46TH

FORTY-SIXTH ANNUAL MEETING

OF THE

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

December 6 - 8, 2018

The Phoenician Resort
Scottsdale, Arizona

Jeffrey C. Wang, MD, ***President***
Christopher P. Ames, MD and Robert A. Hart, MD, ***Scientific Program Co-Chairs***

www.csrs.org

FUTURE INSTRUCTIONAL COURSES

Nov. 20, 2019	Marriott Marquis, New York, NY
Dec. 9, 2020	The Cosmopolitan, Las Vegas, NV

FUTURE ANNUAL MEETINGS

Nov. 21-23, 2019	Marriott Marquis, New York, NY
Dec. 10-12, 2020	The Cosmopolitan, Las Vegas, NV

The material presented at this Annual Meeting has been made available by the CERVICAL SPINE RESEARCH SOCIETY for educational purposes only. This material is not intended to represent the only, nor necessarily best, methods or procedures appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement or opinion of the Author(s), which may be helpful to others who face similar situations.

CONTINUING EDUCATION CREDIT

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of the American Academy of Orthopaedic Surgeons and the Cervical Spine Research Society. The American Academy of Orthopaedic Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

The American Academy of Orthopaedic Surgeons designates this live activity for a maximum of **20.25 *AMA PRA Category 1 Credits™***. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

The American Association of Neurological Surgeons accepts these AMA PRA Category 1 Credits™ *towards the Continuing Education Award in Neurosurgery to maintain membership in the AANS and towards Maintenance of Certification. You must submit a copy of the certificate to AANS for inclusion in your record:*

AANS
Member Services Department
5550 Meadowbrook Industrial Court
Rolling Meadows, IL 60008
Phone: (847) 378-0500
Fax: (847) 378-0638
E-mail: cme@aans.org

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

Cervical Spine Research Society
9400 W. Higgins Rd., Suite 500
Rosemont, IL 60018-4976
Phone: (847) 698-1628 l Fax: (847) 268-9699
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Administrative Staff
Kerri Mink, Executive Director
Lisa DuShane, Society Coordinator

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Cervical Spine Research Society

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Rosemont, Illinois 60018-4976
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CSRS 2018 Annual Meeting – Events

Wednesday, December 5

Faculty Appreciation Reception *Open to all registered attendees*

Camelback Ballroom *No prior registration required*

5:00 pm—6:00 pm

NuVasive Industry Event *Prior registration required*

An Evening & Discussion with Cervical Thought Leaders – A Collegial Exchange of Ideas

Grand Ballroom ABC

6:00 pm—8:00 pm

If you would like to attend this event, please contact Jennica Reeves at jreeves@nuvasive.com

Thursday, December 6

Welcome Reception *Open to all registered attendees*

Camelback Ballroom *No prior registration required*

4:30 pm—6:30 pm

Medtronic Industry Dinner *No prior registration required*

How to Navigate Posterior Cervical: SynergyPCF℠ *with Infinity™ OCT System*

Live Surgeon Panel Broadcast with Navigated C1-T3 Case Discussion

Grand Ballroom ABC

6:30 pm Dinner

7:00 pm Case Discussion

FOUNDED 1973

Origins of the Society

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

The concept of a sub-specialty group devoted to the cervical spine was first considered in 1966.

As interest in this area grew, a preliminary meeting to consider the formation of such an organization was held in Las Vegas, Nevada, in February, 1973, during the annual meeting of the American Academy of Orthopaedic Surgeons.

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

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

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

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

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

J. William Fielding, MD

2018 Officers

President	Jeffrey C. Wang, MD
Immediate Past President	Darrel S. Brodke, MD
Past President	Robert F. Heary, MD
President Elect	Alexander R. Vaccaro, MD, PhD, MBA
Vice-President	Rick Sasso, MD
Treasurer	Alexander J. Ghanayem, MD
Secretary	James S. Harrop, MD

2018 Committees

Awards Committee

D. Greg Anderson, MD, Chair	2018
Erica F. Bisson, MD, MPH	2020
Samuel K. Cho, MD	2020
Gary Ghiselli, MD	2020
Wellington K. Hsu, MD	2018
Sukhvinder Kalsi-Ryan, MSc, PhD	2018
Eric B. Laxer, MD	2020
Michael J. Lee, MD	2020

Board of Specialty Societies

R. Alden Milam, MD - Member Rep	2020
Darrel S. Brodke, MD - PL Rep	2020

Communications Committee

Thomas E. Mroz, MD, Chair	2020
Jeffrey A. Rihn, MD	2018
W. Ryan Spiker, MD	2018
Jim A. Youssef, MD	2018

Continuing Medical Education Committee

Justin Smith, MD, PhD, Chair	2019
Jacob M. Buchowski, MD, MS	2018
Louis G. Jenis, MD	2018
Kristen E. Radcliff, MD	2019
Brian W. Su, MD	2018

Development Committee

Jean-Jacques Abitbol, MD, Chair	2020
Darrel S. Brodke, MD	2018
Sanford E. Emery, MD, MBA	2018
Alexander R. Vaccaro, MD, PhD, MBA	2018
Bruce Darden, MD	2019

Ethics/Conflict of Interest Oversight Committee

Jeffrey S. Fischgrund, MD, Chair	2019
Paul A. Anderson, MD	2019
Leo Spector, MD	2020

Exhibits Committee

Alpesh A. Patel, Chair	2019
Scott C. McGovern, MD	2020
Praveen V. Mummaneni, MD	2018

Finance Committee

Alexander J. Ghanayem, MD, Chair	2020
Darrel S. Brodke, MD	2019
Robert F. Heary, MD	2018
Alan S. Hilibrand, MD	2018
Jim A. Youssef, MD	2020
Jeffrey C. Wang, MD	2018

Instructional Course Planning Committee

Michael D. Daubs, MD, Chair	2019
John C. France, MD	2020
Darren R. Lebl, MD	2018
Praveen V. Mummaneni, MD	2018
Clinton J. Devin, MD	2019
Michael C. Gerling, MD	2020

Long Range Planning Committee

Jeffrey D. Coe, MD, Chair	2018
Timothy A. Garvey, MD	2019
John Heller, MD	2019
Thomas E. Mroz, MD	2020
Clifford B. Tribus, MD	2018

Membership Committee

Timothy A. Garvey, MD, Chair	2018
Andrew T. Dailey, MD	2019
Alexander P. Hughes, MD	2020
Ronald A. Lehman Jr., MD	2018
Ahmad Nassr, MD	2019

Neuro-Ortho Society Liaison Committee

James S. Harrop, MD, Neuro Chair	2018
John C. France, MD, Ortho Chair	2018
Carlo Bellabarba, MD	2020
Michael P. Steinmetz, MD	2020

Nominating Committee

Robert F. Heary, MD, Chair	2018
Darrel S. Brodke, MD	2019
Paul Arnold, MD	2018
Douglas G. Orndorff, MD	2018
Leo Spector, MD	2018

2018 Committees

Patient Education Committee

Christopher I. Shaffrey, MD, Chair	2020
Wayne K. Cheng, MD	2020
Clinton J. Devin, MD	2019
Steven S. Hughes, MD	2020
Douglas G. Orndorff, MD	2020

Program Committee

Christopher P. Ames, MD, Co-Chair	2018
Robert Hart, MD, Co-Chair	2018
Erica F. Bisson, MD	2018
Jacob M. Buchowski, MD	2019
Hans-Ulrich Bueff, MD	2018
Andrew T. Dailey, MD	2020
William F. Donaldson III, MD	2020
Andrew C. Hecht, MD	2020
Han-Jo Kim, MD	2020
Brian K. Kwon, MD	2020
Ronald A. Lehman Jr., MD	2020
Addisu Mesfin, MD	2019
Thomas E. Mroz, MD	2020
Themistocles Protopsaltis, MD	2020
Lee H. Riley, III, MD	2018
P. Bradley Segebarth, MD	2018
Justin Smith, MD, PhD	2018
W. Ryan Spiker, MD	2019
Brian W. Su, MD	2018
Clifford B. Tribus, MD	2018
Eeric Truumees, MD	2020
Jean-Paul Wolinsky, MD	2018
Michael D. Daubs, MD (ex officio)	2019
Lou Jenis, MD (ex officio)	2020
Alpesh A. Patel, MD (ex officio)	2019

Publications Committee

Alpesh A. Patel, MD, Chair	2019
Christopher P. Ames, MD	2018
Jeffrey D. Coe, MD	2018
Rick Sasso, MD	2019
Daniel M. Sciubba, MD	2019

Research Committee

Zoher Ghogawala, MD, Chair	2019

Research Committee (continued)

21st Century Grant Subcommittee

Clifford B. Tribus, MD, Chair	2020
Andrew T. Dailey, MD	2020
Michael P. Kelly, MD	2018
Themistocles Protopsaltis, MD	2019
Daniel M. Sciubba, MD	2018
Tim Yoon, MD	2018

Seed Starter Grant Subcommittee

Brandon D. Lawrence, MD, Chair	2019
Jonathan N. Grauer, MD	2018
Ahmad Nassr MD	2018
Avinash Patwardhan, PhD	2018
Jason Savage, MD	2019
P. Justin Tortolani, MD	2019

Resident Fellow Grant Subcommittee

Paul M. Arnold, MD, Chair	2018
Nitin N. Bhatia, MD	2020
Ivan Cheng, MD	2018
Kristen E. Radcliff, MD	2018
Richard Skolasky, Jr. ScD	2019
Michael P. Steinmetz, MD	2018

Member Survey Subcommittee

James S. Harrop, MD, Chair	2019
Jacob M. Buchowski, MD, MS	2018
Han-Jo Kim, MD	2020
Steven C. Ludwig, MD	2018
Mark L. Prasarn, MD	2018
Kern Singh, MD	2018
Justin Smith, MD, PhD	2020

Special Projects Committee

Jeffrey A. Rihn, MD, Chair	2018
Erica F. Bisson, MD	2019
Christopher M. Bono, MD	2018
Zoher Ghogawala, MD	2019
John K. Houten, MD	2018
John S. Kirkpatrick, MD	2018
Addisu Mesfin, MD	2018
Thomas E. Mroz, MD	2020
Alpesh A Patel, MD	2019
Jim A. Youssef, MD	2020

2018 Committees

Traveling Fellowship Committee

John M. Rhee, MD, Chair	2019
Bruce V. Darden, II, MD	2018
Michael G. Fehlings, MD, PhD	2018
Ivan Cheng, MD	2019
Regis W. Haid Jr., MD	2018
Langston T. Holly, MD	2018

Thank you 2018 Exhibit Companies
Please visit our Exhibitors in the Camelback Ballroom

4WEB Medical
Frisco, TX
Booth #101

AlloSource
Centennial, CO
Booth #500

Biologica Technologies
Carlsbad, CA
Booth #411

Bioventus, LLC
Durham, NC
Booth #107

Centinel Spine
New York, NY
Booth #508

Cerapedics, Inc.
Westminster, CO
Booth #401

DePuy Synthes Spine
Raynham, MA
Booth #400

Globus Medical, Inc.
Audubon, PA
Booth #200

Innovasis
Salt Lake City, UT
Booth #501

K2M, Inc.
Leesburg, VA
Booth #303

Life Instrument Corporation
Braintree, MA
Booth #408

Medfix International, LLC
Tucson, AZ
Booth #509

Medtronic
Memphis, TN
Booth #201

Medyssey USA, Inc.
Elk Grove Village, IL
Booth #503

NeuroStructures, Inc.
Irvine, CA
Booth #510

NuVasive, Inc.
San Diego, CA
Booth #300

Orthofix, Inc.
Lewisville, TX
Booth #211

Piezosurgery, Inc.
Columbus, OH
Booth #410

Providence Medical Technology
Walnut Creek, CA
Booth #403

RayShield, LLC
Tempe, AZ
Booth #602

RTI Surgical
Austin, TX
Booth #209

SeaSpine
Carsbad, CA
Booth #507

SpineFrontier, Inc.
Malden, MA
Booth #310

Spine Wave, Inc.
Shelton, CT
Booth #206

Stryker
Allendale, NJ
Booth #301

TeDan Surgical Innovations
Sugar Land, TX
Booth #502

Terumo BCT
Lakewood, CO
Booth #103

Thompson Surgical Instruments, Inc.
Traverse City, MI
Booth #308

Titan Spine
Mequon, WI
Booth #409

Tobra Medical
Wake Forest, NC
Booth #600

Wiggins Medical
Cincinnati, OH
Booth #109

Zimmer Biomet
Westminster, CO
Booth #309

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President:	Jeffrey C. Wang, MD
Program Co-Chairs:	Christopher P. Ames, MD Robert A. Hart, MD

Scientific Meeting Objectives

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

7:00–7:10 am	**Welcome and Announcements** *Christopher P. Ames, MD and Robert A. Hart, MD, Program Co-Chairs*
7:11–7:48 am	**Session I:** **OUTCOMES I** Moderators: ***Paul M. Arnold, MD & Bradford L. Currier, MD***
7:11–7:16 am Presentation #1 (pg. 104)	**Does the Duration of Cervical Radicular Symptoms Impact Outcomes Following Anterior Cervical Discectomy and Fusion?** *Bryce A. Basques, MD; Philip K. Louie, MD; Michael Nolte, MD; Jannat M. Khan, BS; Deven Carroll, MS; Justin C. Paul, MD; Arya Varthi, MD;* ***Edward J. Goldberg, MD****; Howard S. An, MD*
7:17–7:22 am Presentation #2 (pg. 111)	**Does Duration of Preoperative Radiculopathy Symptoms Impact Postoperative Outcomes and Reoperations After an ACDF?** *Daniel Tarazona, MD; Kerri Bell, BS; Taolin Fang MD; I. David Kaye, MD; Christopher K. Kepler, MD; MBA; Mark F. Kurd, MD; Alan S. Hilibrand, MD; Barrett I. Woods, MD; Kris E. Radcliff, MD; Jeffrey A. Rihn, MD; D. Greg Anderson, MD; Alexander R. Vaccaro, MD, PhD, MBA;* ***Gregory D. Schroeder, MD***
7:23–7:28 am Presentation #3 (pg. 113)	**Effect of Postoperative Increase in Disc Height on Clinical Outcomes in Anterior Cervical Discectomy and Fusion Patients** *Thomas Toole, BS; Swamy Kurra, MBBS; Pierce D. Nunley, MD;* ***Richard A.Tallarico, MD****; William F. Lavelle MD*
7:29–7:34 am Presentation #4 (pg. 115)	**Disparities in Outcomes By Payer Groups for Patients Undergoing Anterior Cervical Discectomy and Fusion** *Jonathan J. Rasouli, MD;* ***Sean N. Neifert, BS****; Daniel J. Snyder, BS; Jonathan S. Gal, MD; Jeremy Steinberger, MD; Brian C. Deutsch, BS; John M. Caridi, MD*
7:35–7:48 am	Discussion
7:49–8:26 am	**Session II:** **SURGICAL TECHNIQUE** Moderators: ***Regis W. Haid Jr., MD & Michael P. Kelly, MD***
7:49–7:54 am Presentation #5 (pg. 117)	**Posterior Foraminotomy vs. Anterior Decompression and Fusion in Patients with Cervical Degenerative Disc Disease with Radiculopathy – Five-Year Outcomes from the National Swedish Spine Register** ***Anna MacDowall, MD, PhD****; Marek Holy, MD; Claes Olerud, MD, PhD*

7:55–8:00 am
Presentation #6
(pg. 118)

In-Situ Decompression to Spinal Cord During Anterior Controllable Antedisplacement Fusion Treating Degenerative Kyphosis with Stenosis: Surgical Outcomes and Analysis of C5 Nerve Palsy Based on 49 Patients
Haisong Yang, MD; ***Jiangang Shi, MD***

8:01–8:06 am
Presentation #7
(pg. 120)

Subgroup Analysis on the Efficacy of Anterior Cervical Discectomy with or without Interbody Fusion or Arthroplasty in the Treatment of Cervical Radiculopathy: Combined Clinical Results of Two Randomised Controlled Trials
Caroline M.W. Goedmakers*; Ronald H.M.A. Bartels; Erik W. van Zwet; Carmen L.A. Vleggeert-Lankamp*

8:07–8:12 am
Presentation #8
(pg. 122)

A Comparison of Three Different Positioning Techniques on Surgical Corrections and Post-Operative Alignment in Cervical Deformity Surgery
Brandon Carlson, MD*; Renaud Lafage, MS; Tejbir S. Pannu, MD, MS; Peter G. Passias, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Christopher I. Shaffrey, MD; Gregory Mundis, MD; Themistocles Protopsaltis, MD; Munish Gupta, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Justin Smith, MD; Virginie Lafage, PhD; Han Jo Kim, MD*

8:13–8:26 am Discussion

8:27–9:10 am **Session III:**
RISK STRATIFICATION/COMPLICATIONS
Moderator: ***R. Alden Milam, MD & Eric W. Nottmeier, MD***

8:27–8:32 am
Presentation #9
(pg. 124)

The Effect of Local Versus Intravenous Steroids on Dysphagia and Dysphonia Following Anterior Cervical Discectomy and Fusion (ACDF): 1-Year Data from a Single-Blinded, Prospective, Randomized Control Trial
Tyler J. Jenkins, MD*; Reuben Nair, MD; Surabhi A. Bhatt, BS; Brett D. Rosenthal, MD; Jason W. Savage, MD; Wellington K. Hsu, MD; Alpesh A. Patel, MD*

8:33–8:38 am
Presentation #10
(pg. 129)

What are the Important Predictors of Postoperative Functional Recovery in Patients with Cervical OPLL? Results of a Multivariate Analysis
Hiroaki Nakashima, MD, PhD; *Tokumi Kanemura, MD, PhD; Kotaro Satake, MD, PhD; Yoshimoto Ishikawa, MD, PhD; Jun Ouchida, MD; Shiro Imagama, MD, PhD*

Individual Disclosures can be found in the Disclosure Index pages 45-102.

8:39–8:44 am
Presentation #11
(pg. 131)

Quantitative Risk Factor Analysis of Post-Operative Dysphagia After Anterior Cervical Discectomy and Fusion (ACDF) Using the Eating Assessment Tool-10 (EAT-10)
Andrew Y. Yew, MD*; Matthew Nguyen, BS; Wellington Hsu, MD; Alpesh A. Patel, MD, FACS*

8:45–8:50 am
Presentation #12
(pg. 134)

Reoperation for Late Neurological Deterioration After Laminoplasty in Cases with Degenerative Cervical Myelopathy: Comparison Between Cervical Spondylosis and Ossification of Posterior Longitudinal Ligament
Hiroaki Nakashima, MD, PhD*; Tokumi Kanemura, MD, PhD; Kotaro Satake, MD, PhD; Yoshimoto Ishikawa, MD, PhD; Jun Ouchida, MD; Shiro Imagama, MD, PhD*

8:51–8:56 am
Presentation #13
(pg. 136)

Complications After Instrumented Posterior Occipitocervical Fusion for Upper Cervical Spine Trauma
Jacob C. Hoffmann, MD*; Aditya Srinivasan, BS; Ryan J. Warth, MD; Shah-Nawaz M. Dodwad, MD; Mark L. Prasarn, MD*

8:57–9:10 am Discussion

9:11–9:41 am **Break**
Camelback Ballroom

9:42–10:25 am **Session IV:**
DEFORMITY/ALIGNMENT I
Moderators: ***K. Daniel Riew, MD & Daniel M. Sciubba, MD***

9:42–9:47 am
Presentation #14
(pg. 139)

Predicting the Occurrence of Post-Operative Distal Junctional Kyphosis in Cervical Deformity Patients
Peter G. Passias, MD; *Samantha R. Horn, BA; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith MD; Themistocles S. Protopsaltis, MD; Cole A. Bortz, BA; Frank A. Segreto, BS; Alan H. Daniels, MD; Daniel M. Sciubba, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames MD; International Spine Study Group*

9:48–9:53 am
Presentation #15
(pg. 141)

Therapeutic Outcomes for Dropped Head Syndrome
Hiroshi Miyamoto, MD*; Terumasa Ikeda, MD; Masao Akagi, MD*

9:54–9:59 am
Presentation #16
(pg. 143)

Postoperative Cervical Kyphosis After Correction of Adult Thoracolumbar Deformity: Is it Permanent?
Kyung-Chung Kang, MD*; Jung-Hee Lee, MD; Won-Ju Shin, MD*

10:00–10:05 am Presentation #17 (pg. 145)	**Surgical Outcomes in Rigid vs. Flexible Cervical Deformities** ***Themistocles S. Protopsaltis, MD****; Nicholas Stekas, BS; Justin S. Smith, MD, PhD; Alexandra Soroceanu, MD; Renaud Lafage, MS; Alan Daniels, MD; Han Jo Kim, MD; Peter G. Passias, MD; Gregory Mundis, MD; Eric O. Klineberg, MD; D. Kojo Hamilton, MD; Munish Gupta, MD; Virginie Lafage, PhD; Robert A. Hart MD; Frank Schwab, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group*
10:06–10:11 am Presentation #18 (pg. 147)	**Cervical and Cervicothoracic Sagittal Alignment by Roussouly Thoracolumbar Subtypes in Asymptomatic Volunteers** ***Alekos A. Theologis, MD****; Sravisht Iyer, MD; Lawrence G. Lenke, MD; Han Jo Kim, MD; Michael P. Kelly, MD, MSc*
10:12–10:25 am	Discussion
10:26–10:30 am	**Introduction of Presidential Guest Speaker** *Jeffrey C. Wang, MD, President*
10:31–11:20 am	**Henry H. Bohlman Presidential Guest Lecture** *Helen Turnbull, PhD, CSP; CEO Human Facets*
11:21–11:30 am	Discussion
11:30 am	**Adjourn to Industry Workshops –** *Lunch Available for Workshop Attendees Only, Prior Registration Not Required, No CME Credits*

INDUSTRY WORKSHOPS
Lunch Included - NO CME Credits

11:30 am– 1:30 pm	**Workshop 1: DEPUY SYNTHES** Innovation in Complex Cervical Reconstruction: What the Research Evidence Tells Us About Alignment, Deformity, Revision and Complications	***Hummingbird Room 18***
	Workshop 2: GLOBUS MEDICAL, INC. Treatment of Severe Stenosis: Anterior v. Posterior v. 360	***Eagle Room 15***
	Workshop 3: MEDTRONIC Posterior Cervical Fixation with Infinity: Techniques and Technologies	***Falcon Room 16***

Individual Disclosures can be found in the Disclosure Index pages 45-102.

