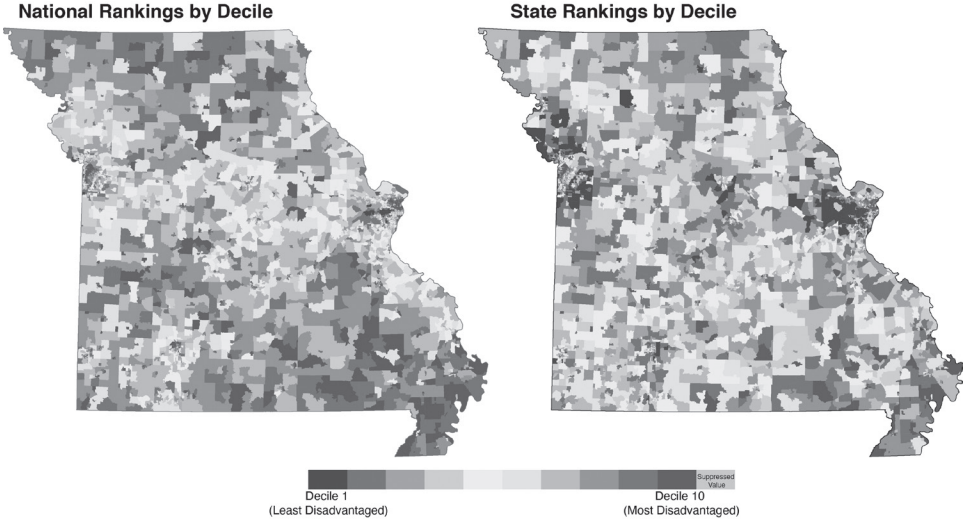
Materials and Methods: A single-center retrospective study identified patients undergoing cervical spine fusion for degenerative disease from 2015-2018. Social deprivation was measured using the Area Deprivation Index (ADI), a validated metric for assessing the impact of neighborhood social/health deprivation (Fig. 1). Study outcomes were the association between ADI and both preoperative PROMIS scores (physical function [PF], pain interference [PI], depression, and anxiety), and change in PROMIS scores after surgery (mean follow-up 27 weeks) according to the minimal clinically important difference (MCID). A conservative MCID of 5 points for change in PROMIS domains was utilized. Missing data were imputed using multiple imputation. Differences between the ADI quartiles were assessed using independent samples t-tests and ANOVA. Multivariable regression was performed to determine the association between ADI and PROMIS scores, independent of confounding variables.

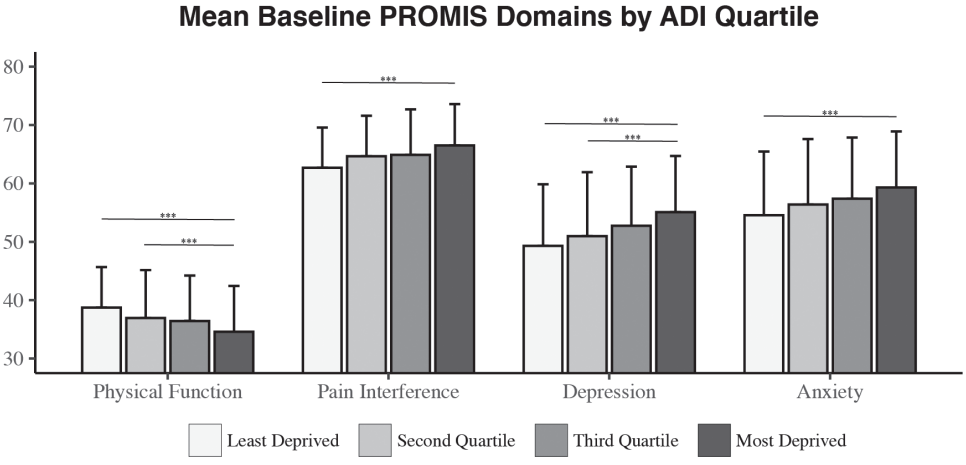
Results: Among 2017 patients, 494 (24%) patients were from the most-deprived and 238 (12%) were from the least-deprived cohorts. Patients living in the most-deprived cohort presented with significantly worse preoperative PROMIS scores across all domains than those in the least-deprived cohort (Mean difference [95% CI]—PF: -4.2 [-6.1, -2.4]; PI: 4.1 [2.4, 5.8]; Depression: 6.8 [3.8, 9.7]; Anxiety: 6.4 [2.7, 10.0], all $p<0.001$, Fig. 2). Corresponding to this finding, increasing ADI (by quartile) was significantly associated with each PROMIS domain in multivariable analysis. When comparing the most-deprived quartile to the least-deprived quartile, there were no significant differences in the number of patients reaching MCID thresholds in change in PROMIS scores at last postoperative follow-up (Mean proportional difference [95% CI]—PF: +4.5% [-18.7, 9.8]; PI: -1.7% [-13.0, 16.3]; Depression: +13.3% [-30.0, 3.4]; Anxiety: -2.7% [-19.1, 24.6], all $p>0.05$, Fig. 3). Likewise, ADI was not a significant predictor of postoperative ***change*** in PROMIS scores in multivariable logistic regression.

Conclusion: Cervical fusion patients with greater social deprivation presented with worse preoperative pain, physical function, and mental health, potentially reflecting limited access to

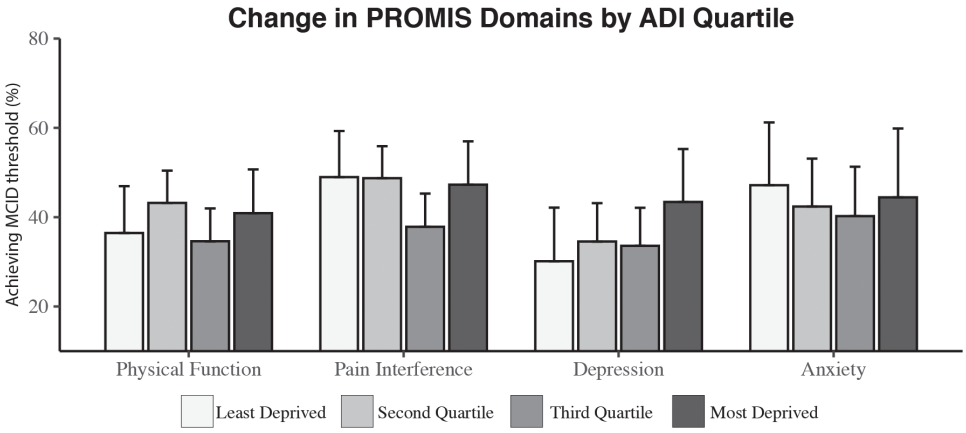
E-POSTER 20 continued

early care in more deprived patients. Nonetheless, social deprivation was not associated with clinical outcome, supporting the important role for surgery in this population.





E-POSTER 20 continued



E-POSTER 21

Differences in Intraoperative Fluoroscopy Utilization Between Total Disc Arthroplasty and Anterior Cervical Discectomy and Fusion

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Introduction: Intraoperative fluoroscopy is essential to ensuring safe and accurate spinal implant placement. Recently, there has been growing awareness to the effects of prolonged radiation exposure to both patients and surgeons. While prior studies have investigated radiation metrics among lumbar procedures, a detailed investigation into the utilization of intraoperative fluoroscopic imaging in cervical surgeries is currently lacking. Therefore, this study was undertaken to compare in vivo fluoroscopic radiation exposure between Total Disc Arthroplasty (TDA) and Anterior Cervical Discectomy and Fusion (ACDF).

Materials and Methods: The authors performed a retrospective chart review of patients who underwent single- or multi-level inpatient TDA or ACDF between 2017 and 2022. Patients were excluded if indicated for revision, trauma, oncologic, or infectious etiologies. TDA and ACDF cohorts were matched according to age, gender, and operative levels. Intraoperative fluoroscopy was performed for identification of level(s), implant positioning, and final confirmation with anteroposterior (AP) and lateral images. Fluoroscopy time was measured in seconds, and estimated radiation dosage was expressed in Gray (Gy). Patient demographics, surgical characteristics, and fluoroscopy parameters were compared between cohorts via independent ***t***-test and across levels via ANOVA.

Results: 168 patients were included for analysis (N = 84 TDA, N = 84 ACDF). All patients had evidence of cervical spinal stenosis, most commonly presenting with cervical myelopathy (N = 41, 24%) and/or cervical radiculopathy (N = 29, 17%). There were no significant differences between groups in mean body mass index (29.18 vs. 29.81, P = 0.73), estimated blood loss (21.4 mL vs. 20.8 mL, P = 0.77) or length of stay (0.71 days vs. 0.83 days, P = 0.52). However, TDA exhibited significantly longer mean operative duration (96.6 minutes vs. 76.4 minutes, P = 0.02). TDA required significantly greater radiation exposure in terms of mean fluoroscopy time, regardless of number of operative levels (Table 1). With regards to radiation dosage, only 3-level TDA required significantly more fluoroscopy than its corresponding ACDF cohort (Table 2). Additionally, a greater BMI was associated with greater radiation burden (Spearman r **=** 0.56, P = 0.02). Level-by-level analysis revealed that fluoroscopic exposure was maximized at more caudal segments (single-level implants: P = 0.02 for time**,** P < 0.001 for dosage; multi-level implants: P < 0.001 for time, P = 0.04 for dosage).

Conclusion: TDA requires a significant amount of intraoperative fluoroscopy, with results demonstrating an over 2.5 times greater duration than that required for ACDF. This difference may be related to the increased intraoperative adjustments necessary for accurate TDA placement. Increased awareness of procedure specific radiation exposure is vital to ensuring the safety of both patients and surgeons.

E-POSTER 21 continued

Table 1. Comparison of fluoroscopy time (mean and standard deviation values expressed as seconds) and dosage (mean and standard deviation values expressed as mGy) between TDA and ACDF.

		Disc Level	TDA	ACDF	P-value
Fluoroscopy Time (s)	1-Level	C4-C5	52.7 ± 1.0	18.1 ± 1.9	**P < 0.001**
		C5-C6	60.9 ± 27.7	19.2 ± 2.8	**P < 0.001**
		C6-C7	61.3 ± 16.2	25.8 ± 8.8	**P < 0.001**
		Overall	59.3 ± 18.9	22.1 ± 7.2	**P < 0.001**
	2-Level	C3-C5	68.4 ± 6.2	19.6 ± 5.0	**P < 0.001**
		C4-C6	89.6 ± 27.6	31.8 ± 11.6	**P < 0.001**
		C5-C7	111.6 ± 43.5	43.0 ± 16.3	**P < 0.001**
		Overall	87.9 ± 32.8	30.5 ± 12.7	**P < 0.001**
	3-Level	C4-C7	103.3 ± 7.7	39.7 ± 6.4	**P < 0.001**
Fluoroscopy Dosage (mGy)	1-Level	C4-C5	4.6 ± 1.0	4.0 ± 2.7	P = 0.69
		C5-C6	5.2 ± 1.0	6.1 ± 0.9	P = 0.18
		C6-C7	23.6 ± 1.3	22.7 ± 23.9	P = 0.91
		Overall	12.21 ± 8.8	11.1 ± 10.2	P = 0.69
	2-Level	C3-C5	2.3 ± 1.2	3.6 ± 1.0	P = 0.1
		C4-C6	9.8 ± 3.8	11.8 ± 4.1	P = 0.45
		C5-C7	11.7 ± 3.2	9.7 ± 5.9	P = 0.52
		Overall	8.1 ± 4.8	8.4 ± 4.3	P = 0.82
	3-Level	C4-C7	13.9 ± 6.3	5.3 ± 2.8	**P = 0.02**

E-POSTER 22

Use of Osteotomy Techniques in Cervical Deformity Procedures: Are Approaches and Practices Changing Over the Years?

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Introduction: Cervical deformity(CD) corrective procedures are ever-evolving, along with the field of spine surgery. The goal of this study was to examine whether surgical advancements over the years have improved or changed outcomes, and the overall way in which we approach CD surgery. The purpose of this study is to investigate if operative approach and outcomes of CD surgery have changed over time in respect to surgical advancements.

Materials and Methods: CD patients(≥18 yrs) with complete BL and 2Y HRQL and radiographic data were included. Descriptive analysis included demographics, radiographic, and surgical details. Patients were stratified into 2 groups based on DOS: early (Group I-2012-2014) and later (Group II-2015-2019). Osteotomies were grouped using grading by Ames et al. into low grade (LGO): Grade 1 & 2, and high grade (HGO): Grade 6 & 7. UVA and MVA analyzed differences in osteotomy usage and radiographic, surgical and clinical parameters. Significant CD was characterized as TS-CL >17° on extension X-ray. Rigid deformity was defined by a change of <10° difference between flexion and extension in cervical lordosis.

Results: 123 CD patients met inclusion criteria(61yrs, 63%F, 29.0kg/m2, CCI: 1±1.4). Radiographically at baseline, patients presented with: PT: 19.6± 11°; PI: 55±13°; PI-LL: .9±17.4°; SVA:-3±68mm, TS-CL: 39 ±21°; cSVA: 45±26. Surgical details were 7.7± 4 levels fused with a mean EBL of 1031mL. By surgical approach, 46% had a posterior approach, 20% anterior, and 37% combined. Group I had 49 patients, and Group II had 74. Group II had a higher CCI (1.1 vs .8, p=.2) while there were no significant differences in number of levels fused, reoperations, DJK development, or HRQL metrics between groups (p>0.05). Overall, 53% of patients had an osteotomy. Patients in Group II had a lower usage of HGO (9% vs 23%, p<0.05). In patients with significant CD, Group II received less HGO(3% vs 33%, p<0.05). In posterior approaches, controlling for age, BL deformity, and CCI, Group II underwent less HGO (OR: .32, 95% CI [.08-1.2] p=.1). Controlling for age, CCI, and BL deformity, Group II had lower usage of HGO in rigid deformity (.197[.04-.97], p<0.05).