INDUSTRY WORKSHOPS (cont.)
Lunch Included - NO CME Credits

11:30 am–
1:30 pm

Workshop 4: NUVASIVE ***Hawk***
Challenges of Cervical Surgery ***Room 17***
Discussion topics include evaluation and management of cervical malalignment, nuances of dysphagia prevention, and posterior infection and treatment.

Workshop 5: STRYKER ***Meadowlark***
A Clinical Update on Tritanium – A Novel, ***Room 19***
Highly Porous Material Designed for Bone In-Growth and Biological Fixation
3D printed interbody devices have flooded the market but most lack evidence. Stryker's proprietary Tritanium In-Growth Technology, used to build the Tritanium PL, TL and C Cages, was designed for bone in-growth and biological fixation. Join us as our distinguished surgeon faculty shares the science behind Tritanium In-Growth Technology.

Workshop 6: ZIMMER BIOMET ***Quail***
Cervical Disc Replacement, ***Room 21***
Why We're Undertreating Patients and
How to Solve the Problem

1:30–2:49 pm **Symposium I: SCOLIOSIS RESEARCH SOCIETY**
Moderator: ***Robert A. Hart, MD***

1:30–1:40 pm **Background and History of Development of the Schwab Clinical Impact Based ASD Classification and Osteotomy Classification Systems in Collaboration with the SRS**
Frank J. Schwab, MD

1:41–1:51 pm **History of the Development, Validation and Modifications of the SRS-22r Outcomes Questionnaire**
Douglas C. Burton, MD

1:52–2:02 pm **Initiation and Completion of the Scoli-Risk 1 as a Collaborative Effort Between SRS and AOSpine**
Christopher I. Shaffrey, MD

2:03–2:13 pm **History of the SRS from Inception to 2018**
David W. Polly Jr., MD

2:14–2:24 pm **Development and Management of the HSG and Use of Benchmarking for Quality Improvement, Including the History of SRS Initiatives with Respect to Pediatric Patients**
Peter O. Newton, MD

2:25–2:35 pm **The Evolution in Thinking about Cervical Deformity over the Past 25 Years: Touchpoints Between SRS and CSRS**
Todd J. Albert, MD

2:36–2:49 pm Discussion

2:50–3:20 pm **Break**
Camelback Ballroom

3:21–3:59 pm **Session V:**
PREDICTIVE ANALYTICS/SHARED DECISION MAKING
Moderators: ***Thomas E. Mroz, MD & Leo R. Spector, MD***

3:16–3:21 pm
Presentation #19
(pg. 149)
Can the American College of Surgeons Risk Calculator Predict 30-Day Complications After Cervical Spine Surgery?
Michael H. McCarthy, MD, MPH; Tyler J. Jenkins, MD; ***Joseph P. Maslak, MD****; Wellington K. Hsu, MD; Alpesh A. Patel, MD*

3:22–3:27 pm
Presentation #20
(pg. 152)
Difference in Patient Cohorts for Cervical Disc Arthroplasty (CDA) and Anterior Cervical Discectomy and Fusion (ACDF)
W. Ryan Spiker, M*D; Darrel S. Brodke, MD; Nicholas Spina, MD; Brandon Lawrence, MD; Vadim Goz, MD; Brook I. Martin, PhD*

3:28–3:33 pm
Presentation #21
(pg. 153)
Does Payer Type Affect Patient Satisfaction Scores?
Michael P. Silverstein, M*D; Susan Odum, PhD; Michael Conti Mica, MD; Bruce Darden, MD; Eric Laxer, MD; Alden Milam, MD; Alfred Rhyne, MD; P. Bradley Segebarth, MD; Leo R. Spector, MD*

3:34–3:39 pm
Presentation #22
(pg. 155)
Development of a Novel Cervical Deformity Surgical Invasiveness Index
Peter G. Passias, MD*; Samantha R. Horn, BA; Alexandra Soroceanu, MD; Cheongeun Oh, PhD; Tamir Ailon, MD, MPH; Brian J. Neuman, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith, MD; Cole A. Bortz, BA; Frank A. Segreto, BS; Shay Bess, MD; Christopher I. Shaffrey MD; Christopher P. Ames, MD; International Spine Study Group*

Individual Disclosures can be found in the Disclosure Index pages 45-102.

3:40–3:45 pm
Presentation #23
(pg. 157)

A Clinical and Radiologic Study on Patients of Cervical Spondylotic Myelopathy with Anterior Cervical Spondylolisthesis Treated by Posterior Decompression Surgery: Retrospective Multicenter Study of 867 Cases
***Ken Ninomiya, MD, PhD**; Narihito Nagoshi, MD, PhD; Ryoma Aoyama, MD, PhD; Satoshi Suzuki, MD, PhD; Yuta Shiono, MD, PhD; Yuichiro Takahashi, MD, PhD; Nobuyuki Fujita, MD, PhD; Eijirou Okada, MD, PhD; Osahiko Tsuji, MD, PhD; Mitsuru Yagi, MD, PhD; Takahito Iga, MD; Masaya Nakamura, MD, PhD; Morio Matsumoto MD, PhD; Kota Watanabe, MD, PhD; Ken Ishii, MD, PhD; Junichi Yamane, MD, PhD*

3:46–3:59 pm Discussion

4:00–4:37 pm **Session VI:**
DIAGNOSTICS/IMAGING
Moderators: ***Alexander J. Ghanayem, MD & James S. Harrop, MD***

4:00–4:05 pm
Presentation #24
(pg. 160)

Effect of Cervical Decompression Surgery on Spine and Lower Extremity Biomechanics in Adult Cervical Spondylotic Myelopathy Patients
***Ram Haddas, PhD**; Isador Lieberman, MD; Raj Arakal, MD; Akwasi Boah, MD; Theodore Belanger, MD; Kevin Ju, MD*

4:06 pm–4:11 pm
Presentation #25
(pg. 164)

The Impact of K-Line (-) in the Neck-Flexion Position on Patient-Based Outcomes After Cervical Laminoplasty for Patients with Ossification of the Posterior Longitudinal Ligament
***Atsushi Kimura, MD, PhD**; Yasuyuki, Shiraishi, MD; Ryo Sugawara, MD; Hirokazu Inoue, MD, PhD; Teruaki Endo, MD, PhD; Katsushi Takeshita, MD, PhD*

4:12 pm–4:17 pm
Presentation #26
(pg. 166)

Brain Functional Connectivity Predicts for Neurological Improvement in Patients with Cervical Myelopathy – A Resting-State fMRI Study
***Takashi Kaito, MD, PhD**; Shota Takenaka, MD, DMSc; Takahiro Makino, MD, DMSc; Yusuke Sakai, MD; Junichi Kushioka, MD; Hisashi Tanaka, MD; Yoshiyuki Watanabe, MD, PhD; Shigeyuki Kan, PhD; Masahiko Shibata, MD*

4:18 pm–4:23 pm
Presentation #27
(pg. 168)

Multiparametric Quantitative Magnetic Resonance Imaging of the Cervical Spine to Measure Microstructure and Tissue Injury
***Muhammad Ali Akbar, MD**; Allan R. Martin, MD, PhD; Jetan H. Badhiwala, MD; Michael G. Fehlings, MD, PhD, FRCSC, FACS*

4:24–4:37 pm Discussion

4:38-6:30 pm **Welcome Reception**
Camelback Ballroom

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

7:00–7:10 am **Welcome and Announcements**
Christopher P. Ames, MD and Robert A. Hart, MD, Program Co-Chairs

7:11–7:48 am **Session VII:**
OUTCOMES II
Moderators: ***Alpesh A. Patel, MD & John M. Rhee, MD***

7:11–7:16 am
Presentation #28
(pg. 170)
Minimal Clinically Important Difference and Substantial Clinical Benefit Using PROMIS CAT in Cervical Spine Surgery
Sravisht Iyer, MD*; Benjamin Khechen, BA; Daniel Stein, BS; Michael Steinhaus, MD; Thomas Ross, RN; Jingyan Yang, PhD; Kern Singh, MD; Todd Albert, MD; Darren Lebl, MD; Russel Huang, MD; Harvinder Sandhu, MD; Bernard Rawlins, MD; Frank Schwab, MD; Virginie Lafage, PhD; Han Jo Kim MD*

7:17–7:22 am
Presentation #29
(pg. 173)
Discordance Between Functional Outcome and Self-Reported Ratings of Health Status After Surgery for Degenerative Cervical Myelopathy
Jefferson R. Wilson, MD, PhD*; Lindsay Tetreault, PhD; Michael Fehlings, MD, PhD, FRCSC, FACS*

7:23–7:28 am
Presentation #30
(pg. 174)
Does Severity of Preoperative Myelopathy Symptoms Impact Health-Related Quality of Life in Cervical Spondylotic Myelopathy?
Daniel Tarazona, MD; ***Gregory D. Schroeder, MD****, Emily Pflug, BS; I. David Kaye, MD; Christopher K. Kepler, MD, MBA; Mark F. Kurd, MD; Alan S. Hilibrand, MD; Barrett I. Woods, MD; Jeffrey A. Rihn MD; D. Greg Anderson, MD; Alexander R. Vaccaro MD, PhD, MBA; Kristen E. Radcliff, MD*

7:29–7:34 am
Presentation #31
(pg. 176)
Risk Factors Associated with Failure to Reach Minimal Clinically Important Difference in Patient-Reported Outcomes Following Anterior Cervical Discectomy and Fusion
Benjamin Khechen, BA; ***Brittany E. Haws, MD****; Dil V. Patel, BS; Ankur S. Narain, BA; Fady Y. Hijji, MD; Daniel D. Bohl, MD, MPH; Jordan A. Guntin, BS; Kaitlyn L. Cardinal, BS; Kern Singh, MD*

7:35–7:48 am Discussion

7:49–8:38 am **Session VIII:**
MOTION/MOTION PRESERVATION
Moderators: ***Frank M. Phillips, MD & Vincent C. Traynelis, MD***

7:49–7:54 am
Presentation #32
(pg. 179)
Evaluating Range of Motion During In-Vivo Dynamic Cervical Spine Motions in Spondylosis Patients
Thomas D. Cha, MD, MBA*; Kamran Z. Khan, MS; Tao Guo; Yan Yu; Guoan Li, PhD*

Individual Disclosures can be found in the Disclosure Index pages 45-102.

7:55–8:00 am
Presentation #33
(pg. 182)

The Rate of Heterotopic Ossification Following Cervical Disc Arthroplasty: A Systematic Review and Comparison of Data
Sam C. Overley, MD*; Jay Levin; Jun Sup Kim, MD; James E. Dowdell III, MD; Steve McAnany, MD; Thomas E. Mroz, MD; Andrew C. Hecht, MD*

8:01–8:06 am
Presentation #34
(pg. 184)

Comparing Range of Motion in Follow Up of Anterior Cervical Discectomy with or without Interbody Fusion and Arthroplasty
Xiaoyu Yang, MD*; Mark P. Arts, MD, PhD; Carmen Vleggeert-Lankamp, MD, MSc, Ph*D

8:07–8:12 am
Presentation #35
(pg. 185)

Timing of Tracheostomy After Anterior Cervical Discectomy and Fusion
Shah-Nowaz Dodwad, MD; ***Mark L. Prasarn, MD;*** *Jason W. Savage, MD, Sasha D. Adams, MD*

8:13–8:18 am
Presentation #36
(pg. 187)

Clinical Adjacent Segment Pathology Risk is Less Following Cervical Disc Arthroplasty Compared to Anterior Cervical Discectomy and Fusion at 7 Years Postop
Pierce D. Nunley, MD*; Eubulus J. Kerr, MD; David A. Cavanaugh, MD; Andrew Utter, MD; Peter Campbell, MD; Kelly A. Frank, MS; Kyle E. Marshall, MS; Marcus B. Stone, PhD*

8:19–8:24 am
Presentation #37
(pg. 188)

Analysis of Re-Operations After Cervical Total Disc Replacement in a Consecutive Series of 504 Patients Receiving the Same Device Type
Jack E. Zigler, MD*; Richard D. Guyer, MD; Scott L. Blumenthal, MD; Donna D. Ohnmeiss, PhD*

8:25–8:38 am — Discussion

8:39–8:44 am — **Preview CSRS 2019 Annual Meeting in New York, NY**
Andrew C. Hecht, MD*, Local Host*

8:45–8:50 am — **Preview CSRS Asia Pacific Section 2019 Annual Meeting**
Takachika Shimizu, MD*, President CSRS Asia Pacific Section*

8:51-8:56 am — **Preview CSRS European Section 2019 Annual Meeting**
Björn Zoëga, MD, PhD*, President CSRS European Section*

8:57–9:27 am — **Break**
Camelback Ballroom

9:28–10:33 am **Session IX:**
FOCUSED PODIUM PRESENTATIONS
Moderators: ***Wellington K. Hsu, MD & Michael P. Steinmetz, MD***

OUTCOMES

9:28–9:30 am
Presentation #38
(pg. 189)

Are Outcomes of ACDF Influenced by Presurgical Depressive Symptoms on the Mental Component Score of the Short Form 12 Survey?
Taolin Fang, MD; Daniel Tarazona, MD; Kristen J. Nicholson, PhD; I. Matthew S. Galetta, BS; I. David Kaye, MD; ***Christopher K. Kepler, MD, MBA****; Mark F. Kurd, MD; Alan S. Hilibrand, MD; Barrett I. Woods, MD; Kristen E. Radcliff, MD; Jeffrey A. Rihn, MD; D. Greg Anderson, MD; Alexander R. Vaccaro, MD, PhD, MBA; Gregory D. Schroeder, MD*

9:31–9:33 am
Presentation #39
(pg. 192)

Crossing the Cervicothoracic Junction in Cervical Spine Fusion Surgery Involves Higher Operative Risks, but Superior Long-Term Outcomes
Alvaro Ibaseta, MS*; Rafa Rahman, BS; Richard L. Skolasky, ScD; Jay S. Reidler, MD, MPH; Lee H. Riley III, MD; Daniel M. Sciubba, MD; David B. Cohen, MD, MPH; Brian J. Neuman, MD*

9:34–9:36 am
Presentation #40
(pg. 194)

Metabolic Syndrome and 30-Day Outcomes Following Elective Anterior Cervical Discectomy and Fusion (ACDF)
Azeem Tariq Malik, MBBS; *Nikhil Jain, MD; Jeffery Kim, MD; Elizabeth Yu, MD; Safdar N Khan, MD*

9:37–9:39 am
Presentation #41
(pg. 196)

Role of the Sodium/Glutamate Blocker Riluzole in Enhancing Functional Outcomes in Patient Undergoing Surgery for Degenerative Cervical Myelopathy: Results of the Prospective, Multicentre Double Blind Controlled CSM-Protect Randomized Trial
Michael Fehlings, MD, PhD, FRCSC, FACS; ***Jetan H. Badhiwala, MD****; Branko Kopjar, MD, PhD; Henry Ahn, MD; Francis Farhadi, MD, PhD; Christopher I. Shaffrey, MD; Ahmad Nassr, MD; Praveen Mummaneni, MD; Paul M. Arnold, MD; W. Bradley Jacobs, MD; K. Daniel Riew, MD; Darrel S. Brodke, MD; Alexander R. Vaccaro, MD, PhD, MBA; Alan Hilibrand, MD; Jason D. Wilson, MD; James Harrop, MD; S. Tim Yoon, MD, PhD; Kee Kim, MD; Daryl Fourney, MD, FRCSC, FACS; Carlo Santaguida, MD*

9:40–9:46 am Discussion

Individual Disclosures can be found in the Disclosure Index pages 45-102.

INNOVATION AND ECONOMICS

9:47–9:49 am
Presentation #42
(pg. 198)

Use of Recombinant Human Bone Morphogenetic Protein-2 at the C1-2 Lateral Articulation in Posterior Atlantoaxial Fusion in Adult Patients with or without Conventional Structural Bone Graft
***Wataru Ishida, MD**; Seba Ramhmdani, MD; Yuanxuan Xia, BS; Thomas A. Kosztowski, MD; Rafael De la Garza Ramos, MD; John Choi, BS; Benjamin D. Elder, MD, PhD; Nicholas Theodore, MD; Ziya L. Gokaslan, MD; Jean-Paul Wolinsky, MD; Daniel M. Sciubba, MD; Ali Bydon, MD; Timothy F. Witham, MD; Sheng-Fu L. Lo, MD*

9:50–9:52 am
Presentation #43
(pg. 201)

Functional Integration of a Tissue Engineered Intervertebral Disc and Translation to a Large Animal Cervical Spine Model
*Sarah E. Gullbrand, PhD; Beth G. Ashinsky, Edward Bonnevie; Dong Hwa Kim; Lachlan J. Smith, PhD; Thomas P. Schaer, DVM; Dawn M. Elliott, PhD; **Harvey E. Smith, MD**; Robert L. Mauck, PhD*

9:53–9:55 am
Presentation #44
(pg. 203)

Correlating Radiologic Signs of Disc Degeneration with Changes in Cervical Spine Biomechanics
***Vijay Permeswaran, PhD**; Anup Gandhi, PhD; Vikas Patel, MD; John Wanebo, MD; Ripul Panchal, MD*

9:56–9:58 am
Presentation #45
(pg. 205)

Cost-Utility of Revisions for Cervical Deformity Correction Warrants Minimization of Reoperations
*Samantha R. Horn, BA; Peter G. Passias, MD**;** Renaud Lafage, MS; Virginie Lafage PhD; Hamid Hassanzadeh, MD; Jason A. Horowitz, BA; Cole A. Bortz, BA; Frank A. Segreto, BS; **Justin S. Smith, MD**; Daniel M. Sciubba, MD; Alan H. Daniels, MD; Christopher I. Shaffrey, MD; Richard A. Hostin, MD; Christopher P. Ames, MD; International Spine Study Group*

9:59–10:01 am
Presentation #46
(pg. 207)

Economic Impact of Older Age on the Initial Spine Care of Individuals with Acute Spine Trauma
***Julio C. Furlan, MD, LLB, MBA, MSc, PhD, FRCPC**; Michael G. Fehlings, MD, PhD, FRCSC, FACS; Catharine Craven, BA, MD, MSc, FRCPC*

10:02–10:08 am Discussion

PREDICTIVE ANALYTICS AND SHARED DECISION MAKING

10:09–10:11 am
Presentation #47
(pg. 209)

30-Day Preoperative Opioid Dosage Predicts 12-Month Satisfaction in Cervical Spine Surgery
***Jeffrey Hills, MD**; Joseph Wick, BA; Jacquelyn Pennings, PhD; Inamullah Khan, MD; Ahilan Sivaganesan, MD; Kristin R. Archer, PhD, DPT; Clinton J. Devin, MD*

10:12–10:14 am
Presentation #48
(pg. 212)

Impact of Neck Disability Index on 12-Months Satisfaction After Elective Surgery for Cervical Radiculopathy
Inamullah Khan, MD*; Ahilan Sivaganesan, MD; Anthony L. Asher, MD; Panagiotis Kerezoudis, MD; Hui Nian, PhD; Frank E. Harrell Jr., PhD; Mohamad Bydon, MD; Kristin R. Archer, PhD, DPT; Clinton J. Devin, MD*

10:15–10:17 am
Presentation #49
(pg. 215)

Thirty-Day Readmission Risk Following Cervical Spine Surgery: Derivation and Validation of a Predictive Model
*Piyush Kalakoti, MD; Alexander J. Volkmar, BS; Alan Shamrock, BS; Yubo Gao, PhD****; Nathan R. Hendrickson, MD****; Andrew J. Pugely, MD*

10:18–10:20 am
Presentation #50
(pg. 218)

Using a Machine Learning Approach to Predict Outcome After Surgery for Degenerative Cervical Myelopathy
Zamir Merali, MD*; Christopher D. Witiw, MD, MSc; Jetan Badhiwala, MD; Jefferson Wilson, MD, PhD, FRCSC; Michael G. Fehlings, MD, PhD, FRCSC, FACS*

10:21–10:23 am
Presentation #51
(pg. 220)

Model for 90-Day and 1-Year Outcome Prediction After Cervical Spine Arthrodesis: A Web-Based Clinical Utility Tool
Piyush Kalakoti, MD; Nicholas A. Bedard, MD; ***Alan Shamrock, BS****; Alexander J. Volkmar, BS; Nathan R. Hendrickson, MD; Andrew J. Pugely, MD*

10:24–10:26 am
Presentation #52
(pg. 222)

The Predictor of Patients Who Failed to Achieve the Minimum Clinical Important Differences Following Laminoplasty for Cervical Spondylotic Myelopathy
Koji Tamai; MD*; Akinobu Suzuki; MD, PhD; Akito Yabu; Hidetomi Terai; MD, PhD; Masatoshi Hoshino, MD, PhD; Hiromitsu Toyoda; Shinji Takahashi; MD; Shoichiro Ohyama; MD; Yusuke Hori; MD; Hiroaki Nakamura, MD*

10:27–10:33 am Discussion

10:34–11:29 am **SESSION X:**
RESEARCH SESSION
Moderator: ***Zoher Ghogawala, MD, FACS***

10:34–10:37 am **Announcement–2018 Research Grant Winners**

10:38–10:39 am **Introduction–2017 Research Grant Updates**

10:40–10:45 am **2017 Medtronic**
Randomized, Controlled Trial of Posterior C1-2 Fusion vs. Bracing Alone for Treatment of Type II Odontoid Process Fractures in the Elderly
Christopher K. Kepler, MD, MBA

Individual Disclosures can be found in the Disclosure Index pages 45-102.

10:46–10:51 am **2017 CSRS 21st Century Research and Education Grants**
Biodegradable Microspheres and Hydrogel Drug Delivery System of Anti-Inflammatory Therapeutics for the Treatment of Chronic Degenerative Disc Disease
Anna Chee, PhD

10:52-10:57 am **2017 Seed Starter Grants**
Exosomes from Hypoxic Pre-conditioned Bone Marrow Stem Cell Media for Acute Spinal Cord Injury
Ankit I. Mehta, MD

10:58–11:03 am **Development of an Innovative Diagnostic Tool for Cervical Spondylotic Myelopathy Using Somatosensory Evoked Potentials Elicited by Proprioceptive Stimulation: A Proof-of-Concept Pilot Study**
Julio C. Furlan, MD, LLB, MBA, MSc, PhD, FRCPC

11:04–11:09 am **Effect of Cervical Decompression Surgery on Neuromuscular Control and Kinematics During Gait in Adult Patients with Cervical Spondylotic Myelopathy**
Ram Haddas, PhD

11:10–11:11 am **Introduction–2016 and 2015 Resident Fellow Research Grant Updates**

11:12–11:17 am **In Situ Tissue Engineering Approach to Intervertebral Disc Regeneration**
Sapan Gandhi, MD

11:18–11:23 am **Omega 3 Fatty Acid Supplementation to Reduce Intervertebral Disc Degeneration**
Zachary NaPier, MD

11:24–11:29 am **Improvement in Grip and Pinch Strength Following Anterior Cervical Discectomy and Fusion Procedures**
Brittany E. Haws, MD

11:30–11:34 am **Introduction of CSRS President**
Alexander R. Vaccaro, MD, PhD, MBA

11:35-12:00 pm **PRESIDENTIAL ADDRESS**
Jeffrey C. Wang, MD

12:00–12:55 pm **Non-Member Lunch**
Camelback Ballroom

12:00–12:55 pm **Member Lunch (CSRS Members Only)**
Ballroom AB

1:00–3:23 pm	**Symposium II: International Collaborative Approaches to Complex Cervical Surgery** Moderator: ***Christopher P. Ames, MD***
1:00–1:15 pm	**Surgical Approaches to CVJ** ***Luis Carelli, MD*** *– Brazil*
1:16–1:31 pm	**Primary Bone Tumors of Cervical Spine** ***Stefano Boriani, MD*** *– Italy*
1:32–1:47 pm	**Management of High Cervical Defects After Tumor Resections: Approaches and Biomechanics** ***Dezoe Jeszensky, MD, PhD*** *– Switzerland*
1:48–2:03 pm	**Correction Techniques for CT Deformity** ***Ibrahim Obeid, MD, MSc*** *– France*
2:04–2:19 pm	**Anterior vs. Posterior Approach to OPLL** ***Yoon Ha, MD, PhD*** *– Korea*
2:20–2:35 pm	**Posterior Correction Techniques with Pedicle Screws** ***Kuniyoshi Abumi, MD*** *– Japan*
2:36–2:51 pm	**The Surgical Challenge of Cervical Sagittal Balance** ***William Sears, FRACS*** *– Australia*
2:52–3:07 pm	**The Value and Application of Pre-operative Correction in the Treatment of Severe Cervical Kyphosis** ***Yu Sun, MD*** *– China*
3:08–3:23 pm	Discussion
3:24–3:40 pm	**Break** *East Foyer*
3:41–4:30 pm	**Session XI:** **DEFORMITY/ALIGNMENT II** Moderators: ***Erica F. Bisson, MD & Robert F. Heary, MD***
3:41–3:46 pm Presentation #53 (pg. 224)	**Selective Surgical Treatment Strategies for Severe Cervical Kyphosis** ***Huajiang Chen, MD****; Jianxi Wang*

Individual Disclosures can be found in the Disclosure Index pages 45-102.

3:47–3:52 pm
Presentation #54
(pg. 226)

Successful Clinical Outcomes Following Surgery for Severe Cervical Deformity are Dependent Upon Achieving Sufficient Cervical Sagittal Alignment
Themistocles S. Protopsaltis, MD; *Nicholas Stekas, BS; Justin S. Smith MD, PhD; Alexandra Soroceanu, MD; Renaud Lafage, MS; Alan Daniels, MD; Han Jo Kim, MD; Peter G. Passias, MD; Gregory Mundis, MD; Eric O. Klineberg, MD; D. Kojo Hamilton, MD; Munish Gupta, MD; Virginie Lafage, PhD; Robert A. Hart, MD; Frank Schwab, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames MD; International Spine Study Group*

3:53–3:58 pm
Presentation #55
(pg. 228)

Effect of Correction Surgery for Cervical Kyphosis on Compensatory Mechanisms in Overall Spinopelvic Sagittal Alignment
Hiroshi Miyamoto MD; *Terumasa Ikeda, MD; Masao Akagi, MD*

3:59–4:04 pm
Presentation #56
(pg. 230)

Validation of a Cervical Spine Deformity Classification System Using a Long-Term Follow-Up Data After Multilevel Posterior Cervical Fusion Surgery
Seung-Jae Hyun, MD, PhD; *Jong-myung Jung, MD; Ki-Jeong Kim, MD, PhD*

4:05–4:10 pm
Presentation #57
(pg. 232)

Changes in Cervical Sagittal Alignment in Adolescent Idiopathic Scoliosis Following Posterior Spinal Instrumented Fusion
Ryan J. Berger, MD*; William A. Cantrell, BS; Joseph Tanenbaum, BA; David P. Gurd, MD; Thomas E. Kuivila, MD; Thomas E. Mroz, MD; Michael P. Steinmetz, MD; Ryan C. Goodwin, MD*

4:11–4:16 pm
Presentation #58
(pg. 234)

Recovery Kinetics: Comparison of Patients Undergoing Primary or Revision Procedures for Adult Cervical Deformity Using a Novel Area Under the Curve Methodology
Frank A. Segreto, BS; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith, MD, PhD; Breton G. Line, BS; Justin K. Scheer, MD; Dean Chou, MD; Nicholas J. Frangella, BS; Cole A. Bortz, BA; Bassel G. Diebo, MD; Themistocles S. Protopsaltis, MD; Han Jo Kim, MD; Christopher P. Ames, MD; ***Brian J. Neuman, MD****; Peter G. Passias, MD; International Spine Study Group*

4:17–4:30 pm Discussion

4:30 pm **Adjourn**

7:00–7:05 am **Welcome and Announcements**
Christopher P. Ames, MD and Robert A. Hart, MD, Program Co-Chairs

7:06–7:49 am **Session XII: OUTCOMES III**
Moderators: ***Douglas G. Orndorff, MD & W. Ryan Spiker, MD***

7:06–7:11 am
Presentation #59
(pg. 236)
Characteristics of Residual Symptoms Following Laminoplasty in Elderly Patients with Cervical Spondylotic Myelopathy: A Prospective Comparative Study of Clinical Outcomes for 1025 Patients
***Masaaki Machino, MD**; Shiro Imagama, MD, PhD; Kei Ando, MD; Naoki Ishiguro, MD, PhD*

7:12–7:17 am
Presentation #60
(pg. 237)
How Does Everyone Stack Up? A Risk-Adjusted Ranking Scheme for Surgeons Performing ACDF for Radiculopathy
***Ahilan Sivaganesan, MD**; Anthony Asher, MD; Mohamad Bydon, MD; Inamullah Khan, MBBS, MD; Hui Nian, PhD; Frank E. Harrell Jr., PhD; Kristin Archer, PhD; Clinton J. Devin, MD*

7:18–7:23 am
Presentation #61
(pg. 240)
Health Outcomes and Patient Satisfaction After Elective Cervical Spine Surgery for Cervical Spondylotic Myelopathy: A Prospective 24-Month Study
***Marjorie C. Wang, MD MPH**; Jianing Li, PhD*

7:24–7:29 am
Presentation #62
(pg. 242)
Preoperative Promis Score Is Not Predictive of Postoperative Pain or Narcotics Consumption After Anterior Cervical Discectomy and Fusion
***Brittany E. Haws, MD**; Benjamin Khechen, BA; Dil V. Patel, BS; Ankur S. Narain, BA; Jordan A. Guntin, BS; Kaitlyn L. Cardinal, BS; Kern Singh, MD*

7:30–7:35 am
Presentation #63
(pg. 244)
Limited Morbidity and Radiographic Benefit of C2 vs. Subaxial Cervical Upper-Most Instrumented Vertebrae
*Peter G. Passias MD; Cole Bortz, BA; Renaud Lafage, MS; **Virginie Lagafe, PhD**; Justin S. Smith, MD, PhD; Breton Line, BS; Samantha R. Horn, BA; Frank A. Segreto, BS; Eric O. Klineberg, MD; Alexandra Soroceanu, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group*

7:36–7:49 am Discussion

Individual Disclosures can be found in the Disclosure Index pages 45-102.

7:50-9:42 am	**Symposium III: Managing Difficult Complications** Moderators: ***Christopher P. Ames, MD*** *and* ***Robert A. Hart, MD***
7:50–8:00 am	**Complication Classification: Surgeon, Patient and Payor and Limitations of Society MM Registries** ***Justin S. Smith, MD***
8:01–8:11 am	**Risk Stratification and Invasiveness** ***Peter G. Passias, MD***
8:12–8:22 am	**Loss of Fixation in Cervical Spine** ***Sang-Hun Lee, MD***
8:23–8:33 am	**Distal Junctional Failure** ***Themistocles S. Protopsaltis, MD***
8:34–8:44 am	**Anterior CSF Leak** ***Christopher I. Shaffrey, MD***
8:45–8:55 am	**Dural Involvement in Tumor Surgery** ***Ziya L. Gokaslan, MD, FAANS, FACS***
8:56–9:06 am	**Oesophagus Fistula After Anterior Cervical Spine Approach, How to Manage this Complication?** ***Philippe Bancel, MD***
9:07–9:17 am	**MEP Loss, C5 and C8 Weakness** ***Lee Tan, MD***
9:18–9:28 am	**Intraoperative Vertebral Artery Injuries: The Uncertainty Continues** ***Jens R. Chapman, MD***
9:29–9:42 am	**Discussion**
9:43–10:20 am	**Session XIII:** **DIAGNOSTICS/IMAGING** Moderators: ***Darrel S. Brodke, MD & Brian K. Kwon, MD***
9:43–9:48 am Presentation #64 (pg. 246)	**Quantitative Analysis of Cervical Spinal Cord Pulsation - Sonographic Evaluation in Anterior Intervertebral Decompression** ***Yohei Ito, MD****; Hisanori Mihara, MD; Yasunori Tatara, MD*
9:49–9:54 am Presentation #65 (pg. 248)	**Cervical Myelopathy Presenting Without Symptoms in the Upper Extremities: Incidence and Presenting Characteristics** ***Robert P. Norton, MD****; Jordan Pasternack, MD; John K. Houten, MD, FAANS*

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

9:55–10:00 am
Presentation #66
(pg. 251)

Assessment of Standing Balance in Normal vs. Cervical Spondylotic Myelopathy Patients
Mikhail Lew P. Ver, MD*; Jeffrey L. Gum, MD; Steven D. Glassman, MD; Portia A. Steele, APRN; Leah Y. Carreon, MD, MSc*

10:01–10:06 am
Presentation #67
(pg. 254)

Clinically Predictive Value of Gray Matter Volume Loss in Cervical Spondylotic Myelopathy (CSM): A Prospective Case-Control Study Utilizing 3T MRI and Volumetric Mapping
Benjamin Hopkins, BS*; Kenneth A. Weber, PhD; Alex Barry, MS; Todd B. Parrish, PhD*

10:07–10:20 am **Discussion**

10:21–10:26 am **Presentation of CSRS Medallion to Alexander R. Vaccaro, MD, PhD, MBA**

10:27–10:48 am **Break**
East Foyer

10:49–11:26 am **Session XIV: BIOLOGY AND FUSION**
Moderators: ***Jens R. Chapman, MD & Timothy A. Garvey, MD***

10:49–10:54 am
Presentation #68
(pg. 257)

NF-kB Inhibitor Reduces the Inflammatory Response and Improves Bone Formation in rhBMP-2-Mediated Spine Fusion
Juliane D. Glaeser, PhD; ***Phillip H. Behrens, MD****; Khosrowdad Salehi, BS; Linda E.A. Kanim, MA; Dmitriy Sheyn, PhD; Zachary NaPier, MD; Jason M. Cuéllar, MD, PhD; Hyun W Bae, MD*

10:55–11:00 am
Presentation #69
(pg. 259)

A Thienoindazole Derivative Small Compound Prevented and Regenerated Intervertebral Disc Degeneration by Enhancing Extracellular Matrix Production
Junichi Kushioka, MD; *Takashi Kaito, MD, PhD; Ryota Chijimatsu; Rintaro Okada, MD; Hiroyuki Ishiguro; Joe Kodama; Yuichiro Ukon; Hideki Yoshikawa, MD*

11:01–11:06 am
Presentation #70
(pg. 261)

Usage Patterns of Intraoperative Neuromonitoring During Degenerative, Non-Deformity, Cervical Spine Surgery: A Survey of the Cervical Spine Research Society
Jeffrey A. Konopka, MD*; Zachary J. Grabel, MD; John M. Rhee, MD*

11:07–11:12 am
Presentation #71
(pg. 264)

Posterior Instrumented Fusion Suppresses the Progression of Ossification of the Posterior Longitudinal Ligament: A Comparison of Laminoplasty with and without Instrumented Fusion by 3-Dimensional Analysis
Keiichi Katsumi; MD, PhD*; Toru Hirano, MD; Kei Watanabe, MD, PhD; Masayuki Ohashi, MD, PhD; Naoto Endo, MD*

11:13–11:26 am Discussion

Individual Disclosures can be found in the Disclosure Index pages 45-102.

11:27 am–12:56 pm **Session XV:**
FOCUSED PODIUM PRESENTATIONS
Moderators: ***Alexander R. Vaccaro, MD, PhD, MBA & Jeffrey C. Wang, MD***

EPIDEMIOLOGY AND OUTCOMES

11:27–11:29 am
Presentation #72
(pg. 266)

Chronic Obstructive Pulmonary Disease (COPD) is an Independent Predictor for 30-Day Complications and Readmissions Following 1-To-2 Level Anterior Cervical Discectomy and Fusion
Azeem Tariq Malik, MBBS; *Nikhil Jain, MD; Jeffery Kim, MD; Safdar N. Khan, MD; Elizabeth Yu, MD*

11:30–11:32 am
Presentation #73
(pg. 269)

Epidemiology of C5 Palsy After Cervical Spine Surgery: 21 Multicenter Studies
Jae Keun Oh, MD, PhD*; Dong Ho Kang, MD, PhD; Ki-Jeong Kim, MD, PhD; Young Jin Kim, MD, PhD; Chi Heon Kim, MD, PhD; Seong Yi, MD, PhD; Jun Ho Lee, MD; Chang-Hyun Lee, MD; Yong Jun Jin, MD, PhD; Jae Taek Hong, MD, PhD*

11:33–11:35 am
Presentation #74
(pg. 271)

Age Is Not a Significant Predictor of Adverse Events After Cervical Spine Surgery: Analysis from the Michigan Spine Surgery Improvement Collaborative (MSSIC)
Jad G. Khalil, MD; Hesham Mostafa Zakaria; ***Daniel Possley, DO****; Daniel Park, MD; Victor Chang, MD*

11:36–11:38 am
Presentation #75
(pg. 273)

Frequency of Typical Myelopathic Symptoms in a Large Surgical Cohort of Cervical Myelopathy Patients: Association with the Level of Maximal Cord Compression and MRI T2 Signal Change
Shuo Niu, MD, PhD*; Thomas M. Neustein, MD; Albert T. Anastasio, BA; Samuel D. Maidman, BA; Razan R. Faraj, MS; John M. Rhee, MD*

11:39–11:41 am
Presentation #76
(pg. 277)

Effect of Modified Japanese Orthopedic Association Scores on Satisfaction with Outcomes 12 Months After Elective Surgery for Cervical Spine Myelopathy
Benjamin Weisenthal, MD**;** *Ahilan Sivaganesan, MD; Silky Chotai, MD; Inamullah Khan, MBBS, MD; Hui Nian, PhD; Frank E. Harrell Jr., PhD; Kristin Archer, PhD; Jacquelyn S. Pennings, PhD; Mohamad Bydon, MD; Praveen V. Mummaneni, MD; Anthony Asher, MD, FACS; Kevin T. Foley, MD; Clinton J. Devin, MD*

11:42–11:48 am Discussion

CRANIO-CERVICAL JUNCTION AND ALIGNMENT

11:49–11:51 am
Presentation #77
(pg. 280)

Increasing Incidence of Non-Rheumatic Retro-Odontoid Pseudotumor with Varied Etiology in Elderly
***Ryota Hyakkan, MD**; Masahiko Takahata, MD*

11:52–11:54 am
Presentation #78
(pg. 282)

The Impact of Cervical Sagittal Balance and Cervical Spine Alignment on Craniocervical Junction Kinematic: An Analysis Using Upright Kinematic MRI
*Permsak Paholpak, MD; Blake Formanek; Andrew Vega, BS; Koji Tamai, MD; Kittipong Sessumpun, MD; **Zorica Buser, PhD**; Jeffrey C. Wang, MD*

11:55–11:57 am
Presentation #79
(pg. 284)

Does Target Level Sagittal Alignment Determine Adjacent Level Disc Height Loss?
***Ryan Snowden, MD**; Justin W. Miller, MD; Tome Saidon, MS; Joseph D. Smucker, MD; K. Daniel Riew, MD; Rick C. Sasso, MD*

11:58–12:00 pm
Presentation #80
(pg. 286)

Redefining the Cervical Disability Threshold of T1 Slope Minus Cervical Lordosis
*Peter G. Passias, MD; Dennis Vasquez-Montes, MS; Samantha R. Horn, BA; Cole A. Bortz, BA; Frank A. Segreto, BS; Aaron J. Buckland, MD; Themistocles S. Protopsaltis, MD; Han Jo Kim, MD; Michael Gerling, MD; Renaud Lafage, MS; Thomas J. Errico, MD; Frank J. Schwab, MD; **Virginie Lafage, PhD***

12:01–12:03 pm
Presentation #81
(pg. 287)

Dynamic Changes in the Reflex Exam of Patients with Sub-Axial Cervical Stenosis
***Alexander Tuchman, MD**; Lee A. Tan, MD; Jamal N. Shillingford, MD; Xudong J. Li, MD, PhD; K. Daniel Riew, MD*

12:04–12:10 pm Discussion

COMPLICATIONS AND NON-OPERATIVE APPROACHES

12:11–12:13 pm
Presentation #82
(pg. 289)

Do Preoperative Cervical Epidural Steroid Injections Affect Outcomes After ACDF for Radiculopathy?
*Daniel Tarazona, MD; Eric Warner, BS; Michael Motto, BS; Taolin Fang, MD; Matthew Galetta, BS; I. David Kaye, MD; Christopher K. Kepler, MD, MBA; Mark F. Kurd, MD; Alan S. Hilibrand, MD; **Barrett I. Woods, MD**; Kristen E. Radcliff, MD; Jeffrey A. Rihn, MD; D. Greg Anderson, MD; Alexander R. Vaccaro MD, PhD, MBA; Gregory D. Schroeder, MD*

12:14–12:16 pm
Presentation #83
(pg. 291)

Perioperative Anesthesia Lean Implementation Is Associated with Increased Operative Efficiency in Posterior Cervical Surgeries at a High-Volume Spine Center
*Simon Ammanuel, BS; **Andrew Chan, MD;** Anthony DiGiorgio, DO; Catherine Miller, MD; Praveen Mummaneni, MD*

Individual Disclosures can be found in the Disclosure Index pages 45-102.