Conclusion: Over time, patients undergoing cervical deformity surgery received less high-grade osteotomies, even with high grade deformities. Despite operating on a cohort with a greater degree of comorbidity, there was no deterioration in clinical and radiographic outcomes. These findings reflect a better understanding of surgical management and the utility of invasive osteotomies in adult cervical deformity.

E-POSTER 23

The Incidence of Peripheral Nerve Compression and Cervical Radiculopathy

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Introduction: Cervical radiculopathy and peripheral entrapment neuropathies often have overlapping symptoms that can be difficult to distinguish on physical examination. The aim of this study was to determine the incidence of concomitant cervical radiculopathy and peripheral nerve compression.

Materials and Methods: The PearlDiver Humana database was queried using Current Procedural Terminology (CPT) and International Classification of Diseases (ICD) version 9 and 10 codes from 2010 to 2020. To ensure that patients had severe disease requiring treatment, only patients requiring surgical treatment were included for analysis. The incidence of peripheral neuropathy in cervical radiculopathy as well as the incidence of cervical radiculopathy in peripheral neuropathy was then assessed over the 10 year study period studied. Propensity score matching was used to assess if patients with cervical radiculopathy were more likely to have peripheral nerve compression compared to controls, and vice versa. Patient demographic and comorbidity differences between groups were also included for analysis.

Results: The database contains records of 90,772,632 patients. The incidence of carpal tunnel syndrome (CTS) or ulnar nerve compression in our cervical radiculopathy cohort was 9.98% and 3.15%, respectively. The incidence of both CTS and ulnar nerve compression in the cervical radiculopathy cohort was 1.84%. Patients with cervical radiculopathy were more likely than matched controls to have both CTS (OR 3.91, $p<0.001$) and peripheral ulnar nerve compression (OR 6.09, $p<0.001$). Compared to those who had isolated cervical radiculopathy, those with two or three diagnoses were more likely to be over the age of 65 ($p<0.001$), have comorbidities including diabetes ($p<0.0001$), and be male ($p<0.001$).

Conclusion: The incidence of carpal tunnel syndrome or ulnar nerve compression in cervical radiculopathy is 9.98% and 3.15%, respectively. The incidence of both carpal tunnel syndrome and ulnar nerve compression in cervical radiculopathy is 1.84%. Patients with cervical radiculopathy are more likely than matched controls to have peripheral nerve compression. Patients who are older with more comorbidities are more likely to have more than one diagnosis.

E-POSTER 24

Accomplishing Realignment Goals Withstands the Test of Time: The Outcomes of a Prospective Consecutively Enrolled Single-Center Adult Cervical Deformity Series With Minimum 5-Year Follow-Up

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Introduction: Adult cervical deformity (CD) has been shown to compromise health-related quality of life. While advances in spinal realignment have shown promising short-term and even two-year clinical results in this parameter, the longer term outcomes of CD corrective surgery remain unclear. The purpose of this study is to describe the 5-year outcomes for patients undergoing surgical correction of cervical deformity.

Materials and Methods: Operative CD patients >18 years eligible for 5-year (5Y) follow-up were included. Cervical deformity was defined as meeting at least one of the following radiographic parameters: C2-C7 sagittal kyphosis >15°, TS-CL >35°, segmental cervical kyphosis >15° across any 3 vertebra between C2-T1, C2-C7 SVA >40mm, McGregor's slope >20°, or CBVA > 25°. Optimal thresholds for C2 Slope and T1 Slope by ***Passfall*** et al were assessed. Student's t-test, paired t-test, binary and multivariable logistic regression analyses were used to evaluate the clinical, radiographic, and complications outcomes of the five-year eligible cohort when appropriate.

Results: 58 patients with cervical deformity were enrolled from 2012 to 2017 (54.5 ± 10.3 years, 57% female, BMI 30.0 ± 7.3 kg/m^2, 16% osteoporosis), and underwent surgical correction (levels fused 5.2 ± 2.6, EBL: 772 ± 672 mL, operative time: 372 ± 139 min, LOS: 5.9 ± 8.1 days). By surgical approach, 13.8% anterior-only, 51.7% posterior-only, and 34.5% combined. 53.1% of patients underwent osteotomy (4.6% had a three-column osteotomy), and 45% received BMP. Of the cohort, 53% had undergone a previous cervical surgery, 41% a fusion. Regarding diagnosis, 62% myelopathy and 94% radiculopathy. The most common UIV was C3, and most common LIV was T1. By 3M, patients improved in cervical lordosis, cSVA, and T1 Slope (all p<.02), but not C2 Slope or TS-CL (both p>.5). These measurements did not differ upon paired t-test with parameters at last follow-up, with improvement of cSVA from 3M to last time point (29.6 mm to 27.2 mm, p=.023). The cohort significantly improved from BL to 2Y in NDI, NRS Neck, and EQ-5D (all P<.02). From 2Y to last follow-up, patients did not improve in mJOA or NDI, but did in EQ-5D (0.441 to 0.509) and NRS-Neck (5.9 to 5.0, both p<.05). There were 14 (24.1%) cases of DJK, 6 were distal junctional failure (10.3%), and 17 (29.3%) underwent reoperation. Adjusted analysis controlling for age, levels fused and baseline deformity revealed patients corrected below the T1 Slope threshold of 26.5° and maintained at last follow-up experienced DJK less often (OR: 0.1, 95% CI: 0.02-0.74). Patients corrected below the C2 Slope threshold of 10° and maintained at last follow-up experienced no DJK, DJF or reoperations.

Conclusion: Although complications including distal junctional failure and reoperation remain prevalent, correction of cervical deformity and achievement of realignment targets results

E-POSTER 24 continued

in notable clinical and radiographic improvement with most patients achieving favorable outcomes after two years, with further improvement seen until last follow-up.

E-POSTER 25

Analysis of Capabilities and Utilization of Artificial Intelligence in Adult Cervical Deformity Surgery

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Introduction: Artificial intelligence (AI) and machine learning analytics represents a broad range of computative advances that may offer enhanced preoperative planning, intraoperative robotic or navigational guidance, and prediction of post-operative complications. However, there remains a paucity of literature in regards to the utility of AI in adult cervical deformity (CD) surgery.

Materials and Methods: Operative CD patients ≥18yrs with complete pre-(BL) and up to 2-year(2Y) postop radiographic/HRQL data were stratified by primary utilization AI-based patient-specific rod customization and robotic or navigational assistance in pre- and peri-operative course (AI+) or not (AI-). Differences in demographics, clinical outcomes, radiographic alignment targets, peri-operative factors and complication rates were assessed via means comparison analysis. Analysis of covariance (ANCOVA) assessed post-operative complications while controlling for BL age and CCI.