12:17–12:19 pm
Presentation #84
(pg. 294)

Undergoing Bariatric Surgery Lowers Complication Rates Following Spine Surgery in Morbidly Obese Patients
Peter G. Passias, MD; Samantha R. Horn, BA; Dennis Vasquez-Montes, MS; Frank A. Segreto, BS; Cole A. Bortz, BA; Cyrus M. Jalai, BA; Daniel M. Sciubba, MD; Micheal Raad, MD; Bassel G. Diebo, MD; Shaleen Vira, MD; Jason A. Horowitz, BA; Hamid Hassanzadeh, MD; Renaud Lafage, MS; Virginie Lafage, PhD; ***Michael C. Gerling, MD***

12:20–12:22 pm
Presentation #85
(pg. 296)

The Risk of Recurrent Laryngeal Nerve Injury with Laterality of Approach in Anterior Cervical Discectomy and Fusion Procedures: A Randomized, Prospective Study Over 10 Years
Shalin Shah, DO*; Manminder Bhatia, DO*

12:23–12:25 pm
Presentation #86
(pg. 298)

Perioperative Complications of Anterior Decompression with Fusion vs. Posterior Decompression with Fusion for the Treatment of Cervical Ossification of the Posterior Longitudinal Ligament: Propensity Score Matching Analysis Using a National Inpatient Database
Toshitaka Yoshii, MD; *Shingo Morishita, MD; Takashi Hirai, MD; Kenichiro Sakai, MD; Tsuyoshi Yamada, MD; Masato Yuasa, MD; Atsushi Okawa, MD*

12:26–12:32 pm Discussion

SURGICAL TECHNIQUES AND TRAUMA

12:33–12:35 pm
Presentation #87
(pg. 301)

The Clinical Study on a Minimally Invasive Muscle-Splitting Approach to Posterior C1–C2 Fixation for the Treatment of Fresh Odontoid Fracture
Guohua Xu, MD*; Xiaogang Bao*

12:36–12:38 pm
Presentation #88
(pg. 302)

Short-Term Outcomes Following Cervical Laminoplasty and Laminectomy and Fusion with Instrumentation
Anthony J. Boniello MD; Samantha R. Horn BA; Frank A. Segreto, BS; Cole A. Bortz, BA; Amrit Khalsa, MD; ***Michael C. Gerling, MD****; Peter G. Passias, MD*

12:39–12:41 pm
Presentation #89
(pg. 304)

Surgical Treatment for Cervical Spine Trauma in Ankylosing Spine with Diffuse Idiopathic Skeletal Hyperostosis: Surgery within 8-Hours After Injury Affects Prognosis
Osahiko Tsuji, MD; *Kota Suda, MD, PhD; Masahiko Takahata, MD; Miki Komatsu, MD, PhD; Norimasa Iwasaki, MD, PhD; Morio Matsumoto, MD; Masaya Nakamura, MD; Kota Watanabe, MD, PhD*

12:42–12:44 pm
Presentation #90
(pg. 306)

SMaRT Human Neural Stem Cells to Degrade Scar and Optimize Regeneration After Traumatic Cervical Spinal Cord Injury
Christopher S. Ahuja, MD*; Mohamad Khazaei, PhD; Priscilla Chan; Jian Wang, MD; Jinil Bhavsar; Michael G. Fehlings, MD, PhD, FRCSC, FACS*

12:45–12:47 pm
Presentation #91
(pg. 310)

Radiologic Factors to Predict Injury of Transverse Atlantal Ligament in Unilateral Sagitally Split Fracture of C1 Lateral Mass
Jae Won Lee, MD; *Jong-Beom Park, MD, PhD; Han Chang, MD, PhD*

12:48–12:50 pm
Presentation #92
(pg. 311)

Treatment Algorithm for Dens Fractures
Amelie Kanovsky, MD; *Ernst Josef Mueller*

12:51–12:57 pm Discussion

12:57 pm **Adjourning Notices**
Alexander R. Vaccaro, MD, PhD, MBA

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Piyush Kalakoti, MD; James Hall, BS; Andrew J. Pugely, MD

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Peter G. Passias, MD; Frank A. Segreto, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Breton G. Line, BS; Justin K. Scheer, MD; Cole A. Bortz, BA; Samantha Horn, BA; D. Kojo Hamilton, MD; Bassel G. Diebo, MD; Frank J. Schwab, MD; Christopher P. Ames, MD; Shay Bess, MD; International Spine Study Group

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Samantha R. Horn, BA; Dennis Vasquez-Montes, MS; Frank A. Segreto, BS; Cole A. Bortz, BA; Aaron Hockley, MD; Bassel G. Diebo, MD; Renaud Lafage, MS; Shaleen Vira, MD; Michael Gerling, MD; Virginie Lafage, PhD; Aaron J. Buckland, MD; Themistocles S. Protopsaltis, MD; Thomas J. Errico, MD; Peter G. Passias, MD

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Narihito Nagoshi, MD, PhD; Hitoshi Kono, MD, PhD; Osahiko Tsuji, MD, PhD; Ryoma Aoyama, MD, PhD; Kanehiro Fujiyoshi, MD, PhD; Yuta Shiono, MD, PhD; Masayuki Ishikawa, MD, PhD; Kenshi Daimon, MD; Naobumi Hosogane, MD, PhD; Kota Watanabe, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Ken Ishii, MD, PhD; Junichi Yamane, MD, PhD

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Chi Heon Kim, MD, PhD; Chun Kee Chung, MD, PhD; Seung Heon Yang, MD

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Jung-Ki Ha, MD; Dong-Ho Lee, MD, PhD; Jin Hoon Park, MD, PhD

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Jetan H. Badhiwala, MD; Muhammad A. Akbar, MD; Fan Jiang, MD; Farshad Nassiri, MD; Christopher D. Witiw, MD, MSc; Robert G. Grossman, MD; Jefferson R. Wilson, MD, PhD; Michael G. Fehlings, MD, PhD

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Daniel Tobert, MD; Hai Le, MD; Justin Blucher; Mitchel B. Harris, MD; Andrew J. Schoenfeld, MD

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Alphabetical Participant Disclosure List

Disclosure information submitted to the AAOS Orthopaedic Disclosure Program.

Alphabetical Participant Disclosure List

Name	Disclosure Information	Presentations	E-Posters
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Abumi, Kuniyoshi [S]	Asia-Pacific Spine Society: Board or committee member; Cervical Spine Research Society Asia-Pacific Section: Board or committee member; Craniovertebral Junction and Spine: Editorial or governing board; European Spine Journal: Editorial or governing board; International Journal of Spine Surgery: Editorial or governing board; SAS Journal: Editorial or governing board; Spine: Editorial or governing board; Submitted on: 06/03/2018		
Adams, Sasha	No Conflicts to Disclose; Submitted on: 04/23/2018	35	
Ahn, Henry	Canadian Spine Research Education Fund: Board or committee member; Submitted on: 10/02/2018	41	
Ahuja, Christopher	No Conflicts to Disclose; Submitted on: 10/02/2018	90	
Ailon, Tamir	No Conflicts to Disclose; Submitted on: 10/02/2018	22	
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Akbar, Muhammad	No Conflicts to Disclose; Submitted on: 04/26/2018	27	56
Albert, Todd [S]	ASIP: Stock or stock Options; Biomet: IP royalties Biometrix: Stock or stock Options; Breakaway Imaging: Stock or stock Options; Crosstree: Stock or stock Options; DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Facetlink: Stock or stock Options; Gentis: Stock or stock Options; In ViVo Therapeutics: Stock or stock Options; Invuity: Stock or stock Options; Jay Pee: Publishing royalties, financial or material support; Journal of Bone and Joint Surgery - American: Editorial or governing board; Nuvasive:	28	49

Name	Disclosure Information	Presentations	E-Posters
Albert, Todd [S] *continued*	Paid consultant; Paradigm Spine: Stock or stock Options; PMIG: Stock or stock Options; Saunders/Mosby-Elsevier: Publishing royalties, financial or material support; Scoliosis Research Society: Board or committee member; Spine: Editorial or governing board; Spine Deformity Journal: Editorial or governing board; Spinicity: Stock or stock Options; Thieme: Publishing royalties, financial or material support; United Healthcare: Other financial or material support; Vertech: Stock or stock Options; Submitted on: 04/22/2018	28	49
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Ammanuel, Simon	No Conflicts to Disclose; Submitted on: 04/26/2018	83	
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Anastasio, Albert	No Conflicts to Disclose; Submitted on: 05/31/2018	75	
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Anderst, William	Journal of Biomechanics: Editorial or governing board; Journal of Orthopaedic Research: Editorial or governing board; Smith & Nephew: Research support; Submitted on: 02/19/2018		7
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Name	Disclosure Information	Presentations	E-Posters
Andrade, Nicholas	No Conflicts to Disclose; Submitted on: 04/22/2018		40
Aoyama, Ryoma	No Conflicts to Disclose; Submitted on: 04/13/2018	23	52
Arai, Yoshiyasu	No Conflicts to Disclose; Submitted on: 04/15/2018		47
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Arnold, Paul RC, M *continued*	Journal of Spine, PLOS One, Public Library of Science One, Public Library of Science One: Editorial or governing board; LANX: Research support; LSRS Board of Directors, NASS Professional Compliance Panel, NASS Ethics Committee: Board or committee member; Medtronic Sofamor Danek: Paid consultant; NASS Ethics: Board or committee member; Spine Trauma Study Group: Research support; SpineEx: Stock or stock Options; Spinewave: IP royalties; Paid consultant; Stryker: Paid consultant; Ulrich: IP royalties; Paid consultant; Z-plasty: Stock or stock Options; Submitted on: 04/20/2018	41	
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Badhiwala, Jetan	No Conflicts to Disclose; Submitted on: 04/23/2018	27, 41, 50	56
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Baker, Joseph	No Conflicts to Disclose; Submitted on: 10/03/2018		37

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Barry, Alexander	No Conflicts to Disclose; Submitted on: 10/02/2018	67	
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Bedard, Nicholas	No Conflicts to Disclose; Submitted on: 09/20/2018	51	45
Behrens, Phillip	No Conflicts to Disclose; Submitted on: 10/06/2018	68	
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Berger, Ryan	No Conflicts to Disclose; Submitted on: 05/31/2018	57	
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Bhatia, Manminder	No Conflicts to Disclose; Submitted on: 04/01/2018	85	

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Bhatt, Surabhi	No Conflicts to Disclose; Submitted on: 04/13/2018	9	
Bhavsar, Jinil	No Conflicts to Disclose; Submitted on: 10/14/2018	90	
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Blucher, Justin	No Conflicts to Disclose; Submitted on: 03/07/2018		57
Blumenthal, Scott	Aesculap/B.Braun: Paid consultant; Paid presenter or speaker; Baylis Medical: Paid consultant; Centinel spine: Paid consultant; European Spine Journal: Editorial or governing board; Fziomed: Other financial or material support; Stock or stock Options; Orthofix, Inc.: Paid consultant; Vertiflex: Other financial or material support; Vertiflex, Centinel: Stock or stock Options; Submitted on: 10/04/2018	37	
Boah, Akwasi	No Conflicts to Disclose; Submitted on: 04/20/2018	24	
Bohl, Daniel	American Orthopaedic Foot and Ankle Society: Board or committee member; OPED: Research support; Submitted on: 10/02/2018	31	
Boniello, Anthony	No Conflicts to Disclose; Submitted on: 10/02/2018	88	
Bonnevie, Edward	No Conflicts to Disclose; Submitted on: 04/24/2018	43	

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Name	Disclosure Information	Presentations	E-Posters
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Bortz, Cole	No Conflicts to Disclose; Submitted on: 04/19/2018	14, 22, 45, 58, 63, 80, 84, 88	6, 12, 13, 15, 37, 43
Brodke, Darrel [M]	Amedica: IP royalties AOSpine: Board or committee member; Cervical Spine Research Society: Board or committee member; Clinical Orthopaedics and Related Research: Editorial or governing board; Lumbar Spine Research Society: Board or committee member; Medtronic: IP royalties; Vallum: Paid consultant; Submitted on: 10/03/2018	20, 41	
Bronson, Wesley	No Conflicts to Disclose; Submitted on: 08/28/2018		26
Bruce, Jeffrey	Merck: Paid consultant; Submitted on: 11/02/2018		1
Buchowski, Jacob [PC]	AAOS: Board or committee member American Orthopaedic Association: Board or committee member; American Spinal Injury Association: Board or committee member; Association of Bone and Joint Surgeons: Board or committee member; Cervical Spine Research Society: Board or committee member; FOSA: Board or committee member; Globus Medical: IP royalties K2M: IP royalties; Lumbar Spine Research Society: Board or committee member; Scoliosis Research Society: Board or committee member; Spine Deformity: Editorial or governing board Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support; Submitted on: 10/12/2018		
Buckland, Aaron	American Spinal Injury Association: Board or committee member; Association of Bone and Joint Surgeons: Board or committee member; Cervical Spine Research Society: Board or committee member; Submitted on: 10/20/2018	80	6, 13, 37
Bueff, Hans-Ulrich [PC]	Cervical Spine Research Society: Board or committee member; Submitted on: 11/08/2018		

Name	Disclosure Information	Presentations	E-Posters
Burton, Douglas [S]	FOSA: Board or committee member; Globus Medical: IP royalties; K2M: IP royalties; Lumbar Spine Research Society: Board or committee member; Scoliosis Research Society: Board or committee member; Submitted on: 05/11/2018	8, 17, 54	11, 14, 15, 43
Buser, Zorica	Spine Deformity: Editorial or governing board; Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support; Submitted on: 05/02/2018	78	
Bydon, Ali	DePuy, A Johnson & Johnson Company: Research support; Submitted on: 04/25/2018	42	
Bydon, Mohamad	No Conflicts to Disclose; Submitted on: 06/12/2018	48, 60, 76	
Campbell, Peter	No Conflicts to Disclose; Submitted on: 04/25/2018	36	
Cantrell, William	No Conflicts to Disclose; Submitted on: 10/03/2018	57	
Cardinal, Kaitlyn	No Conflicts to Disclose; Submitted on: 10/02/2018	31, 62	42, 46
Caridi, John	North American Spine Society: Board or committee member; Scoliosis Research Society: Board or committee member; Zimmer: Paid consultant; Research support; Submitted on: 04/17/2018	4	
Carlson, Brandon	No Conflicts to Disclose; Submitted on: 10/04/2018	8	
Carelli, Luis [S]	Medtronic - consultant; Nuvasive- consultant; Ossea Technology- consultant; Submitted on 10/19/2018		
Carreon, Leah	AOSpine: Research support; Editorial Advisory Board Spine, The Spine Journal: Editorial or governing board; Integra, Intellirod: Research support; Norton Healthcare: Employee; Research support; OREF: Research support; Pfizer: Research support; Scoliosis Research Society: Board or committee member; Research support; Spine Deformity: Editorial or governing board Trips and Travel from Center for Spine Surgery and Research, University of Denmark: Other financial or material support; University of Louisville Institutional review Board: Board or committee member; Submitted on: 04/23/2018	66	
Carroll, Deven	No Conflicts to Disclose; Submitted on: 04/20/2018	1	
Cavanaugh, David	No Conflicts to Disclose; Submitted on: 04/25/2018	36	

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Name	Disclosure Information	Presentations	E-Posters
Cha, Thomas	Bio2: Paid consultant; GE Healthcare: Paid consultant; K2M: Paid consultant; Research support Nuvasive: Paid consultant; Research support; Submitted on: 04/27/2018	32	
Chan, Andrew	No Conflicts to Disclose; Submitted on: 10/02/2018	83	
Chan, Priscilla	No Conflicts to Disclose; Submitted on: 04/26/2018	90	
Chang, Han	No Conflicts to Disclose; Submitted on: 04/18/2018	91	34
Chang, Kevin	No Conflicts to Disclose; Submitted on: 04/24/2018		4
Chang, Victor	Globus Medical: Paid consultant; Medtronic: Research support; Submitted on: 04/24/2018	74	
Chapman, Jens S, M	AO North America Board of Directors: Board or committee member Evidence Based Spine JournalSpineGlobal Spine Journal: Editorial or governing board EvidenceBased Spine Journal: Publishing royalties, financial or material support Global Spine Journal: Publishing royalties, financial or material support Journal of Spine: Editorial or governing board Renovis Medical: Stock or stock Options Spine: Editorial or governing board; Submitted on: 02/23/2018		
Chee, Ana RS	No Conflicts to Disclose; Submitted on: 11/02/2018		
Chen, Huajiang	No Conflicts to Disclose; Submitted on: 10/08/2018	53	
Cheng, Ivan RC	AAOS: Board or committee member; Cervical Spine Research Society: Board or committee member; Globus Medical: Paid consultant; Nuvasive: IP royalties; Stock or stock Options Scoliosis Research Society: Board or committee member; Spinal Cyte: Stock or stock Options Spine Wave: IP royalties; Stock or stock Options SpineCraft: Paid consultant SpineThe Spine Journal: Editorial or governing board Stryker: Paid consultant; Submitted on: 04/18/2018		
Cheng, Joseph	Journal of Neurosurgery: Spine: Editorial or governing board; North American Spine Society: Board or committee member; Submitted on: 04/25/2018		18
Chijimatsu, Ryota	No Conflicts to Disclose; Submitted on: 04/24/2018	69	