Results: 215 patients were included (58.11 ± 11.97 years, 48% female, 29.13 ± 6.89 kg/m^2) Of these patients, 32 (11.9%) were classified as AI+. At baseline, patient groups were comparable in BL age, gender, BMI, and CCI (all $p>.05$). In terms of BL radiographic parameters, AI+ patients presented with increased global deformity ($p<.001$), though remained similar in segmental regional deformity (all $p>.05$). Surgically, AI+ patients had significantly shorter operative times overall ($p=.022$) and decreased EBL, regardless if the procedure was staged or same-day ($p=.033$). Though length of stay was equivalent between groups ($p>.05$), AI+ patients were significantly more likely to be discharged to home versus acute or subacute rehab centers ($p<.001$). Post-operatively, AI+ patients with custom rods were noted to have significantly improved global alignment per decreased PI-LL and SVA by 2Y (both $p<.001$). Adjusted complications analysis revealed that AI+ patients were significantly less likely to experience any post-operative complication by 2Y ($p<.001$), radiographic complications ($p=.002$), or operative complications such as dysphasia ($p=.047$). Adjusted analysis of HRQLs also revealed that AI+ patients improved in NDI more rapidly by 1Y versus AI- patients ($p=.011$).

Conclusion: Artificial intelligence, as well as machine learning algorithms, may play a crucial role in the advancement of adult cervical deformity surgery. This study demonstrates that when using AI-based technologies, patients demonstrated lower intra-operative invasiveness, increased likelihood of reaching radiographic alignment targets, improvement in patient-reported outcomes, and decreased complication rates by 2Y.

E-POSTER 26

The Clinical Impact of Addressing Thoracic Secondary Drivers Concurrently at the Onset of Corrective Realignment Surgery for Adult Cervical Deformities

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Introduction: There is a paucity in the literature regarding the clinical and radiographic outcomes of patients with secondary drivers with fusion constructs extending to or past the thoracic apex. Comparative analyses of including or excluding secondary deformity drivers have yet to be conducted.

Materials and Methods: Operative CD patients with Baseline (BL) and 2Year (2Y) HRQL and radiographic data were included, characterized by their primary deformity driver (Cervical/Cervical Thoracic Junction[C]) then further stratified by the presence or absence of a secondary thoracic driver (SD). Patients with a thoracic secondary driver were divided into two groups based on the inclusion (IN) or exclusion (EX) of the thoracic driver apex in the fusion construct. Means comparison tests assessed differences in surgical and radiographic factors between groups. Conditional backstep binary regression controlling for Passias et al. frailty scores and history of prior fusion assessed the effect of secondary driver exclusion on postoperative outcomes.

Results: 94 patients (62.1yrs, 65%F, 27.6kg/m2) were included. 20.2% of patients were categorized as SD+IN. Controlling for BL age, sex, and presence of symptomatic adult cervical deformity requiring operation, BL SD+LF pts had a significantly lower mean BMI (p=.006), significantly lower mean TS-CL (p=.048), and were significantly more likely to be categorized as cSVA-Moderate by Ames et al. criteria (p=.019) than SD+EX patients. SD+IN patients were also significantly less likely to report BL hand numbness (p=.004) or hand clumsiness (p=.008). In terms of surgical differences, SD+ IN patients were significantly more likely to undergo a posterior only approach (p=.001). Additionally, SD+LF patients were more likely to undergo any osteotomy (p=.002), a Smith-Peterson osteotomy (p=.045), or VCR (p=.005). At 1Y post-op, SD+ IN patients had significantly higher mean EQ5D VAS scores (p<.001). Additionally, if the secondary driver was not included in the fusion, patients were significantly more likely to be reoperated for DJK (p=.030). Binary risk analysis revealed that SD+EX patients were at significantly increased risk of severe DJK by 1Y (OR: 10.57 [1.76-63.38], p=.010) and 2Y (OR: 12.09 [1.78-82.19], p=.010), and having short construct alone was associated with significantly increased risk of reoperation by 2Y (OR: 3.79 [1.042-13.80], p=.043).

Conclusion: Patients with secondary thoracic drivers that had fusions extending to the thoracic apex were noted to have more invasive surgical treatment including greater levels fused and greater likelihood of undergoing an osteotomy. Despite the more severe radiographic and neurological markers noted and more invasive surgeries undertaken, patients whose fusions extended past the thoracic driver demonstrated significantly lowered risk of distal junctional kyphosis (DJK) or subsequent reoperation.

E-POSTER 27

Cervical Decompression Surgery Improves Postural Stability and Gait Velocity in Patients with Cervical Spondylotic Myelopathy

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Introduction: CSM is a progressive degenerative condition that can lead to functional deficits and gait instability. Biomechanical changes to a patient's dynamic and postural stability after decompressive surgery are poorly understood. The aim of this study was to determine how spatiotemporal gait parameters, postural stability, and dynamic stability change after decompressive surgery in patients with cervical spondylotic myelopathy (CSM).

Materials and Methods: 47 subjects, including 23 Nurick grade 2 or 3 CSM patients and 24 controls, were included. Biomechanical gait measurements including tilted ellipse area, stride length, cadence, gait velocity, step width, toe-off, double support, and angular momentum excursion were taken at baseline in both cohorts and then at three- and six months following decompression in the CSM cohort. Standing balance trials were performed on a single force plate, and walking trials were conducted at a self-selected pace over a 15m runway and a series of five force plates. All trials were recorded with 3D motion analysis cameras, and gait modeling software was utilized. Statistical analysis was completed using repeated-measures ANOVA to compare measurements at three timepoints, followed by paired t-tests. The significance value was set at $P < 0.05$.

Results: *Tilted Ellipse Area (Postural Stability)*
Postoperative CSM patients had a significant change in postural stability following decompression surgery ($P = 0.030$). Specifically, the CSM group at 6 months (598.0 ± 391.1 mm^2) following surgery was associated with a significant decrease in tilted ellipse area compared to baseline (258.18 ± 103.4 mm^2) measurements ($P = 0.018$). However, there was no difference between 3 (696.2 ± 697.2 mm^2) and 6-months tilted ellipse area ($P = 0.422$).

Spatiotemporal Gait Parameters
The postoperative CSM cohort had a significant change in their gait speed following decompression surgery ($P = 0.029$). Velocity was significantly increased at 6 months compared to baseline (0.852 ± 0.257 m/s) ($P = 0.039$), increasing by 8.14%. Similarly, stride length (m/leg length) and toe-off (% gait cycle) significantly changed during the study period ($P=0.021$ and $P = 0.048$, respectively). However, baseline measurements were not significantly different compared to 3- and 6-months postoperative measurements. Therefore, stride length and toe-off were not considered to have significantly improved following surgery. Finally, step-width (mm/leg length), double support (% gait cycle), and cadence (steps/min) were not statistically significant following surgery ($P > 0.05$).

Angular Momentum Excursion (Dynamic Stability)
Whole-body angular momentum was not significantly different in any anatomic plane during the study period ($P > 0.05$).

Conclusion: Decompressive surgery in CSM patients was associated with significant improvement in gait velocity and postural stability. However, there was no significant change

E-POSTER 27 continued

in dynamic stability throughout the study period.