Name	Disclosure Information	Presentations	E-Posters
Cho, Samuel [AC]	AAOS: Board or committee member American Orthopaedic Association: Board or committee member; AOSpine North America: Board or committee member Cervical Spine Research Society: Board or committee member; Corentec: Paid consultant; Globus Medical: Paid consultant; Medtronic: Paid consultant; North American Spine Society: Board or committee member; Scoliosis Research Society: Board or committee member; Zimmer: Paid consultant; Research support; Submitted on: 04/24/2018		
Choi, John	No Conflicts to Disclose; Submitted on: 04/24/2018	42	
Chotai, Silky	No Conflicts to Disclose; Submitted on: 04/24/2018	76	
Chou, Dean	Globus Medical: IP royalties; Paid consultant; Medtronic: Paid consultant; Submitted on: 04/02/2018	58	
Chung, Chun	No Conflicts to Disclose; Submitted on: 11/02/2018		53
Cohen, David	No Conflicts to Disclose; Submitted on: 04/23/2018	39	40
Cohen, Jeffrey	SpecialtyCare: Employee; Submitted on: 04/25/2018		16
Conti Mica, Michael	No Conflicts to Disclose; Submitted on: 04/22/2018	21	
Cook, David	No Conflicts to Disclose; Submitted on: 04/23/2018		48
Coronado, Rogelio	No Conflicts to Disclose; Submitted on: 10/03/2018		30
Craven, Cathy	Rick Hansen Institute Care Committee: Board or committee member; Submitted on: 05/01/2018	46	
Cuellar, Jason	Cytonics Corp: Stock or stock Options; Unpaid consultant; Submitted on: 04/23/2018	68	
Currier, Bradford [M]	DePuy, A Johnson & Johnson Company: IP royalties; Lumbar Spine Research Society: Board or committee member; Spine Study Group: Board or committee member; SpinologyTenex: Stock or stock Options; Stryker: IP royalties; Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support; Zimmer: IP royalties; Submitted on: 04/06/2018		

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Name	Disclosure Information	Presentations	E-Posters
Dailey, Andrew [RC, PC]	Biomet: IP royalties; Cervical Spine Research Society: Board or committee member; K2M: Paid consultant; Research support Lumbar Spine Research Society: Board or committee member; Medtronic Sofamor Danek: Paid consultant; Submitted on: 03/05/2018		
Daimon, Kenshi	The General Insurance Association of Japan: Research support; Submitted on: 04/26/2018		19, 38, 52
Daniels, Alan	EOS: Paid consultant; Orthofix, Inc.: Paid consultant; Research support; SpineArt: Paid consultant; Springer: Publishing royalties, financial or material support; Stryker: Paid consultant; Submitted on: 10/02/2018	14, 17, 45, 54	15, 50
Darden, Bruce	4Web: Stock or stock Options; BioMedFlex: Stock or stock Options; Cervical Spine Research Society, Lumbar Spine Research Society: Board or committee member; Clear Edge Spine: IP royaltie;s DePuy, A Johnson & Johnson Company: Research support; Spine: Editorial or governing board; Spine-guard: Paid consultant; Stryker: Paid consultant; Paid presenter or speaker; Synthes: Paid presenter or speaker; Research support; Submitted on: 10/02/2018	21	
Daubs, Michael [PC]	Cervical Spine Research Society: Board or committee member; DePuy, A Johnson & Johnson Company: IP royalties; Pfizer: Research support The Spine Journal: Editorial or governing board; Submitted on: 10/03/2018		
Davidson, Iyooh Uchechukwu	No Conflicts to Disclose; Submitted on: 10/02/2018		32
Depasse, John	No Conflicts to Disclose; Submitted on: 10/10/2018		50
Deutsch, Brian	No Conflicts to Disclose; Submitted on: 04/19/2018	4	
Devin, Clinton	Cervical Spine Research Society: Board or committee member; Medtronic Sofamor Danek: Other financial or material support; North American Spine Society: Board or committee member; Stryker: Paid consultant; Research support; Wright Medical Technology, Inc.: Paid consultant; Submitted on: 03/20/2018	47, 48, 60, 76	30
Diebo, Bassel	No Conflicts to Disclose; Submitted on: 10/02/2018	58, 84	6, 11, 12, 13, 37
Digiorgio, Anthony	No Conflicts to Disclose; Submitted on: 10/02/2018	83	

Name	Disclosure Information	Presentations	E-Posters
Dodwad, Shah-Nawaz	Lumbar Spine Research Society: Board or committee member; Nuvasive: Paid consultant; Stryker: Paid consultant; Submitted on: 05/29/2018	13, 35	
Dombrowski, Malcolm	No Conflicts to Disclose; Submitted on: 05/31/2018		7
Donaldson, William [PC]	AAOS: Board or committee member; Submitted on: 04/25/2018		7
Dowdell, James	No Conflicts to Disclose; Submitted on: 10/02/2018	33	
Driscoll, Adam	No Conflicts to Disclose; Submitted on: 04/23/2018		4
Dunn, Conor	No Conflicts to Disclose; Submitted on: 10/04/2018		51
Durand, Wesley	No Conflicts to Disclose; Submitted on: 04/28/2018		50
DuShane, Lisa [C]	No Conflicts to Disclose; Submitted on: 02/22/2018		
Egawa, Satoru	No Conflicts to Disclose; Submitted on: 04/24/2018		25
Elder, Benjamin	No Conflicts to Disclose; Submitted on: 04/26/2018	42	
Elliott, Dawn	Biomedical Engineering Society, International Society for the Study of Lumbar Spine: Board or committee member; Discgenics: Research support; Submitted on: 04/24/2018	43	
Elysee, Jonathan	No Conflicts to Disclose; Submitted on: 10/07/2018		14
Emami, Arash	Nuvasive: Research support; Submitted on: 04/18/2018		51
Endo, Naoto	No Conflicts to Disclose; Submitted on: 04/25/2018	71	44
Endo, Teruaki	No Conflicts to Disclose; Submitted on: 10/03/2018	25	
Errico, Thomas	Fastenetix: IP royalties; Harms Study Group: Board or committee member; International Spine Study Group (ISSG): Board or committee member; K2M: Other financial or material support; Paid consultant; Paid presenter or speaker; Medtronic: Research support; Paradigm Spine: Research support; Pfizer: Research support; Submitted on: 05/03/2018	80	6, 13, 37
Fahs, Adam	No Conflicts to Disclose; Submitted on: 04/26/2018		5

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Name	Disclosure Information	Presentations	E-Posters
Faloon, Michael	AAOS: Board or committee member; K2M: Paid presenter or speaker; Research support; North American Spine Society: Board or committee member; Scoliosis Research Society: Board or committee member; Submitted on: 10/02/2018		51
Fang, Taolin	Annals of Plastic Surgery: Editorial or governing board; Merck: Employee; Submitted on: 04/23/2018	2, 38, 82	26
Faraj, Razan	No Conflicts to Disclose; Submitted on: 04/24/2018	75	
Farhadi, H. Francis	DePuy, A Johnson & Johnson Company: Research support; Submitted on: 04/24/2018	41	
Fehlings, Michael	Fortuna Fix: Paid consultant; None: Board or committee member; Editorial or governing board; Submitted on: 10/03/2018	27, 29, 41, 46, 50, 90	18, 56
Fischer, Charla	Expert Connect: Paid presenter or speaker; Stryker: Paid consultant; Submitted on: 04/14/2018		6
Fleischer, Mackenzie	No Conflicts to Disclose; Submitted on: 04/18/2018		5
Foley, Kevin	Discgenics: Stock or stock Options; Medtronic: Stock or stock Options; Medtronic Sofamor Danek: IP royalties; Paid consultant; Nuvasive: Stock or stock Options; Society for Minimally Invasive Spine Surgery (SMISS): Board or committee member; Spinewave: Stock or stock Options; TrueVision: Stock or stock Options; Submitted on: 03/21/2018	76	
Formanek, Blake	No Conflicts to Disclose; Submitted on: 04/26/2018	78	
Fourney, Daryl	Canadian Journal of Neurological Sciences: Editorial or governing board Neurosurgery: Editorial or governing board Spine: Editorial or governing board Vertex Pharmaceuticals: Research support; Submitted on: 10/03/2018	41	
Frangella, Nicholas	No Conflicts to Disclose; Submitted on: 10/07/2018	58	
Frank, Kelly	No Conflicts to Disclose; Submitted on: 04/25/2018	36	
Fujita, Nobuyuki	No Conflicts to Disclose; Submitted on: 10/03/2018	23	19, 38
Fujiwara, Hirokazu	Magnetic Resonance in Medical Sciences: Editorial or governing board, Submitted on: 04/24/2018		19, 38
Fujiyoshi, Kanehiro	No Conflicts to Disclose; Submitted on: 04/21/2018		52

Name	Disclosure Information	Presentations	E-Posters
Furlan, Julio [RS]	No Conflicts to Disclose; Submitted on: 04/25/2018	46	33
Furuya, Takeo	No Conflicts to Disclose; Submitted on: 04/26/2018		28, 41
Gal, Jonathan	American Society of Anesthesiologists: Board or committee member; Obagi: Employee; Submitted on: 04/23/2018	4	
Galetta, Matthew	No Conflicts to Disclose; Submitted on: 04/23/2018	38, 82	26
Gandhi, Anup	Zimmer: Employee; Stock or stock Options; Submitted on: 04/26/2018	44	
Gandhi, Sapan [RS]	Stryker: Other financial or material support; Synthes: Other financial or material support; Submitted on: 04/07/2018		5
Gang, Catherine Himo	No Conflicts to Disclose; Submitted on: 05/15/2018		49
Gao, Yubo	No Conflicts to Disclose; Submitted on: 10/03/2018	49	8
Garvey, Timothy [M]	Medtronic: Paid presenter or speaker; Medtronic Sofamor Danek: IP royalties; Submitted on: 04/20/2018		
Gerling, Michael	AAOS: Board or committee member; Cervical Spine Research Society: Board or committee member; CTL Medical: Other financial or material support; Wolf Endoscopic: Paid consultant; Submitted on: 05/01/2018	80, 84, 88	6, 13
Ghanayem, Alexander [M]	American Orthopaedic Association: Board or committee member; Cervical Spine Research Society: Board or committee member; Journal of Spinal Disorders and Techniques: Editorial or governing board; Submitted on: 04/23/2018		
Ghiselli, Gary [AC]	Colorado Orthopedic Society: Board or committee member; Difusion Technologies: Stock or stock Options; New Era Orthopedics: Paid consultant; North American Spine Society: Board or committee member; Submitted on: 02/25/2017		
Ghogawala, Zoher [M]	Cervical Spine Research Society: Board or committee member; North American Spine Society: Board or committee member; Submitted on: 08/24/2018		
Glaeser, Juliane	Medtronic: Research support; Submitted on: 04/20/2018	68	
Glassman, Steven	K2M: Paid consultant; Medtronic: IP royalties; Paid consultant; Scoliosis Research Society: Board or committee member; Submitted on: 07/13/2018	66	
Goedmakers, Caroline	No Conflicts to Disclose; Submitted on: 10/04/2018	7	

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Name	Disclosure Information	Presentations	E-Posters
Gokaslan, Ziya [S]	AO Spine: Research support; spinal kinetics: Stock or stock Options; Submitted on: 10/02/2018	42	
Goldberg, Edward	Bonivo: Stock or stock Options; Theracell: Stock or stock Options; Submitted on: 10/02/2018	1	27
Goodwin, Ryan	K2M: Paid consultant; Orthopediatrics: Paid consultant Stryker: Paid consultant; Submitted on: 06/01/2018	57	
Goz, Vadim	No Conflicts to Disclose; Submitted on: 04/11/2018	20	
Grabel, Zachary	No Conflicts to Disclose; Submitted on: 05/07/2018	70	
Grauer, Jonathan [RC]	American Journal of Orthopedics: Editorial or governing board; Cervical Spine Research Society: Board or committee member; Contemporary Spine Surgery: Editorial or governing board; NASS Spine Line: Editorial or governing board; North American Spine Society: Board or committee member; TIDI Products: Paid consultant; Submitted on: 10/02/2018		
Grossman, Robert	American Board of Neurological Surgery: Board or committee member; Neurosurgery: Editorial or governing board; vertex pharma: Paid consultant; World Neurosurgery: Editorial or governing board; Submitted on: 03/21/2018		56
Gullbrand, Sarah	No Conflicts to Disclose; Submitted on: 04/24/2018	43	
Gum, Jeffrey	Acuity: IP royalties; Paid consultant; Alphatec Spine: Paid consultant; American Journal of Orthopedics: Editorial or governing board; DePuy, A Johnson & Johnson Company: Paid consultant; K2M: Paid consultant; Medtronic: Paid consultant; Stryker: Paid consultant; The Spine Journal - Reviewer: Editorial or governing board; Submitted on: 04/23/2018	66	
Guntin, Jordan	No Conflicts to Disclose; Submitted on: 04/19/2018	31, 62	42, 46
Guo, Qian	No Conflicts to Disclose; Submitted on: 04/24/2018		22
Guo, Tao	No Conflicts to Disclose; Submitted on: 04/27/2018	32	
Gupta, Munish	DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Paid presenter or speaker; European Spine Journal-Reviewer: Editorial or governing board; Global Spine	8, 17, 54	

Name	Disclosure Information	Presentations	E-Posters
Gupta, Munish *continued*	Journal-Reviewer: Editorial or governing board; Johnson & Johnson: Stock or stock Options; Medtronic: Paid consultant; Procter & Gamble: Stock or stock Options; Spine Deformity, Associate Editor: Editorial or governing board; Submitted on: 06/20/2018	8, 17, 54	
Gurd, David	No Conflicts to Disclose; Submitted on: 10/15/2018	57	
Guyer, Richard	Alphatec: IP royalties; Carevature: Paid presenter or speaker; DePuy, A Johnson & Johnson Company: Paid presenter or speaker; K2M: IP royalties; Paid presenter or speaker; Lattice Biologics: Stock or stock Options; Medacta: Paid presenter or speaker; Medtronic: Paid presenter or speaker; Nanovis: IP royalties; Orthofix, Inc.: Paid presenter or speaker; Spinal Kinetics: Stock or stock Options; Synthes: Paid presenter or speaker; Submitted on: 10/02/2018	37	
Ha, Jung-Ki	No Conflicts to Disclose; Submitted on: 04/22/2018		55
Ha, Yoon [S]	No Conflicts to Disclose; Submitted on: 04/26/2018		
Haddas, Ram [RS]	Alphatec Spine: Research support; Aspen Bracing: Research support; Cervical Spine Research Society: Research support; Medtronic: Research support; Submitted on: 10/03/2018	24	
Haid, Regis W. Jr [M]	American Association of Neurological Surgeons: Board or committee member; Contemporary Neurosurgery: Editorial or governing board; Elsevier, Inc.: Publishing royalties, financial or material support Globus Medical: IP royalties; Stock or stock Options; Lumbar Spine Research Society: Board or committee member; Medtronic Sofamor Danek: IP royalties; Neurosurgery Research and Education Foundation: Board or committee member; Nuvasive: Paid consultant; Society for Minimally Invasive Spine Surgery: Board or committee member; SpineUniverse: Stock or stock Options; SpineWave: Stock or stock Options; Submitted on: 11/15/2018		
Haleem, Meraaj	No Conflicts to Disclose; Submitted on: 04/23/2018		4
Hall, James	No Conflicts to Disclose; Submitted on: 10/02/2018		8, 9

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Name	Disclosure Information	Presentations	E-Posters
Hamilton, D. Kojo	European Spine Journal: Editorial or governing board; Nuvasive: Research support; Pfizer: Research support; Submitted on: 10/03/2018	17, 54	12
Harrell, Frank	American Heart Journal: Editorial or governing board; Bayer: Paid consultant; Journal of Clinical Epidemiology: Editorial or governing board; Medtronic Sofamor Danek: Paid consultant; Research support; Norvartis: Paid presenter or speaker; Science Translational Medicine: Editorial or governing board; Statistics in Medicine: Editorial or governing board; Submitted on: 04/23/2018	48, 60, 76	
Harris, Mitchel	No Conflicts to Disclose; Submitted on: 05/20/2018		57
Harrop, James [M]	Asterias: Other financial or material support; Bioventus: Other financial or material support; DePuy, A Johnson & Johnson Company: Paid consultant; Paid presenter or speaker; ethicon: Paid consultant; Globus Medical: Paid presenter or speaker; Spine Universe, CNS quarterly, Congress of Neurosurgeons Executive Board, CSRS,PNS, Jefferson University Physicians, LSRS, COSSS: Board or committee member; Editorial or governing board Tejjin: Other financial or material support; Submitted on: 10/03/2018	41	
Hart, Robert [PC, M]	American Orthopaedic Association: Board or committee member; Cervical Spine Research Society: Board or committee member; depuy: Paid consultant; Paid presenter or speaker; Research support DePuy, A Johnson & Johnson Company: IP royalties; Globus Medical: IP royalties; Paid consultant; Paid presenter or speaker; International Spine Study Group: Board or committee member; ISSLS Textbook of the Lumbar Spine: Editorial or governing board; Medtronic: Paid consultant; Misonix: Research support; North American Spine Society: Board or committee member; Orthofix, Inc.: Paid presenter or speaker Scoliosis Research Society: Board or committee member; SeaSpine: IP royalties; Western Ortho Assn: Board or committee member; Submitted on: 04/26/2018	8, 14, 17, 54	11, 15, 43
Hartner, Samantha	No Conflicts to Disclose; Submitted on: 10/11/2018		5

Name	Disclosure Information	Presentations	E-Posters
Hassanzadeh, Hamid	4Web: Stock or stock Options; DePuy, A Johnson & Johnson Company: Paid consultant; Medtronic: Paid presenter or speaker; Research support; Misonix: Stock or stock Options; Norvartis: Stock or stock Options; Nuvasive: Paid presenter or speaker; Stock or stock Options; Orthofix, Inc.: Paid presenter or speaker; Research support; Pacira: Stock or stock Options; Pfizer: Paid consultant; Research support; Scoliosis Research Society: Board or committee member; Submitted on: 10/02/2018	45, 84	
Haws, Brittany RS	No Conflicts to Disclose; Submitted on: 05/15/2018	31, 62	42, 46, 49
Heary, Robert M	Cervical Spine Research Society: Board or committee member; DePuy, A Johnson & Johnson Company: IP royalties; Neurosurgery, World Neurosurgery, Indian Journal of Orthopaedics, Clinical Spine Surgery, Journal of Spinal Cord Medicine, Neural Regeneration Research, Spinal Deformity: Editorial or governing board; Thieme Medical Publishers, Inc.: Publishing royalties, financial or material support; Zimmer: IP royalties; Submitted on: 04/26/2018		
Hecht, Andrew PC, SP	AAOS, Musculoskeletal Transplant Foundation: Board or committee member; American Journal of Orthopedics: Editorial or governing board; atlas spine: IP royalties; Paid consultant; Global Spine Journal: Editorial or governing board; Johnson & Johnson: Stock or stock Options; journal of spinal disorders and techniques: Editorial or governing board; Medtronic Sofamor Danek: Paid consultant; Orthopaedic Knowledge Online Journal: Editorial or governing board; Orthopedics Today: Editorial or governing board; Stryker Spine; Zimmer Spine: Paid consultant Zimmer: IP royalties; Paid consultant: Submitted on: 04/26/2018	33	
Hendrickson, Nathan	No Conflicts to Disclose; Submitted on: 04/10/2018	49, 51	8
Hijji, Fady	No Conflicts to Disclose; Submitted on: 10/02/2018	31	
Hilibrand, Alan	AAOS: Board or committee member; Amedica: IP royalties; Biomet: IP royalties; Lifespine: Stock or stock Options; Paradigm spine: Stock or stock Options; Submitted on: 10/08/2018	2, 30, 38, 41, 82	26

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Name	Disclosure Information	Presentations	E-Posters
Hill, Patrick	No Conflicts to Disclose; Submitted on: 04/24/2018		49
Hills, Jeffrey	No Conflicts to Disclose; Submitted on: 04/23/2018	47	30
Himed, Khaled	No Conflicts to Disclose; Submitted on: 04/23/2018		39
Hirai, Takashi	No Conflicts to Disclose; Submitted on: 04/15/2018	86	25, 47
Hirano, Toru	No Conflicts to Disclose; Submitted on: 04/24/2018	71	44
Ho, Alisha	No Conflicts to Disclose; Submitted on: 04/14/2018		48
Hockley, Aaron	No Conflicts to Disclose; Submitted on: 10/02/2018		13
Hoffmann, Jacob	No Conflicts to Disclose; Submitted on: 09/06/2018	13	
Holy, Marek	No Conflicts to Disclose; Submitted on: 04/19/2018	5	
Hong, Jae Taek	Korean Neurosurgical Spine Society: Board or committee member; Submitted on: 04/26/2018	73	
Hopkins, Benjamin	No Conflicts to Disclose; Submitted on: 04/26/2018	67	
Hori, Yusuke	No Conflicts to Disclose; Submitted on: 04/22/2018	52	
Horn, Samantha	No Conflicts to Disclose; Submitted on: 10/02/2018	14, 22, 45, 63, 80, 84, 88	6, 12, 13, 15, 37, 43
Horowitz, Jason	No Conflicts to Disclose; Submitted on: 04/18/2018	45, 84	
Hoshino, Masatoshi	No Conflicts to Disclose; Submitted on: 10/02/2018	52	
Hosogane, Naobumi	No Conflicts to Disclose; Submitted on: 04/14/2018		52
Hospital, Seoul National	RIWOspine, Richard Wolf GmBH: Unpaid consultant; Submitted on: 04/23/2018		
Hostin, Richard	DePuy, A Johnson & Johnson Company: Paid consultant; Submitted on: 04/19/2018	45	14
Houten, John	No Conflicts to Disclose; Submitted on: 04/22/2018	65	