Parameters		Mean ± SD								P Repeated Measures ANOVA	P Paired T-Test Baseline vs. 3M	P Paired T-Test Baseline vs. 6M	P Paired T-Test 3M vs. 6M
		Control Baseline		CSM Baseline		3 Months Post		6 Months Post					
Postural Stability	Tilted Ellipse Area (mm^2)	258.18	±103.35	979.8	±856.7	696.2	±697.2	598.0	±391.1	**0.03**	**0.012**	**0.018**	0.422
	Variance A/P (mm)	9.17	±4.83	50.1	±62.5	31.5	±34.8	25.3	±25.6	0.136			
	Variance M/L (mm)	29.15	±14.95	79.5	±57.7	66.0	±76.2	63.6	±36.9	0.401			

Parameters		Mean ± SD								P Repeated Measures ANOVA	P Paired T-Test Baseline vs. 3M	P Paired T-Test Baseline vs. 6M	P Paired T-Test 3M vs. 6M
		Control Baseline		CSM Baseline		3 Months Post		6 Months Post					
Spatiotemporal Parameters	Stride Length(m/leg length)	1.32	±0.12	1.042	±0.230	1.060	±0.228	1.112	±0.216	**0.021**	0.594	0.105	**0.005**
	Cadence (steps/min)	107.37	±9.87	96.3	±14.9	98.3	±13.8	101.0	±14.2	0.055			
	Velocity ((m/s)/leg length)	1.18	±0.15	0.852	±0.257	0.883	±0.251	0.948	±0.248	**0.029**	0.395	**0.039**	**0.008**
	Step width(mm/leg length)	0.154	±0.035	0.212	±0.061	0.204	±0.059	0.207	±0.060	0.251			
	Toe off (% gait cycle)	63.27	±1.96	67.1	±5.1	66.9	±4.6	66.1	±3.9	**0.048**	0.707	0.219	**0.014**
	Double support (% gait cycle)	27.0	±0.04	34.6	±9.9	33.8	±9.2	32.4	±7.5	0.085			

E-POSTER 27 continued

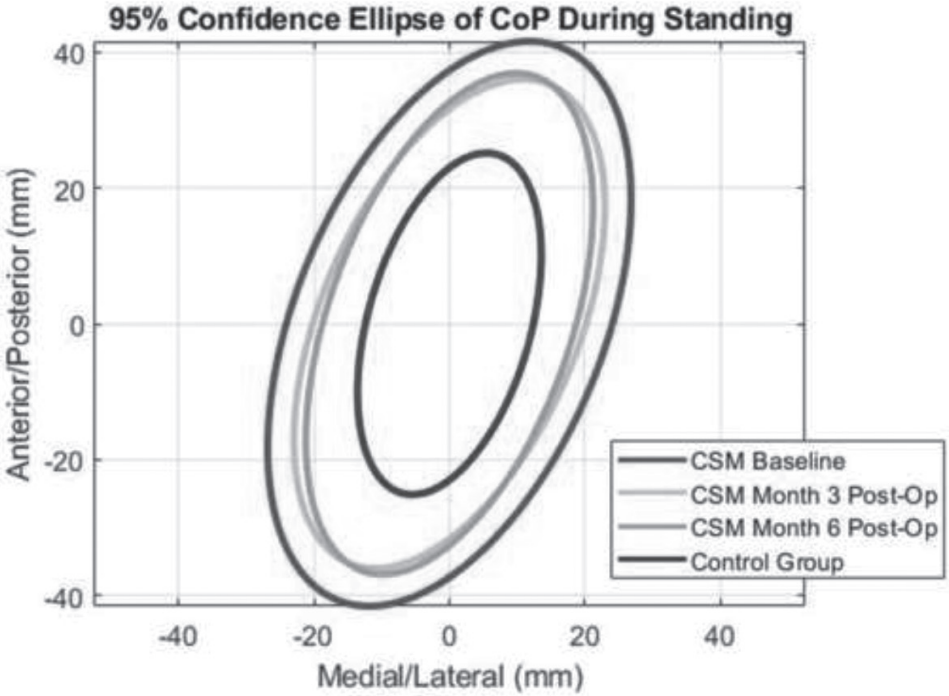

Figure 1. Postural Stability measured through center of pressure (CoP). Baseline CSM patients with corresponding ellipse area in red. Representative ellipse area of controls in shown in blue. Postoperative tilted ellipse measurements for three and six months are represented in yellow and green respectively

E-POSTER 28

Correlation between Horizontal gaze and Sagittal Cervical Alignment New morphological parameters correlated to Sagittal Cervical Parameters

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Introduction: Cervical lordosis and sagittal cervical parameters are known to be correlated to C7-slope

Little or not of the horizontal gaze parameters correlates with cervical lordosis and sagittal cervical parameters

To introduce new orbito-cervical parameters correlated to sagittal cervical parameters

Materials and Methods: 127 Asymptomatic volunteers maintaining a horizontal gaze undergoing an upright from head to foot lateral radiograph in a single institution. Statistical correlation between Orbito-Cervical Incidence (OCI), Orbito-Cervical Tilt (OCT), C1-Slope (C1S) and sagittal cervical parameters OCI, OCT, C1S, McGregor Slope (McGS) and C1-C7 Cervical Lordosis were evaluated in 127 asymptomatic volunteers (52 male, 75 female; mean age 27 years; range 18-48 yrs). Comparison between sagittal cervical parameters used Shapiro-Wilk, Lilliefors, Anderson-Darling, Agostino and Jarque-Bera tests

Results: Mean OCI, OCT, C1S and McGS were respectively 75.9° 7.2°, 66.8° 6.9°, 9.8° 6.6°, and -5,46,7. Normal distribution was observed for this parameters. Linear regression was observed for the formula : OCI=C1S+OCT (r^2=0,91). Significant correlation was observed between C1S and OCI (r=0,5, p=0,01), C1S and OCT (r=-0,51, p=0,01), C1S and C1-C7 lordosis (r=0,65, p=0,01), C1S and McGS (r=0,64, p=0,01), OCT and McGS (r=-0,78, p=0,01). No significant correlation was found with pelvic parameters.

Conclusion: Although asymptomatic adults stood with stable horizontal gaze, this is the first description of morphological parameters connected to sagittal cervical parameters. These findings open a new point of view on normal and pathological sagittal cervical alignment

E-POSTER 29

Comparison of Opioid Prescription with One Level Anterior Cervical Discectomy and Fusion between Years 2014-2015 and 2018-2019: Risks and Regional/Specialty Variations

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Introduction: Perioperative pain management especially opioid prescriptions has been implicated as a significant contributing factor in the United States (US) opioid crisis. As spine surgeons' work primarily deals with painful conditions, changing recommendations for opioid prescriptions in the past decade has necessitated considerable alterations in practice patterns. However, the large-scale implementation of these changes, along with variations and changes by specialty training or region, have not been well characterized. In this study, a national database was used to investigate such differences in opioid use in patients undergoing one-level anterior cervical discectomy and fusion (ACDF).

Materials and Methods: This study utilized the PearlDiver national claims database, composed of 91 million longitudinally followed patients. We identified patients who underwent a single-level ACDF in 2014-2015 and 2018-2019 for comparison, as there were numerous and significant national/regional changes in guidelines on opioid prescriptions from 2016-2017. We compared opioid use by morphine milligram equivalents (MME) within three-time points (TPs): 90 days before, 90 days after, and 365 days after the surgery. The MME data was then compared between operating specialties: neurosurgery vs orthopedics. Mean differences in MME use between the years and specialties were compared using t-tests, and differences in the percent of users were compared using contingency table analyses. The MME data was also further analyzed for regional differences by dividing the US into four separate regions: Northeast (NE), Midwest (MW), West (WE), and South (SO), compared using ANOVA statistics. Logistic regression was performed to find factors associated with opioid use for both 2014-2015 and 2018-2019.

Results: There was an overall 44.3%, 44.2%, and 47.1% decrease in mean MME use 90 days pre-op, 90 days post-op, and 365 days post-op, respectively, from 2014-2015 to 2018-2019 (Figure 1). In 2014-2015, univariate analysis showed opioid use was statistically significantly higher among orthopedic patients (12.6%, 11.8%, 9.7% by TPs) compared with neurosurgery patients. For 2018-2019, these differences stayed significant at 90 days pre-op and 90 days post-op (9.6% and 12.5% higher for orthopedics), however, the MME difference was only 0.8% at 365 days postop ($p=0.4626$). For both composite groups, the highest opioid use was seen in the WE and the lowest in the MW for all three TPs ($p<0.0001$), with a greater than 40% difference between the WE and MW at 365 days post-op (Figure 2). Multivariate logistic regression for opioid use 90 days after the surgery showed no significant differences between the specialties in either of the two-year composite groups, whereas the regional variations remained statistically significant.

Conclusion: The numerous changes in state and medical society opioid guidelines published around 2016-2017 appear to have had a substantial impact on postoperative opioid prescribing in patients who underwent ACDF. Although some differences were found in opioid use between the two specialties in univariate analysis, these differences disappeared in multivariate logistic regression analysis. Despite the reduction in opioid MME use in all four

E-POSTER 29 continued

regions, significant regional variations remain. Pre-op opioid use remains the highest risk for post-op opioid use both in 2014-2015 and 2018-2019.

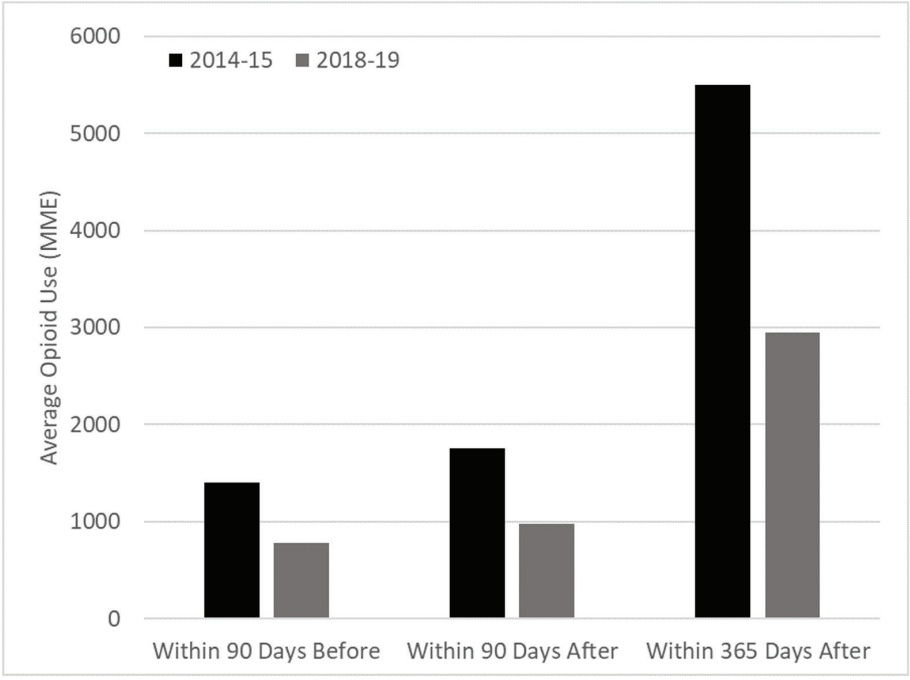

Figure 1. National average opioid use in patients undergoing ACDF during 2014-2015 versus 2018-2019.

E-POSTER 29 continued

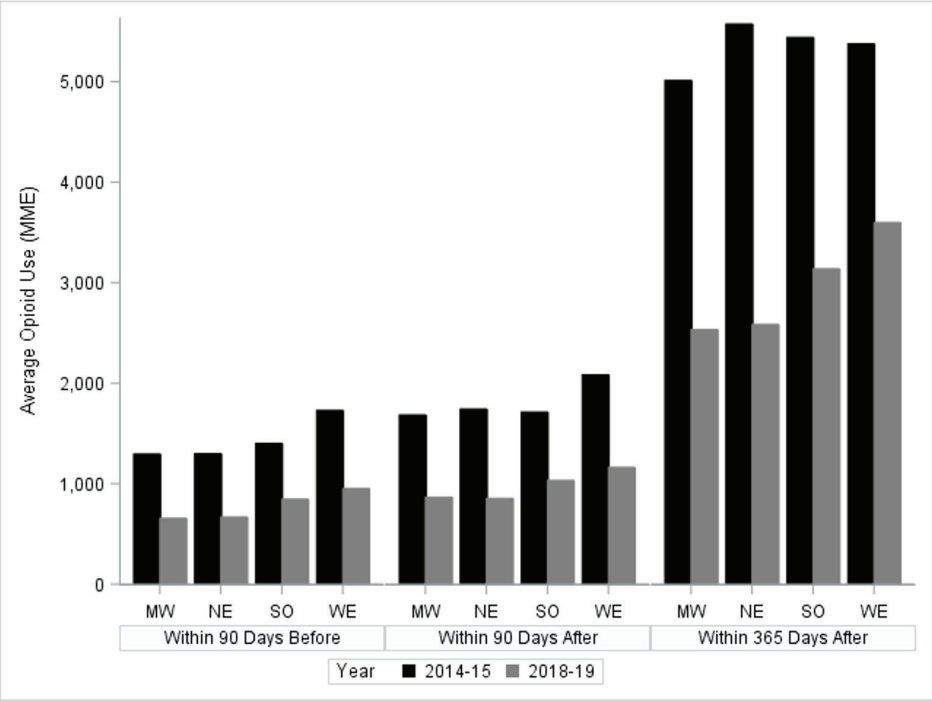

Figure 2. Regional average opioid use in patients undergoing ACDF during 2014-2015 versus 2018-2019.

E-POSTER 30

Sex Differences in Response to Recombinant Human Bone Morphogenetic Protein-2 (rhBMP-2) in a Rat Posterolateral Fusion Spine Model

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Introduction: Estrogen modulates bone activity largely through inhibition of osteoclast bone resorption and bone morphogenetic protein-2 (BMP-2) signaling pathways in osteoblasts. Minimal data exist concerning potential sex-dependent differences in BMP-2-mediated bone regeneration. Here, we aimed to quantify sex dependent differences in the bone healing response to recombinant human BMP-2 (rhBMP-2) treatment in a rat posterolateral spinal fusion model.