Name	Disclosure Information	Presentations	E-Posters
Hsu, Erin	AAOS: Board or committee member; Bacterin: Paid consultant; Bioventus: Paid consultant; Cervical Spine Research Society: Board or committee member; Globus Medical: Paid consultant; Journal of Bone and Joint Surgery - American: Editorial or governing board; Lifenet: Paid consultant; LSRS: Board or committee member; Medtronic Sofamor Danek: Paid consultant; Pioneer Surgical: Paid consultant; Relievant Medsystems: Paid consultant; RMEC: Board or committee member; Spinesmith: Paid consultant; Stryker: IP royalties; Paid consultant; Terumo: Paid consultant; Zimmer: Paid consultant; Submitted on: 04/23/2018		4
Hsu, Wellington [AC, M]	Allosource: Paid consultant; Bioventus: Paid consultant; Journal of Bone and Joint Surgery - American: Editorial or governing board; Lumbar Spine Research Society: Board or committee member; Medtronic: Research support Medtronic Sofamor Danek: Paid consultant; Mirus: Paid consultant; North American Spine Society: Board or committee member; Nuvasive: Paid consultant; Stryker: IP royalties; Paid consultant; Wright Medical Technology, Inc.: Paid consultant; Submitted on: 10/03/2018	9, 11, 19	4
Huang, Russel	Clinical Orthopaedics and Related Research: Editorial or governing board; HSS Journal: Editorial or governing board; Spine: Editorial or governing board; The Spine Journal: Editorial or governing board; Submitted on: 04/25/2018	28	
Hwang, Ki	DePuy, A Johnson & Johnson Company: Paid presenter or speaker; GLobal Spine Journal: Editorial or governing board; Submitted on: 04/18/2018		51
Hyakkan, Ryota	No Conflicts to Disclose; Submitted on: 10/02/2018	77	
Hyun, Seung-Jae	Medtronic: Unpaid consultant; Submitted on: 04/03/2018	56	
Ibaseta, Alvaro	No Conflicts to Disclose; Submitted on: 10/02/2018	39	
Ichihara, Daisuke	No Conflicts to Disclose; Submitted on: 04/26/2018		38
Iga, Takahito	No Conflicts to Disclose; Submitted on: 04/23/2018	23	
Ikeda, Terumasa	No Conflicts to Disclose; Submitted on: 04/27/2018	15, 55	

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Name	Disclosure Information	Presentations	E-Posters
Iloanya, Michael	No Conflicts to Disclose; Submitted on: 10/04/2018		27
Imagama, Shiro	No Conflicts to Disclose; Submitted on: 10/02/2018	10, 12, 59	
Inage, Kazuhide	No Conflicts to Disclose; Submitted on: 04/23/2018		28, 41
Inose, Hiroyuki	No Conflicts to Disclose; Submitted on: 04/24/2018		25
Inoue, Hirokazu	No Conflicts to Disclose; Submitted on: 10/02/2018	25	
International Spine Study Group	DePuy, A Johnson & Johnson Company: Research support; K2M: Research support; Medtronic Sofamor Danek: Research support; Nuvasive: Research support; Orthofix, Inc.: Research support; Stryker: Research support; Submitted on: 04/23/2018	14, 17, 22, 45, 54, 58, 63	
Ishida, Wataru	No Conflicts to Disclose; Submitted on: 04/24/2018	42	1
Ishiguro, Hiroyuki	No Conflicts to Disclose; Submitted on: 04/19/2018	59, 69	
Ishihama, Hiroko	No Conflicts to Disclose; Submitted on: 04/26/2018		19, 38
Ishii, Ken	No Conflicts to Disclose; Submitted on: 06/01/2018	23	52
Ishikawa, Masayuki	No Conflicts to Disclose; Submitted on: 04/14/2018		52
Ishikawa, Yoshimoto	No Conflicts to Disclose; Submitted on: 10/03/2018	10, 12	
Issa, Kimona	Medtronic: Other financial or material support; Stryker: Other financial or material support; Submitted on: 05/31/2018		51
Ito, Shuhei	No Conflicts to Disclose; Submitted on: 04/26/2018		23, 36
Ito, Yohei	No Conflicts to Disclose; Submitted on: 04/25/2018	64	
Iwasaki, Norimasa	Asahi Kasei Pharma: Paid presenter or speaker; Daiichi Sankyo Company: Paid presenter or speaker; Eli Lilly: Paid consultant; Hisamitsu Pharm.: Paid presenter or speaker; Hitachi High-technologies: Other financial or material support; Medicalview: Editorial or governing board; Mochida Pharm.: Other financial or material support; Paid consultant; Nippon Zoki Pharm.: Paid presenter or speaker; Pfizer: Paid presenter or speaker; Teijin Pharma limited: Paid presenter or speaker; Submitted on: 10/05/2018	89	

Name	Disclosure Information	Presentations	E-Posters
Iyer, Sravisht	No Conflicts to Disclose; Submitted on: 10/03/2018	18, 28	
Jacobs, W. Bradley	Medtronic: Paid consultant; Paid presenter or speaker; Stryker: Paid consultant; Paid presenter or speaker; Submitted on: 04/23/2018	41	
Jain, Nikhil	No Conflicts to Disclose; Submitted on: 10/02/2018	40, 72	39
Jalai, Cyrus	No Conflicts to Disclose; Submitted on: 04/20/2018	84	
Jenis, Louis [PC]	American Journal of Orthopedics: Editorial or governing board; Cervical Spine Research Society: Board or committee member; Contemporary Spine Surgery: Editorial or governing board; NASS Spine Line: Editorial or governing board; North American Spine Society: Board or committee member; TIDI Products: Paid consultant; Submitted on: 10/10/2018		
Jenkins, Tyler	No Conflicts to Disclose; Submitted on: 04/11/2018	9, 19	
Jeong, Soyeon	No Conflicts to Disclose; Submitted on: 05/30/2018		4
Jeszensky, Dezoe [S]	DePuy Synthes Spine, MEDACTA: Paid consultant, IP royalties; Submitted on: 11/14/2018		
Jiang, Fan	No Conflicts to Disclose; Submitted on: 10/04/2018		56
Jiang, Liang	No Conflicts to Disclose; Submitted on: 04/23/2018		3
Jin, Yong Jun	No Conflicts to Disclose; Submitted on: 11/02/2018	73	
Ju, Kevin	No Conflicts to Disclose; Submitted on: 10/03/2018	24	
Jung, Jong-Myung	No Conflicts to Disclose; Submitted on: 04/24/2018	56	
Kaito, Takashi	Aesculap/B.Braun: Paid consultant; Paid presenter or speaker; Asahi Kasei Pharma: Paid consultant; Asahi Kasei Pharma.: Research support; Eisai: Paid presenter or speaker; Japanese Orthopaedic Association: Board or committee member; Japanese Scoliosis Society: Board or committee member; Kyocera: Paid consultant; Medacta: Paid consultant; Medtronic Sofamor Danek: Paid consultant; Paid presenter or speaker; Nippon Zoki Pharma: Paid presenter or speaker; Nuvasive: Paid consultant; Paid presenter or speaker; Pfizer: Paid presenter or speaker;	26, 69	

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Name	Disclosure Information	Presentations	E-Posters
Kaito, Takashi *continued*	PIP: Research support; Rhoto: Research support; Scoliosis Research Society: Board or committee member; Taisho Toyama Pharma: Paid presenter or speaker; The Japanese Society for Spine Surgery and Related Research: Board or committee member; The Japanese Spinal Instrumentation Society: Board or committee member; Twocell: Research support; Zimmer: Paid presenter or speaker; Submitted on: 04/23/2018	26, 69	
Kalakoti, Piyush	No Conflicts to Disclose; Submitted on: 04/21/2018	49, 51	8, 9, 45
Kalsi-Ryan, Sukhvinder AC	Asterias: Paid consultant; Daichii Sankyo: Paid consultant; Neural Outcomes Consulting Inc: Paid consultant; Neural Outcomes Consulting Inc. - CSO: Board or committee member; Neuro Recovery Technologies: Paid consultant; Renetx: Paid consultant; Spine Therapy Network - Founding Member: Board or committee member; Stem Cells Inc: Paid consultant; Vertex: Paid consultant; Submitted on: 3/12/18		
Kan, Shigeyuki	No Conflicts to Disclose; Submitted on: 04/26/2018	26	
Kanemura, Tokumi	astellas: Paid presenter or speaker Biomet: Paid consultant Eisai: Paid presenter or speaker Medtronic: Paid consultant; Paid presenter or speaker Nuvasive: Paid consultant; Paid presenter or speaker Pfizer: Paid presenter or speaker; Submitted on: 10/07/2018	10, 12	
Kang, Dong Ho	No Conflicts to Disclose; Submitted on: 04/24/2018	73	
Kang, Kyung-Chung	No Conflicts to Disclose; Submitted on: 10/09/2018	16	
Kang, Moo Sung	TDM: Paid consultant; Submitted on: 04/25/2018		24
Kanim, Linda	Medtronic < 5,000$: Stock or stock Options; Submitted on: 05/07/2018	68	
Kanovsky, Amelie	No Conflicts to Disclose; Submitted on: 10/06/2018	92	
Kaskovich, Samuel	No Conflicts to Disclose; Submitted on: 04/23/2018		48
Kato, So	No Conflicts to Disclose; Submitted on: 03/02/2018		18, 20
Katoh, Hiroyuki	Journal of Clinical Medicine: Editorial or governing board; Submitted on: 10/03/2018		19, 38

Name	Disclosure Information	Presentations	E-Posters
Katsumi, Keiichi	No Conflicts to Disclose; Submitted on: 04/30/2018	71	44
Katsumi, Keiiti	No Conflicts to Disclose; Submitted on: 04/23/2018		
Kaye, Ian David	No Conflicts to Disclose; Submitted on: 10/03/2018	2, 30, 38, 82	26
Kearney, Chrissy	No Conflicts to Disclose; Submitted on: 04/26/2018		16
Kelly, Michael L.	No Conflicts to Disclose; Submitted on: 04/25/2018		32
Kelly, Michael P. RC, M	DePuy, A Johnson & Johnson Company: Research support; Submitted on: 10/03/2018	18	
Kepler, Christopher RS	Biomet: Research support; Clinical spine surgery: Editorial or governing board; Medtronic: Research support; Pfizer: Research support; Regeneration Technologies, Inc.: Research support; Submitted on: 10/02/2018	2, 30, 38, 82	26
Kerezoudis, Panagiotis	No Conflicts to Disclose; Submitted on: 10/02/2018	48	
Kerr, Eubulus	No Conflicts to Disclose; Submitted on: 04/25/2018	36	
Khalil, Jad	AAOS: Board or committee member; Camber Spine: Paid consultant; Centinel Spine: Research support; Innovasis: Paid consultant; Innovative surgical designs: Research support; JAAOS: Editorial or governing board; Johnson & Johnson: Paid consultant; Paid presenter or speaker; Research support; Stock or stock Options; Limiflex: Research support Medtronic: Research support; Stock or stock Options; Relievant: Research support; Spinewave: Paid presenter or speaker; Stryker: Paid consultant; Paid presenter or speaker; Submitted on: 10/02/2018	74	
Khalsa, Amrit	No Conflicts to Disclose; Submitted on: 04/22/2018	88	
Khan, Inamullah	No Conflicts to Disclose; Submitted on: 04/10/2018	47, 48, 60, 76	
Khan, Jannat	No Conflicts to Disclose; Submitted on: 04/18/2018	1	27
Khan, Kamran	No Conflicts to Disclose; Submitted on: 04/26/2018	32	
Khan, Safdar	No Conflicts to Disclose; Submitted on: 04/23/2018	40, 72	39
Khazaei, Mohamad	No Conflicts to Disclose; Submitted on: 04/24/2018	90	

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Name	Disclosure Information	Presentations	E-Posters
Khechen, Benjamin	No Conflicts to Disclose; Submitted on: 04/21/2018	28, 31, 62	42, 46, 49
Kim, Chi Heon	RIWOspine: Paid presenter or speaker; Submitted on: 11/01/2018	73	53
Kim, Dong Hwa	No Conflicts to Disclose; Submitted on: 04/25/2018	43	
Kim, Han Jo PC	AAOS: Board or committee member; AO SPINE: Board or committee member; Cervical Spine Research Society: Board or committee member; HSS Journal, Asian Spine Journal: Editorial or governing board; ISSGF: Research support K2M: IP royalties Scoliosis Research Society: Board or committee member; Zimmer: IP royalties; Submitted on: 10/08/2018	8, 17, 18, 28, 54, 58, 80	14
Kim, Jeffery	No Conflicts to Disclose; Submitted on: 04/23/2018	40, 72	
Kim, Jun	No Conflicts to Disclose; Submitted on: 04/24/2018	33	
Kim, Kee	Corentec: Paid consultant; Empirical Spine: Research support; Fziomed: Research support; Globus Medical: IP royalties; LDR: IP royalties Medtronic: Research support; Mesoblast: Research support; Molecular Matrix International: Stock or stock Options; Orthofix, Inc.: Research support; Spinal USA: IP royalties; Vertex Pharmaceutical: Paid consultant; Submitted on: 06/20/2018	41	
Kim, Ki-Jeong	No Conflicts to Disclose; Submitted on: 10/04/2018	56, 73	
Kim, Young-Jin	No Conflicts to Disclose; Submitted on: 04/24/2018	73	
Kimura, Atsushi	No Conflicts to Disclose; Submitted on: 10/02/2018	25	
Kitamura, Mitsuhiro	No Conflicts to Disclose; Submitted on: 04/23/2018		28, 41
Klineberg, Eric	Allosource: Paid consultant; AO Spine: Paid presenter or speaker; Research support; DePuy Synthes Spine: Research support; DePuy, A Johnson & Johnson Company: Paid consultant; K2M: Paid presenter or speaker; Medicrea: Paid consultant; OREF: Research support; Springer: Paid consultant; Stryker: Paid consultant; Trevena: Paid consultant; Submitted on: 10/03/2018	8, 17, 54, 63	11, 14, 15
Koda, Masao	No Conflicts to Disclose; Submitted on: 04/23/2018		28, 41

Name	Disclosure Information	Presentations	E-Posters
Kodama, Joe	No Conflicts to Disclose; Submitted on: 04/24/2018	69	
Kojima, Kota	No Conflicts to Disclose; Submitted on: 04/25/2018		17, 23, 36
Komatsu, Miki	No Conflicts to Disclose; Submitted on: 04/24/2018	89	35
Kono, Hitoshi	No Conflicts to Disclose; Submitted on: 04/16/2018		52
Konomi, Tsunehiko	No Conflicts to Disclose; Submitted on: 04/23/2018		35
Konopka, Jeffrey	No Conflicts to Disclose; Submitted on: 10/03/2018	70	
Kopjar, Branko	Amendia Spinal Elements: Paid consultant; AOSpine North America: Paid consultant; Research support; Baronova: Paid consultant; Cerapedics: Paid consultant; Hip Innovation Technology: Paid consultant; Notogen: Paid consultant; PorOsteon: Paid consultant; Smith & Nephew: Paid consultant; Research support; Submitted on: 06/01/2018	41	
Kosztowski, Thomas	No Conflicts to Disclose; Submitted on: 04/28/2018	42	
Kuivila, Thomas	No Conflicts to Disclose; Submitted on: 06/22/2018	57	
Kuprys, Tomas	No Conflicts to Disclose; Submitted on: 04/23/2018		37
Kurd, Mark	Clinical Spine Surgery: Editorial or governing board; Duratap LLC: Stock or stock Options; Innovative Surgical Designs: Research support; ISASS: Board or committee member; Submitted on: 04/23/2018	2, 30, 38, 82	26
Kurra, Swamy	No Conflicts to Disclose; Submitted on: 04/23/2018	3	
Kushioka, Junichi	No Conflicts to Disclose; Submitted on: 10/03/2018	26, 69	
Kwon, Brian [PC, M]	Vertex Pharmaceuticals: Paid consultant; Submitted on: 10/02/2018		
Lafage, Renaud	Nemaris: Stock or stock Options; Submitted on: 10/05/2018	8, 14, 17, 22, 45, 54, 58, 63, 80, 84	6, 11, 12, 13, 14, 15, 37, 43

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Name	Disclosure Information	Presentations	E-Posters
Lafage, Virginie	DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Research support;; Globus Medical: Paid consultant; International Spine Study Group: Board or committee member; K2M: Paid presenter or speaker; Medtronic: Research support; Nemaris Inc: Stock or stock Options; Nuvasive: Research support; Scoliosis Research Society: Board or committee member; Stryker: Research support; Submitted on: 10/03/2018	8, 14, 17, 22, 28, 45, 54, 58, 63, 80, 84	6, 11, 12, 13, 14, 37, 43
Lavelle, William	4-Web: Stock or stock Options; AAOS: Board or committee member; Cardan Robotics: Stock or stock Options; DePuy Spine: Research support; Innovasis-Scientific Advisory Board: Board or committee member; K2M, Inc.: Research support; Lumbar Spine Research Society: Board or committee member; Prosydian: Stock or stock Options; Prosydian-Surgeon Advisory Board: Board or committee member; SAS: Editorial or governing board; Scoliosis Research Society: Board or committee member; Signus, Inc.: Research support; Spinal Kinetics: Research support; Vertebral Technologies, Inc.: Research support; Submitted on: 10/03/2018	3	
Lawrence, Brandon RC	AO Spine Fellowship Committee: Board or committee member; AO Spine North America: Paid presenter or speaker; Cervical Spine Research Society: Board or committee member; K2M: Paid presenter or speaker; Submitted on: 04/18/2018	20	
Laxer, Eric AC	Nuvasive: Other financial or material support Stryker: IP royalties; Submitted on: 04/03/2018	21	
Le, Hai	No Conflicts to Disclose; Submitted on: 03/07/2018		57
Lebl, Darren	American Orthopaedic Association: Board or committee member; Cervical Spine Research Society: Board or committee member; K2M: Paid consultant North American Spine Society: Board or committee member; Nuvasive: Paid consultant; Scoliosis Research Society: Board or committee member; Woven: Stock or stock Options; Submitted on: 04/26/2018	28	
Lee, Chang-Hyun	No Conflicts to Disclose; Submitted on: 04/20/2018	73	
Lee, Dong-Ho	No Conflicts to Disclose; Submitted on: 04/23/2018		55

Name	Disclosure Information	Presentations	E-Posters
Lee, Jae Won	No Conflicts to Disclose; Submitted on: 10/06/2018	91	34
Lee, Joon	No Conflicts to Disclose; Submitted on: 04/25/2018		7
Lee, Jun Ho	No Conflicts to Disclose; Submitted on: 10/03/2018	73	
Lee, Jung-Hee	No Conflicts to Disclose; Submitted on: 04/24/2018	16	
Lee, Michael [AC]	DePuy, A Johnson & Johnson Company: Paid consultant; Globus Medical: Paid consultant; Stryker: Paid consultant; Submitted on: 09/24/2018		48
Lee, Sang-Hun [S]	Medtronic: Paid consultant; Paid presenter or speaker; Submitted on: 10/03/2018		
Lehman, Ronald [PC]	AOSpine: Board or committee member; Associate Editor - Spine Deformity: Editorial or governing board; Cervical Spine Research Society: Board or committee member; Deputy Editor for Deformity - The Spine Journal: Editorial or governing board; DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Medtronic: Paid consultant; Paid presenter or speaker; North American Spine Society: Board or committee member; Scoliosis Research Society: Board or committee member; Stryker: Paid presenter or speaker; Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support; Submitted on: 10/03/2018		
Lenke, Lawrence	AOSpine: Research support; Backtalk (Scoliosis Assn): Editorial or governing board; DePuy, A Johnson & Johnson Company: Paid consultant; Research support; EOS: Research support Evans Family Donation - grateful patient - philanthropic supprot: Other financial or material support; Fox Family Foundation - philanthropic research funding from grateful patient: Other financial or material support Fox Rothschild, LLC - expert witness in a Patent Infringement case: Other financial or material support; Global Spine Outreach: Board or committee member; Journal of Neurosurgery: Spine: Editorial or governing board; K2M: Paid consultant; Medtronic: IP royalties; Paid consultant; Orthopaedic Research and Education Foundation: Board or committee member; Quality Medical Pub: IP royalties; Quality Medical	18	