Materials and Methods: Forty-eight female and male Sprague-Dawley rats (N=24/group), underwent L4-L5 posterolateral fusion with bilateral placement of recombinant human BMP-2 (rhBMP-2) implants. At 8 weeks post-operatively, spines were evaluated for mobility and bone fusion by range of motion (ROM), blinded manual palpation, and microCT. Adipocyte concentration quantification was accomplished by counting adipocytes in equally sized fields of view on histological imaging.

Results: Males had significantly higher rates of fusion compared to females when assessed by manual palpation. ROM was significantly greater and more variable for females versus males. microCT showed fine bone structures developing in both sexes at the 8 week time point. In females, there was significantly smaller total volume of fusion masses, but significantly higher bone volume fraction when compared to males. Mean trabecular thickness was not different, but trabecular number was significantly greater in females. Adipocyte concentration quantification showed a higher adipocyte concentration in males versus females.

Conclusion: This study demonstrates that sex-based factors may influence both the quantity and quality of bone formation in patients receiving rhBMP-2 for a variety of orthopaedic applications. We found that male rats had significantly higher fusion scores, greater fusion-mass volume, and lower ratio of new bone volume to total volume as well as greater adipocyte concentration compared to female rats. Male and female mean trabecular thicknesses were equal, but the female fusion masses were more densely filled with trabeculae (higher trabecular number) than those of males. Incomplete fusions on three female rats, evidenced by high ROM and small gaps on microCT, suggest that females may have a more variable response to rhBMP-2. Investigation into whether these sex-based differences are specific to rhBMP-2-induced bone formation or are more general to bone regeneration/healing is prudent.

E-POSTER 30 continued

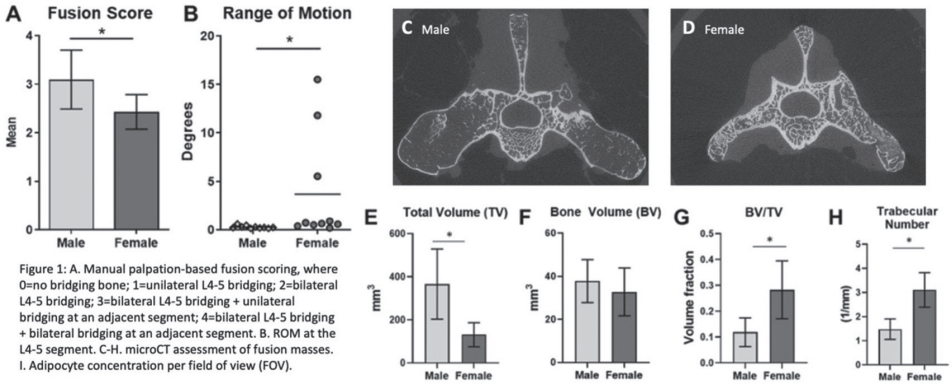
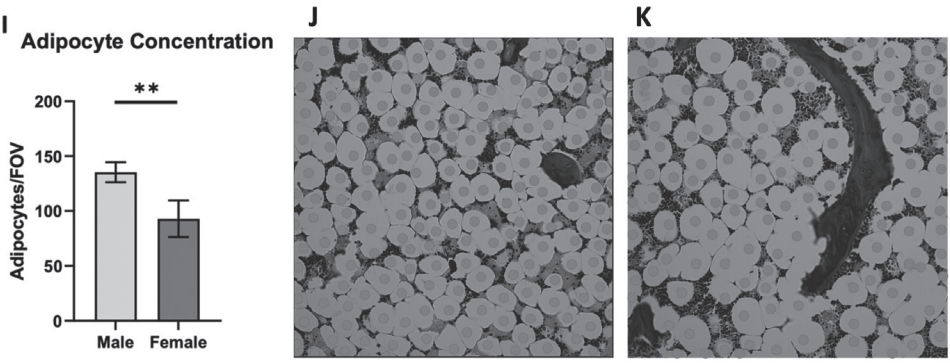


Figure 1: A. Manual palpation-based fusion scoring, where 0=no bridging bone; 1=unilateral L4-5 bridging; 2=bilateral L4-5 bridging; 3=bilateral L4-5 bridging + unilateral bridging at an adjacent segment; 4=bilateral L4-5 bridging + bilateral bridging at an adjacent segment. B. ROM at the L4-5 segment. C-H. microCT assessment of fusion masses. I. Adipocyte concentration per field of view (FOV).



E-POSTER 31

A New High-Speed Shielded Curved Drill for Osteophyte Removal in Cervical Corpectomy and Fusion Procedures: A Retrospective Case Series

Hani Malone, MD, Richard Guyer, MD, Michael Millgram, MD[1], Ely Ashkenazi, MD
Israel Spine Center[1]

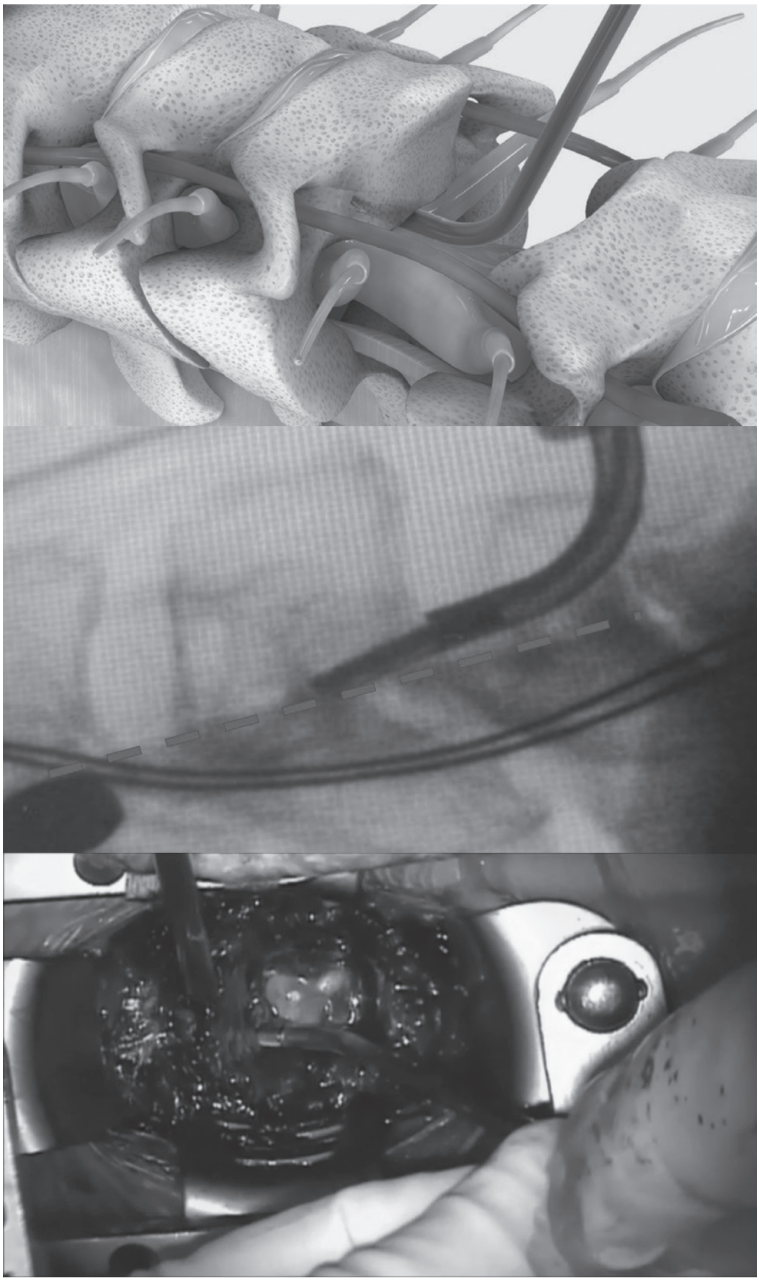
Introduction: Anterior Cervical Corpectomy and Fusion (ACCF) is an effective technique to address multi-level degenerative cervical myelopathy (DCM). However, as the number of surgical levels increases, the outcomes worsen with respect to complication rates, range of motion, and length of surgery. This study aimed to determine the clinical outcome of ACCF procedures performed using a new distally curved and shielded drilling device.