Name	Disclosure Information	Presentations	E-Posters
Lenke, Lawrence *continued*	Publishing: Publishing royalties, financial or material support; Scoliosis: Editorial or governing board; Scoliosis Research Society: Research support; Setting Scoliosis Straight Foundation: Research support; Spine Deformity Journal: Editorial or governing board; Spine, Journal of Spinal Disorders & Techniques: Editorial or governing board; www.iscoliosis.com: Editorial or governing board; www.spineuniverse.com: Editorial or governing board; Submitted on: 10/04/2018	18	
Levasseur, Clarissa	No Conflicts to Disclose; Submitted on: 04/26/2018		7
Levin, Jay	No Conflicts to Disclose; Submitted on: 04/24/2018	33	
Li, Feng	No Conflicts to Disclose; Submitted on: 04/23/2018		22
Li, Guoan	Mako Medical, Inc: Paid consultant; Submitted on: 10/02/2018	32	
Li, Jianing	Merck: Employee; Stock or stock Options; Submitted on: 04/23/2018	61	
Li, Xudong	No Conflicts to Disclose; Submitted on: 04/26/2018	81	
Lieberman, Isador	AAOS: Board or committee member; Bioniks Laboratories: Stock or stock Options; Clinical Spine Surgery: Editorial or governing board; European Spine Journal: Editorial or governing board; Globus Medical: Paid consultant; International Society for Advancement of Spine Surgery: Board or committee member; MAZOR Surgical Technologies: Paid consultant; Stock or stock Options; Medtronic: Paid consultant; Misonix Inc: Paid presenter or speaker; North American Spine Society: Board or committee member; Safe Orthopaedics: Paid consultant; Scoliosis Research Society: Board or committee member; SIbone Inc: Paid consultant; Society for Minimally Invasive Spine Surgery: Board or committee member; Spine: Editorial or governing board Stryker: Paid consultant; Submitted on: 10/03/2018	24	
Lim, Michael	No Conflicts to Disclose; Submitted on: 10/03/2018		1
Line, Breton	AlloSource: Paid consultant; ISSGF: Paid consultant; Submitted on: 10/02/2018	58, 63	11, 12
Liu, Hao	No Conflicts to Disclose; Submitted on: 04/26/2018		

Name	Disclosure Information	Presentations	E-Posters
Lo, Sheng-Fu	No Conflicts to Disclose; Submitted on: 04/24/2018	42	1
Louie, Philip	StreaMD: Stock or stock Options; Submitted on: 05/24/2018	1	27
Lubbe, Ryan	No Conflicts to Disclose; Submitted on: 04/10/2018		4
Ludwig, Steven	American Board of Orthopaedic Surgery, Inc.: Board or committee member; American Orthopaedic Association: Board or committee member; AO Spine North America Spine Fellowship Support: Research support; ASIP, ISD: Stock or stock Options; Cervical Spine Research Society: Board or committee member; DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Paid presenter or speaker Globus Medical: Paid consultant; Research support; Journal of spinal disorders and techniques: Editorial or governing board; K2M spine: Research support; K2Medical: Paid consultant; OMEGA: Research support; Pacira: Research support; Smiss: Board or committee member; Synthes: Paid consultant; Paid presenter or speaker; Thieme, QMP: Publishing royalties, financial or material support; Submitted on: 04/19/2018		
Mac Dowall, Anna	No Conflicts to Disclose; Submitted on: 04/18/2018	5	
Machino, Masaaki	No Conflicts to Disclose; Submitted on: 06/01/2018	59	
Mahajan, Aayushi	No Conflicts to Disclose; Submitted on: 04/24/2018		1
Maidman, Samuel	No Conflicts to Disclose; Submitted on: 10/02/2018	75	
Maki, Satoshi	No Conflicts to Disclose; Submitted on: 04/26/2018		28, 41
Makino, Takahiro	Eisai: Paid presenter or speaker; Japan spinal instrumentation society: Board or committee member; Pfizer: Paid presenter or speaker; Stryker: Paid presenter or speaker; Taisho Toyama: Paid presenter or speaker; Submitted on: 10/02/2018	26	
Malik, Azeem	No Conflicts to Disclose; Submitted on: 04/26/2018	40, 72	
Marshall, Kyle	No Conflicts to Disclose; Submitted on: 04/25/2018	36	
Martin, Allan	No Conflicts to Disclose; Submitted on: 04/26/2018	27	

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Name	Disclosure Information	Presentations	E-Posters
Martin, Brook	STATIX, LLC: IP royalties; The Spine Journal: Editorial or governing board; Submitted on: 10/03/2018	20	
Maslak, Joseph P.	No Conflicts to Disclose; Submitted on: 10/02/2018	19	
Matsumoto, Morio	Biomet: Research support; Chugai: Research support; Daiichi Sankyo: Paid presenter or speaker; Eli Lilly: Paid presenter or speaker; Hisamitsu: Paid presenter or speaker; Research support; Jansen: Paid presenter or speaker; Kaken: Paid presenter or speaker; Kyocera: Research support; Medtronic Sofamor Danek: Paid presenter or speaker; Research support; Merck: Paid presenter or speaker; Monthly Orthopedics: Editorial or governing board; Nuvasive: Paid consultant; Paid presenter or speaker; Research support; Ono: Research support; Pfizer: Paid presenter or speaker; Research support; Rinsho Seikeigeka: Editorial or governing board; Taisho Toyama: Paid presenter or speaker; Zimmer: Research support; Submitted on: 05/30/2018	23, 89	19, 23, 36, 38, 52
Mauck, Robert	Journal of Orthopaedic Research: Editorial or governing board; Tissue EngineeringJournal of the Mechanical Behavior of Biomedical Materials: Editorial or governing board; Submitted on: 04/25/2018	43	
McAnany, Steven	No Conflicts to Disclose; Submitted on: 11/02/2018	33	49
McCarthy, Michael	No Conflicts to Disclose; Submitted on: 10/03/2018	19	
McClendon, Mark	No Conflicts to Disclose; Submitted on: 04/24/2018		4
Mehta, Ankit RS	DePuy, A Johnson & Johnson Company: Paid consultant Globus Medical: Paid consultant: Submitted on: 11/01/2018		
Merali, Zamir	No Conflicts to Disclose; Submitted on: 04/26/2018	50	
Mesfin, Addisu PC	AAOS: Board or Committee member; AxioMed: Stock or Stock options; Cervical Spine Reserch Society: Board or Committee member; Corelink: Maryland Orthopaedic Association: Board or committee member; Seaspine: IP royalties; Paid consultant; St Judes ANS: Paid presenter or speaker; Stryker: Paid consultant; Submitted on: 10/01/2018		

Name	Disclosure Information	Presentations	E-Posters
Mihara, Hisanori	Biomet: Paid consultant Cervical Spine Research Society Asia Pacific Section: Board or committee member; Clinical Spine Surgery: Editorial or governing board; DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Medtronic Sofamor Danek: Unpaid consultant; Submitted on: 04/26/2018	64	
Milam, R Alden [M]	AAOS: Board or committee member; Altum: Research support; AO Foundation: Other financial or material support; Bioventus: Research support; Cervical Spine Research Society: Board or committee member; Cutting Edge Spine: IP royalties; Fziomed: Research support; K2M: Paid consultant; Nuvasive: Other financial or material support; Pacira: Research support; RTI: Paid consultant; Spinal Kinetics: Research support; Spinewave: Paid consultant; Stryker: IP royalties; Paid consultant; Submitted on: 10/27/2018	21	
Miller, Catherine	No Conflicts to Disclose; Submitted on: 04/26/2018	83	
Miller, Justin	No Conflicts to Disclose; Submitted on: 04/22/2018	79	
Mink, Kerri [C]	No Conflicts to Disclose; Submitted on: 10/02/2018		
Miyamoto, Hiroshi	No Conflicts to Disclose; Submitted on: 10/09/2018	15, 55	
Miyamoto, Takuya	No Conflicts to Disclose; Submitted on: 04/26/2018		28, 41
Mizouchi, Tatsuki	No Conflicts to Disclose; Submitted on: 04/26/2018		44
Moawad, Mohamed	No Conflicts to Disclose; Submitted on: 10/02/2018		37
Moore, Jeffrey	No Conflicts to Disclose; Submitted on: 04/18/2018		51
Moore, Timothy	AAOS: Board or committee member; Cervical Spine Research Society: Board or committee member; Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board; Lumbar Spine Research Society: Board or committee member; Submitted on: 05/01/2018		32
Morishita, Shingo	No Conflicts to Disclose; Submitted on: 04/25/2018	86	
Motto, Michael	No Conflicts to Disclose; Submitted on: 10/07/2018	82	

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Name	Disclosure Information	Presentations	E-Posters
Mroz, Thomas PC, M	Cervical Spine Research Society: Board or committee member; North American Spine Society: Board or committee member; Pearl Diver, Inc: Stock or stock Options; Spine-Line, EditorGlobal Spine Journal, Deputy Editor: Editorial or governing board; Stryker: IP royalties; Paid consultant; Submitted on: 06/01/2018	33, 57	
Mueller, Ernst	No Conflicts to Disclose; Submitted on: 04/26/2018	92	
Mummaneni, Praveen AC	AANS/CNS Spine Section and Scoliosis Research Society: Board or committee member; American Association of Neurological Surgeons: Board or committee member; Cervical Spine Research Society: Board or committee member; Congress of Neurological Surgeons: Board or committee member; DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Global Spine Journal: Editorial or governing board; Globus Medical: Paid consultant; Journal of Neurosurgery: Editorial or governing board; Neurosurgery: Editorial or governing board; Spinal Deformity: Editorial or governing board; Spinicity/ISD: Stock or stock Options; Springer: Publishing royalties, financial or material support; Stryker: Paid consultant; Taylor and Francis: Publishing royalties, financial or material support; World Neurosurgery: Editorial or governing board; Submitted on: 04/02/2018	41, 76, 83	
Mundis, Gregory	DePuy, A Johnson & Johnson Company: Paid presenter or speaker; ISSGF: Research support; K2M: IP royalties; Paid consultant; Paid presenter or speaker; Nuvasive: IP royalties; Paid consultant; Paid presenter or speaker; Research support; Submitted on: 04/03/2018	8, 17, 54	14
Nagoshi, Narihito	No Conflicts to Disclose; Submitted on: 10/02/2018	23	17, 23, 36, 52
Nair, Rueben	Graymont Medical: Paid presenter or speaker; Submitted on: 10/06/2018	9	
Nakamura, Hiroaki	Daiichi Sankyo Company, Limited: Paid Presenter or Speaker; Shionogi & Co., LTD: Paid presenter or speaker; Submitted on: 06/01/2018	52	
Nakamura, Masaya	Eli Lilly: Paid presenter or speaker; Medtronic Sofamor Danek: Paid presenter or speaker; Pfizer: Paid presenter or speaker; Submitted on: 04/11/2018	23, 89	17, 23, 36, 38, 52

Name	Disclosure Information	Presentations	E-Posters
Nakashima, Hiroaki	No Conflicts to Disclose; Submitted on: 10/02/2018	10, 12	
NaPier, Zachary [RS]	No Conflicts to Disclose; Submitted on: 04/20/2018	68	
Narain, Ankur	No Conflicts to Disclose; Submitted on: 04/19/2018	31, 62	
Nassiri, Farshad	No Conflicts to Disclose; Submitted on: 04/22/2018		56
Nassr, Ahmad [RC]	American Orthopaedic Association: Board or committee member; AO Spine: Research support; Cervical Spine Research Society: Board or committee member; DePuy, A Johnson & Johnson Company: Paid consultant; Lumbar spine research society: Board or committee member; Pfizer: Research support; Premia Spine: Research support; Scoliosis Research Society: Board or committee member; Techniques in Orthopedics: Editorial or governing board; Submitted on: 10/16/2018	41	
Neifert, Sean	No Conflicts to Disclose; Submitted on: 04/22/2018	4	
Neuman, Brian	DePuy, A Johnson & Johnson Company: Research support; Submitted on: 04/18/2018	22, 39, 58	40
Neustein, Thomas	No Conflicts to Disclose; Submitted on: 10/03/2018	75	
Newton, Michael	No Conflicts to Disclose; Submitted on: 04/19/2018		5
Newton, Peter [S]	Alphatec Spine: Research support; DePuy Synthes Spine via Setting Scoliosis Straight Foundation: Research support; DePuy Synthes Spine, A Johnson & Johnson Company: IP royalties; ElectroCore: Stock or stock Options; EOS Imaging: Paid consultant; Research support; Harms Study Group: Board or committee member; International Pediatric Orthopedic Think Tank: Board or committee member; K2M: IP royalties; Paid consultant; K2M via Setting Scoliosis Straight Foundation: Research support MAZOR Surgical chnologies: Research support; Medtronic via Setting Scoliosis Straight: Research support; Nuvasive: Research support; Nuvasive via Setting Scoliosis Straight Foundation:		

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Name	Disclosure Information	Presentations	E-Posters
Newton, Peter [S] *continued*	Research support; Orthopediatrics: Research support; Scoliosis Research Society: Board or committee member; Setting Scoliosis Straight Foundation: Board or committee member; Theime Publishing: Publishing royalties, financial or material support; Zimmer: Research support; Submitted on: 10/17/2018		
Nguyen, Matthew	No Conflicts to Disclose; Submitted on: 04/19/2018	11	
Nian, Hui	No Conflicts to Disclose; Submitted on: 04/24/2018	48, 60, 76	
Nicholson, Kristen	No Conflicts to Disclose; Submitted on: 05/23/2018	38	26
Ninomiya, Ken	No Conflicts to Disclose; Submitted on: 10/05/2018	23	
Nishiwaki, Yuji	No Conflicts to Disclose; Submitted on: 04/24/2018		19, 38
Niu, Shuo	No Conflicts to Disclose; Submitted on: 10/02/2018	75	
Nojiri, Kenya	No Conflicts to Disclose; Submitted on: 04/27/2018		19, 38
Nolte, Michael	No Conflicts to Disclose; Submitted on: 04/22/2018	1	27
Norton, Robert	4Web: Stock or stock Options; Baxter: Paid consultant; Paid presenter or speaker; Integrity Spine: IP royalties; Paid consultant; Paid presenter or speaker; Stock or stock Options; Medicrea: Paid consultant; NuVasive: Paid consultant; Osseus: IP royalties; Paid consultant; Stock or stock Options; Precision Spine: IP royalties; Paid consultant; Sintea: Paid consultant; Spinal Elements: IP royalties; Paid consultant; Paid presenter or speaker; Stock or stock Options; Submitted on: 03/05/2018	65	
Nottmeier, Eric W. [M]	Globus Medical: IP royalties; LessRay: Stock or stock Options; Medtronic Sofamor Danek: Paid presenter or speaker; Mirus Spine: Stock or stock Options; Unpaid consultant; OR Hub: Stock or stock Options; TrackX: Stock or stock Options; 11/18/2018		
Nouri, Aria	North American Spine Society: Board or committee member Rexahn Pharmaceuticals: Stock or stock Options; Submitted on: 04/25/2018		18

Name	Disclosure Information	Presentations	E-Posters
Nunley, Pierce	ABSS - American Board of Spine Surgery: Board or committee member; Amedica: Stock or stock Options; AxioMed: Research support; K2M: IP royalties; Paid consultant; Paid presenter or speaker; Research support; LDR: Paid presenter or speaker; LDR Spine: IP royalties; Mesoblast: Research support; Organogenesis: Research support; Paradigm Spine: Stock or stock Options; Pfizer: Research support; Seikagaku Corporation: Research support; Simplify: Research support; Spinal Kinetics: Research support; Spineology: Research support; Stock or stock Options; Vertiflex: Research support ZimmerBiomet: Research support; Submitted on: 04/03/2018	3, 36	
Obeid, Ibrahim [S]	Alphatec Spine: IP royalties; Paid consultant; Clariance: IP royalties; DePuy, A Johnson & Johnson Company: Paid consultant; Paid presenter or speaker; Research support; Medtronic Sofamor Danek: Paid consultant; Paid presenter or speaker; SPINEART: IP royalties; Submitted on: 11/09/2018		
Odum, Susan	Journal of Arthroplasty: Editorial or governing board; North American Spine Society: Board or committee member; Submitted on: 10/02/2018	21	
Oh, Cheongeun	No Conflicts to Disclose; Submitted on: 05/14/2018	22	43
Oh, Jae Keun	No Conflicts to Disclose; Submitted on: 04/19/2018	73	
Ohashi, Masayuki	No Conflicts to Disclose; Submitted on: 04/25/2018	71	44
Ohnmeiss, Donna	International J Spine Surgery (published by ISASS): Editorial or governing board; International Society for Advancement of Spine Surgery: Board or committee member; North American Spine Society: Board or committee member; Spine: Editorial or governing board Spine J: Editorial or governing board; Submitted on: 10/17/2018	37	
Ohtori, Seiji	No Conflicts to Disclose; Submitted on: 04/26/2018		28, 41
Ohyama, Shoichiro	No Conflicts to Disclose; Submitted on: 10/02/2018	52	
Oichi, Takeshi	No Conflicts to Disclose; Submitted on: 04/24/2018		20
Okada, Eijiro	No Conflicts to Disclose; Submitted on: 04/11/2018	23	19, 38

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Name	Disclosure Information	Presentations	E-Posters
Okada, Rintaro	Osteopharma Inc. /Osaka, Japan: Other financial or material support; Submitted on: 04/20/2018	69	
Okawa, Atsushi	Asah-Kasei: Research support; Asteras: Research support; Dai-ichi Sankyo: Research support; Dainihon-Sumitomo, Chugai: Research support; Eizai: Research support; Eli Lilly: Research support; HOYA: Research support; Janssen: Research support; Kyphon Inc.: Research support; Medtronic Sofamor Danek: Research support; Pfizer: Research support; Stryker: Research support; Teijin: Research support; Submitted on: 10/03/2018	86	25, 47
Okubo, Toshiki	No Conflicts to Disclose; Submitted on: 03/01/2018		36
Olerud, Claes	Cervical Spine Research Society European Section: Board or committee member; DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Research support; Medtronic: Paid presenter or speaker; Submitted on: 04/18/2018	5	
Onuma, Hiroaki	No Conflicts to Disclose; Submitted on: 04/24/2018		25
Orita, Sumihisa	No Conflicts to Disclose; Submitted on: 04/23/2018		28, 41
Orndorff, Douglas M	SeaSpine: IP royalties; NuVasive: Paid consultant, Paid presentations; Stryker: Paid consultant; SeaSpine: Paid consultant; Integra LifeSciences: Research support; Medtronic: Research support; Vertiflex: Research Support; Maxor, NuVasive, SeaSpine, Stryker: Other financial or material support; Submitted on 12/15/2018		
Oshima, Yasushi	No Conflicts to Disclose; Submitted on: 03/15/2018		18, 20
Ouchida, Jun	No Conflicts to Disclose; Submitted on: 10/03/2018	10, 12	
Overley, Samuel	No Conflicts to Disclose; Submitted on: 04/17/2018	33	32
Ozaki, Masahiro	No Conflicts to Disclose; Submitted on: 04/23/2018		35
Pahapill, Richard	No Conflicts to Disclose; Submitted on: 04/24/2018		4
Paholpak, Permsak	No Conflicts to Disclose; Submitted on: 04/27/2018	78	