Materials and Methods: A retrospective study of forty-three patients treated for osteophyte removal using the device during ACCF procedures was conducted. Patient files were reviewed to assess the early clinical results and complications following ACCF. Clinical outcomes were evaluated using patient neck and arm pain scores and SF-36 questionnaires.

Results: All procedures were uneventful and without major complications or neurological deterioration. Single-level ACCF procedures required an average of 71 minutes and followed by an average hospitalization of 3.3 days. Osteophyte removal, verified by intraoperative imaging, was satisfactory. Average neck pain score was improved by 0.9 points (p=0.24). Average arm pain score was improved by 1.8 points (p=0.06). SF-36 scores were improved in all domains.

Conclusion: The new curved device enabled safe and efficient removal of osteophytes sparing adjacent vertebral removal in ACCF procedures, thus improving the clinical outcome.

E-POSTER 31 continued



E-POSTER 32

Are Variable Screw Angle Change and Screw-to-Vertebral Body Ratio Associated with Radiographic Subsidence following Anterior Cervical Discectomy and Fusion?

Philip Louie, MD[1], Spencer Raub, BS, Jesse Shen, MD[2], Caroline Drolet, PhD, Nicole Vivelo, ARNP, Michelle Gilbert, PA-C, Kellen Nold, PA-C, Jean-Christophe Leveque, MD, Venu Nemani, MD, PHD
Virginia Mason Franciscan Health[1] Virginia Mason Medical Center[2]

Introduction: Graft subsidence has been described as an inherent process in graft placement and healing following anterior cervical discectomy and fusion. However, excessive subsidence can lead to worsening neck pain, additional stenosis, and thus, a potential re-operation. Various factors have been identified as risk factors for subsidence including graft type, graft location, sagittal alignment change, number of levels, and bone mineral density. However, two other important variables: screw length and changes in variable screw angle over time, have not been evaluated in relation to subsidence. Longer screws are correlated with increased pull-out strength and reduction in pseudarthrosis rates. No studies have examined the impact of the change in angle of variable screw placement over time. Thus, the purpose of this study was to evaluate the impact of the screw-to-vertebral body ratio and change in angle of variable screws placed at the cephalad and caudal aspects of the construct on subsidence rates, based on interscrew distance and intradiscal heights (anterior/middle/posterior).

Materials and Methods: A retrospective cohort analysis was performed on consecutive patients who underwent a 1-3 level ACDF (allograft or PEEK cage) for degenerative pathology between January 2018 and June 2021 with 6 months follow-up by 3 spine-fellowship trained surgeons with similar techniques at a single center. Pre- and 6-month post-operative radiographic assessment included intradiscal height (ant/mid/post), intervertebral screw distance, and screw-vertebral body ratio of the cephalad and caudal screws (Figure 1). Demographic information, complications, and re-operation data was obtained.

A multivariate analysis was performed between the various radiographic measurements and demographic variables.

Results: In total, 65 patients undergoing a 1-3 level ACDF met inclusion criteria with 6 months follow-up. Graft type and number of levels fused consistently have no significant effect on any of the subsidence outcomes. Aside from females experiencing greater subsidence than males based on interscrew distance at both the top ($p=0.02$) and bottom levels ($p=0.01$), demographic variables are not associated with amount of subsidence.

Greater screw-to-vertebral body ratio is associated with less subsidence ($p<0.05$; Table 1). The amount of variable screw angle change at the cephalad and caudal aspect of the construct do not impact the amount of subsidence observed. No patients reported neck pain in the setting subsidence greater than 3mm in any of the 4 measurements. Overall, no re-operations were performed for subsidence-related pathology.

Conclusion: At a single center with similar surgical techniques, the change in angle of variable screws placed at the cephalad and caudal aspect are not associated with radiographic subsidence following anterior cervical discectomy and fusion for degenerative pathology 6 months following surgery. Greater screw-to-vertebral body ratio may be protective against some regions of radiographic subsidence. The clinical impact of these subsidence differences

E-POSTER 32 continued

is an area of ongoing investigation.

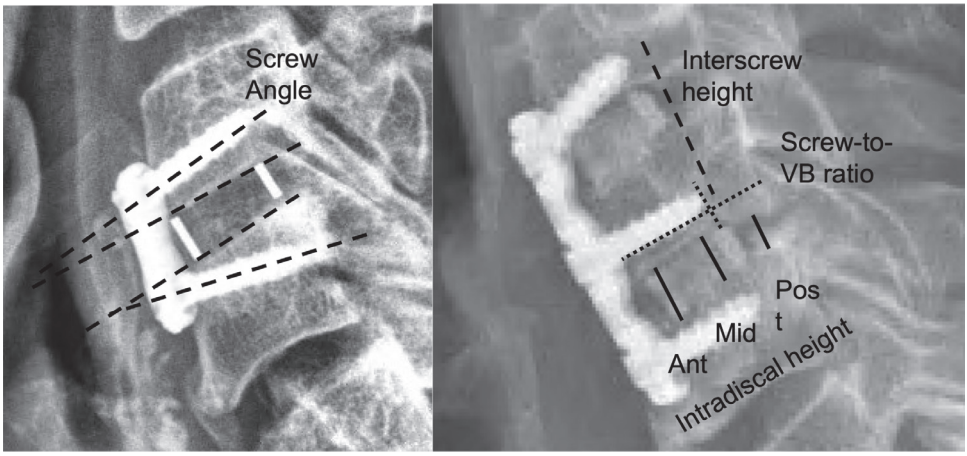


Figure 2. Subsidence Evaluation and Associations

	Anterior Disc Height	Middle Disc Height	Posterior Disc Height	Interscrew Distance
Top Level	None	**Screw-vertbody ratio (p=0.04)**	**Screw-vertbody ratio (p=0.04)**	**Female**
Bottom Level	None	None	None	**Female**

"**None" –** no significant association between variable screw angle change or screw-to-vertebral body ratio and the subsidence measurement listed.
"**Screw-vertbody ratio"** - greater screw-to-vertebral body ratio was associated with less subsidence
"**Female"** – female patients experienced greater subsidence compared to male patients

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