Name	Disclosure Information	Presentations	E-Posters
Panchal, Ripul	Epiom: Employee; Globus Medical: Research support; GS Medical: Paid consultant; Medtronic: Paid consultant; Paid presenter or speaker; Research support; MizuhoOSI: Paid consultant; SpineGuard: Research support; Xenco: Employee; ZimmerBiomet: Research support; Submitted on: 06/05/2018	44	
Pannu, Tejbir	No Conflicts to Disclose; Submitted on: 07/24/2018	8	
Park, Daniel	Aegis Spine: Paid consultant; HD Lifesciences: Paid consultant; Johnson and Johnson: Stock or stock Options; K2M: Paid consultant; Medyssey: Paid consultant; Stryker: Paid consultant; Submitted on: 10/02/2018	74	
Park, Jin Hoon	No Conflicts to Disclose; Submitted on: 03/13/2018		55
Park, Jong-Beom	AOSpine KF: Board or committee member; Asian Spine Journal: Editorial or governing board; Cervical Spine Research Society Asia Pacific Section: Board or committee member; Clinics in Orthopedic Surgery: Editorial or governing board; European Spine Journal: Editorial or governing board; Global Spine Journal: Editorial or governing board; ISSLS: Board or committee member; SICOT: Board or committee member; Submitted on: 10/02/2018	91	34
Parrish, Todd	No Conflicts to Disclose; Submitted on: 03/10/2018	67	
Passias, Peter [S]	Allosource: Other financial or material support; Cervical Scoliosis Research Society: Research support; Globus Medical: Paid presenter or speaker; Medicrea: Paid consultant; SpineWave: Paid consultant; Zimmer: Paid presenter or speaker; Submitted on: 06/28/2018	8, 14, 17, 22, 45, 54, 58, 63, 80, 84, 88	6, 10, 11, 12, 13, 14, 15, 37, 43
Pasternack, Jordan	No Conflicts to Disclose; Submitted on: 10/03/2018	65	
Patel, Alpesh [PC, M]	Amedica: IP royalties; Paid consultant; Stock or stock Options; American Orthopaedic Association: Board or committee member; AO Spine North America: Board or committee member; Cervical Spine Research Society: Board or committee member; Cytonics: Stock or stock Options; DePuy, A Johnson & Johnson Company: Paid consultant; EndoLuxe: Stock or stock Options; International Society for the Advancement of Spine Surgery: Board or committee member; Journal of the American Academy of Orthopaedic Surgeons:	9, 11, 19	

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Name	Disclosure Information	Presentations	E-Posters
Patel, Alpesh [PC, M] *continued*	Editorial or governing board; Publishing royalties, financial or material support; Lumbar Spine Research Society: Board or committee member; Nocimed: Stock or stock Options; North American Spine Society: Board or committee member; Nuvasive: IP royalties; Paid consultant; nView Medical Inc: Stock or stock Options; Springer: Publishing royalties, financial or material support; Surgical Neurology International: Editorial or governing board Tissue Differentiation Intelligence: Stock or stock Options; Vital5: Stock or stock Options; Wolters Kluwer Health - Lippincott Williams & Wilkins: Editorial or governing board; Zimmer: IP royalties; Paid consultant; Submitted on: 04/13/2018	9, 11, 19	
Patel, Dil	No Conflicts to Disclose; Submitted on: 05/02/2018	31, 62	42, 46
Patel, Vikas	Aesculap: Research support Aesculap/B. Braun: IP royalties; Paid consultant; Baxter: Paid presenter or speaker; Biomet: IP royalties; Medtronic, Medicrea: Research support; OREF: Research support; Orthofix: Research support; Orthopedics: Editorial or governing board; Pfizer: Research support; SLACK Incorporated: Publishing royalties, financial or material support; Springer: IP royalties; Publishing royalties, financial or material support; Stryker: Paid presenter or speaker; Synthes: Research support; Vertiflex: Research support; Submitted on: 04/23/2018	44	
Patwardhan, Avinash [RC]	Spinal Kinetics: Stock or Stock Option; Submitted on: 04/23/2018		
Paul, Justin	No Conflicts to Disclose; Submitted on: 10/24/2018	1	27
Pennings, Jacquelyn	No Conflicts to Disclose; Submitted on: 10/03/2018	47, 76	30
Permeswaran, Vijay	Biomet: Employee Zimmer: Employee; Submitted on: 04/25/2018	44	
Pflug, Emily	No Conflicts to Disclose; Submitted on: 04/24/2018	30	
Phillips, Frank [M]	Cervical Spine Research Society: Board or committee member; Int. Spine Journal: Editorial or governing board; ISASS: Board or committee member; Mainstay: Stock or stock Options; Medtronic: IP royalties; Nuvasive: IP royalties; Paid consultant; Stock or stock		39

Name	Disclosure Information	Presentations	E-Posters
Phillips, Frank [M] *continued*	Options; PearDiver: Stock or stock Options; Providence: Stock or stock Options; SI Bone: Paid consultant; Stock or stock Options; Society of Minimally invasive Spine Surgery: Board or committee member; Spinal Simplicity: Stock or stock Options; Stryker: IP royalties; Surgio: Stock or stock Options; Theracell: Stock or stock Options; Vertiflex: Stock or stock Options; Vital 5: Stock or stock Options; Submitted on: 04/18/2018		39
Pilla, Neil	No Conflicts to Disclose; Submitted on: 04/25/2018		16
Pirkle, Sean	No Conflicts to Disclose; Submitted on: 10/03/2018		48
Pitcairn, Samuel	No Conflicts to Disclose; Submitted on: 04/26/2018		7
Polly, Dave [S]	Scoliosis Research Society: Board or committee member Springer: Publishing royalties, financial or material support; Submitted on: 10/02/2018		
Possley, Daniel	No Conflicts to Disclose; Submitted on: 09/25/2018	74	5
Prasarn, Mark	Eli Lilly: Paid presenter or speaker; Nuvasive: Paid presenter or speaker; Stryker: Paid consultant; Paid presenter or speaker; Submitted on: 10/02/2018	13, 35	
Protopsaltis, Themistocles [RC, S, PC]	Cervical Spine Research Society: Research support; Innovasis: Paid consultant; Medicrea International: Paid consultant; Nuvasive: Paid consultant; Submitted on: 05/30/2018	8, 14, 17, 54, 58, 80	6, 11, 13, 37
Pugely, Andrew	AAOS: Board or committee member; Clinical Orthopaedics and Related Research: Editorial or governing board; Globus Medical: IP royalties; Paid consultant; Submitted on: 10/06/2018	49, 51	8, 9, 45
Qureshi, Sheeraz	AAOS: Board or committee member; Cervical Spine Research Society: Board or committee member; Clinical Orthopaedics and Related Research: Editorial or governing board; Contemporary Spine Surgery: Editorial or governing board; Global Spine Journal: Editorial or governing board; Globus Medical: Paid consultant; Musculoskeletal Transplant Foundation: Board or committee member; NASS: Board or committee member; Spine (reviewer): Editorial or governing board; Spine Journal (reviewer): Editorial or governing board; Stryker: IP royalties; Paid consultant; Zimmer: IP royalties; Paid consultant; Submitted on: 04/28/2018		49

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Name	Disclosure Information	Presentations	E-Posters
Raad, Micheal	No Conflicts to Disclose; Submitted on: 04/25/2018	84	
Radcliff, Kristen RC	4 Web Medical: Stock or stock Options; AAOS: Board or committee member; Cervical Spine Research Society: Board or committee member; CTL Medical: Other financial or material support; Globus Medical: IP royalties; Paid consultant; Innovative Spine Devices: IP royalties; ISASS: Board or committee member; Lilly USA: Other financial or material support; Medtronic: Paid consultant; NEXXT Spine: Other financial or material support; North American Spine Society: Board or committee member; Orthofix, Inc.: Research support; Orthopedic Sciences, Inc: IP royalties; Paid consultant; Pacira pharmaceuticals: Research support; Paxeon, LLC: Other financial or material support; Rothman Institute: Stock or stock Options; Simplify Medical: Research support; SMISS: Board or committee member; Spinal Elements: Other financial or material support; Stryker: Other financial or material support; Paid consultant; Zimmer: Unpaid consultant Zimmer Biomet: Other financial or material support; Submitted on: 10/03/2018	2, 30, 38, 82	26
Rahman, Rafa	No Conflicts to Disclose; Submitted on: 10/17/2018	39	
Ramhmdani, Seba	No Conflicts to Disclose; Submitted on: 04/24/2018	42	
Ramos, Rafael	No Conflicts to Disclose; Submitted on: 10/02/2018	42	
Rasouli, Jonathan	No Conflicts to Disclose; Submitted on: 04/23/2018	4	
Rawlins, Bernard	No Conflicts to Disclose; Submitted on: 04/26/2018	28	
Reidler, Jay	No Conflicts to Disclose; Submitted on: 10/04/2018	39	
Reihani-Kermani, Hamed	No Conflicts to Disclose; Submitted on: 03/02/2018		18

Name	Disclosure Information	Presentations	E-Posters
Rhee, John M	Alphatec Spine: Stock or stock Options; Biomet: IP royalties; BiometDepuy: Paid presenter or speaker; Biometsynthes: Paid consultant; Cervical Spine Research Society: Board or committee member; DePuy, A Johnson & Johnson CompanyKineflexMedtronic: Research support; Phygen: Stock or stock Options Stryker: IP royalties; Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support; Zimmer: Paid presenter or speaker; Submitted on: 04/22/2018	70, 75	16
Rhyne, Alfred	Stryker: IP royalties; Paid consultant; Paid presenter or speaker; Submitted on: 05/18/2018	21	
Riew, K. Daniel M	Advanced Medical: Other financial or material support; Amedica: Stock or stock Options; AO Spine: Other financial or material support; AOSpine: Board or committee member; Research support; AxioMed: Stock or stock Options; Benvenue: Stock or stock Options; Biomet: IP royalties; Paid consultant; Paid presenter or speaker; Clinics in orthopedics: Editorial or governing board; European Spine Journal: Editorial or governing board; Expanding Orthopedics, PSD: Stock or stock Options; global spine journal: Editorial or governing board; Medtronic: IP royalties; Paid consultant; Paid presenter or speaker; Neurosurgery: Editorial or governing board; Nexgen Spine: Stock or stock Options; Nuvasive: Paid consultant; Osprey: Stock or stock Options; Paradigm Spine: Stock or stock Options; Spinal Kinetics: Stock or stock Options; Spine: Editorial or governing board; spine surgery today: Editorial or governing board; Spineology: Stock or stock Options; Vertiflex: Stock or stock Options; Zeiss: Other financial or material support; Paid presenter or speaker; Submitted on: 10/03/2018	41, 79, 81	
Rihn, Jeffrey	Cervical Spine Research Society: Board or committee member; Globus Medical: Paid consultant; North American Spine Society: Board or committee member; The Spine Journal: Editorial or governing board; XTANT Medical: Stock or stock Options; Submitted on: 04/24/2018	2, 30, 38, 82	26

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Riley, Lee [PC]	Avitus: IP royalties; Stock or stock Options; Cervical Spine Research Society: Board or committee member; Lifenet Health: Other financial or material support; North American Spine Society: Board or committee member; Spinal Kinetics: Stock or stock Options; Spin-eThe Journal of Spinal Disorders: Editorial or governing board; Submitted on: 04/25/2018	39	40
Rosenthal, Brett	No Conflicts to Disclose; Submitted on: 10/04/2018	9	
Ross, Thomas	No Conflicts to Disclose; Submitted on: 04/24/2018	28	
Sahai, Nikhil	No Conflicts to Disclose; Submitted on: 04/18/2018		51
Saidon, Tome	No Conflicts to Disclose; Submitted on: 10/02/2018	79	
Sakai, Kenichiro	No Conflicts to Disclose; Submitted on: 04/15/2018	86	47
Sakai, Yusuke	No Conflicts to Disclose; Submitted on: 04/26/2018	26	
Salehi, Khosrowdad	No Conflicts to Disclose; Submitted on: 06/04/2018	68	
Sandhu, Harvinder	Allergan: Stock or stock Options; Amedica: Stock or stock Options; Paradigm Spine: Stock or stock Options; Prosydian Medical: Paid consultant; Stock or stock Options; Providence Medical Technology: Stock or stock Options; Spinewave: Stock or stock Options; Submitted on: 04/26/2018	28	
Santaguida, Carlo	Clinical Spine Surgery: Editorial or governing board; CSL Behring: Research support; Medtronic: Paid consultant; Stryker: Paid consultant; Submitted on: 03/21/2018	41	
Sasso, Rick	Cerapedics: Research support; Cervical Spine Research Society: Board or committee member; journal of spinal disorders and techniquespine arthroplasty society journal: Editorial or governing board; Medtronic: IP royalties; Research support; Parexel: Research support; Relievant: Research support Saunders/Mosby-Elsevier: Publishing royalties, financial or material support; Smith & Nephew: Research support; Spinal Kinetics: Research support; Stryker: Research support; Submitted on: 04/29/2018	79	
Satake, Kotaro	No Conflicts to Disclose; Submitted on: 10/03/2018	10, 12	

Name	Disclosure Information	Presentations	E-Posters
Savage, Jason [RC]	Journal of Spinal Disorders and Techniques: Editorial or governing board; Stryker: Paid consultant; Wright Medical Technology, Inc.: Paid consultant; Submitted on: 04/20/2018	9, 35	
Schaer, Tom	Acuitive: Paid consultant; AO Foundation: Board or committee member; Diamond Orthopedics: Unpaid consultant; Johnson & Johnson: Research support; PSI: Stock or stock Options; Synthes: Research support; Xerathera: Research support; Submitted on: 04/24/2018	43	
Scheer, Justin	No Conflicts to Disclose; Submitted on: 06/18/2018	58	12
Schoenfeld, Andrew	AAOS: Board or committee member; Journal of Bone and Joint Surgery - American: Editorial or governing board; North American Spine Society: Board or committee member; Springer: Publishing royalties, financial or material support; Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support; Submitted on: 10/03/2018		57
Schroeder, Gregory	Advance Medical: Paid consultant; AOSpine: Other financial or material support; Medtronic: Other financial or material support; Medtronic Sofamor Danek: Research support; Stryker: Paid consultant; Wolters Kluwer Health - Lippincott Williams & Wilkins: Editorial or governing board; Zimmer: Paid consultant; Submitted on: 04/23/2018	2, 30, 38, 82	26
Schuster, James	No Conflicts to Disclose; Submitted on: 04/26/2018		
Schwab, Frank [S]	DePuy, A Johnson & Johnson Company: Research support; K2M: IP royalties; Paid consultant; Paid presenter or speaker; Medicrea: Paid consultant; Medtronic: Paid consultant; Medtronic Sofamor Danek: IP royalties; Paid presenter or speaker; Nemaris: Stock or stock Options; Nuvasive: Paid consultant; Paid presenter or speaker; Research support; Scoliosis Research Society: Board or committee member; spine deformity: Editorial or governing board; Stryker: Research support; VP of International Spine Society Group (ISSG): Board or committee member; Zimmer: IP royalties; Paid consultant; Paid presenter or speaker; Submitted on: 04/19/2018	17, 28, 54, 63, 80	6, 11, 12, 14, 15, 43
Schwarz, Jacob	No Conflicts to Disclose; Submitted on: 04/24/2018		30

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Name	Disclosure Information	Presentations	E-Posters
Sciubba, Daniel AC, RC, M	DePuy, A Johnson & Johnson Company: Paid consultant; K2M: Paid consultant; Medtronic: Paid consultant; Nuvasive: Paid consultant; Stryker: Paid consultant; Submitted on: 05/16/2018	14, 39, 42, 45, 84	
Sears, William S	Medtronic: IP royalties; Paid consultant; Paradigm Spine: IP royalties; Paid consultant; Stock or stock Options; Spine Society of Australia: Board or committee member; Submitted on: 11/08/2018		
Segebarth, Paul Bradley PC	Medtronic Sofamor Danek: Research support; Nuvasive: Paid consultant; Paid presenter or speaker; Research support; Submitted on: 04/22/2018	21	
Segreto, Frank	No Conflicts to Disclose; Submitted on: 04/19/2018	14, 22, 45, 58, 63, 80, 84, 88	6, 10, 11, 12, 13, 15, 37, 43
Sessumpun, Kittipong	No Conflicts to Disclose; Submitted on: 04/21/2018	78	
Sestokas, Anthony	Journal of Clinical Monitoring and Computing / Springer: Editorial or governing board; KSPC Holdings, Inc.: Stock or stock Options; North American Spine Society: Board or committee member; Remote Neuromonitoring Physicians, PC: Employee SpecialtyCare: Employee; Stock or stock Options; Submitted on: 06/05/2018		16
Shaffrey, Christopher S	AANS: Board or committee member; Biomet: Paid consultant; Cervical Spine Research Society: Board or committee member; DePuy, A Johnson & Johnson Company: Research support; Globus Medical: Research support; Medtronic: Other financial or material support; Paid consultant; Medtronic Sofamor Danek: IP royalties; Paid presenter or speaker; Research support Neurosurgery RRC: Board or committee member; Nuvasive: IP royalties; Paid consultant; Paid presenter or speaker; Research support; Stock or stock Options; Spinal Deformity: Editorial or governing board; Spine: Editorial or governing board; Stryker: Paid consultant; Zimmer: IP royalties; Submitted on: 10/02/2018	8, 14, 17, 22, 41, 45, 54, 63	14, 15, 43
Shah, Shalin	No Conflicts to Disclose; Submitted on: 04/15/2018	85	
Shamrock, Alan	No Conflicts to Disclose; Submitted on: 10/02/2018	49, 51	8, 45

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Sheyn, Dmitriy	No Conflicts to Disclose; Submitted on: 04/21/2018	68	
Shi, Jiangang	No Conflicts to Disclose; Submitted on: 04/18/2018	6	
Shi, Lewis	AAOS Shoulder/Elbow content committee: Board or committee member; DePuy, A Johnson & Johnson Company: Paid consultant; Novation Orthopaedic Council: Board or committee member; Submitted on: 10/02/2018		48
Shibata, Masahiko	No Conflicts to Disclose; Submitted on: 04/26/2018	26	
Shiga, Yasuhiro	No Conflicts to Disclose; Submitted on: 04/26/2018		28, 41
Shillingford, Jamal	No Conflicts to Disclose; Submitted on: 05/29/2018	81	
Shimizu, Kentaro	No Conflicts to Disclose; Submitted on: 04/24/2018		19, 38
Shimizu, Takachika SP	DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Submitted on: 11/05/2018		
Shin, Won Ju	No Conflicts to Disclose; Submitted on: 04/24/2018	16	
Shiono, Yuta	No Conflicts to Disclose; Submitted on: 04/14/2018	23	52
Shiraishi, Yasuyuki	No Conflicts to Disclose; Submitted on: 04/18/2018	25	
Shoji, Hirokazu	No Conflicts to Disclose; Submitted on: 04/26/2018		44
Silverstein, Michael	No Conflicts to Disclose; Submitted on: 05/10/2018	21	

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Name	Disclosure Information	Presentations	E-Posters
Singh, Kern	AAOS: Board or committee member; Avaz Surgical, LLC: Stock or stock Options; Cervical Spine Research Society: Board or committee member; ISASS: Board or committee member; Jaypee Publishing: Publishing royalties, financial or material support; K2M: Paid consultant; Pioneer: IP royalties; Scoliosis Research Society: Board or committee member ; SLACK Incorporated: Publishing royalties, financial or material support; SMISS: Board or committee member; Spine Surgery Today: Editorial or governing board; Stryker: IP royalties; Thieme: Publishing royalties, financial or material support; Vertebral Columns - ISASS: Editorial or governing board; Vital 5, LLC: Stock or stock Options; Wolters Kluwer Health - Lippincott Williams & Wilkins: Editorial or governing board; Publishing royalties, financial or material support; Zimmer: IP royalties; Paid consultant; Submitted on: 10/02/2018	28, 31, 62	42, 46, 49
Sinha, Kumar	No Conflicts to Disclose; Submitted on: 04/26/2018		51
Sivaganesan, Ahilan	No Conflicts to Disclose; Submitted on: 04/21/2018	47, 48, 60, 76	
Skolasky, Richard RC	Cervical Spine Research Society: Board or committee member; North American Spine Society: Board or committee member; Quality of Life Research: Editorial or governing board; Submitted on: 04/16/2018	39	40
Smith, Andrew Craig	No Conflicts to Disclose; Submitted on: 03/11/2018	67	
Smith, Harvey	American Board of Orthopaedic Surgery, Inc.: Board or committee member; Johnson & Johnson: Research support; Stock or stock Options; North American Spine Society: Board or committee member; Submitted on: 10/02/2018	43	
Smith, Justin S, PC	AlloSource: Paid consultant; Cerapedics: Paid consultant; Cervical Spine Research Society: Board or committee member; DePuy: Research support K2M: Paid consultant; Neurosurgery: Editorial or governing board; Nuvasive: Paid consultant; Operative Neurosurgery: Editorial or governing board; Zimmer: IP royalties; Paid consultant; Submitted on: 10/02/2018	8, 14, 17, 22, 45, 54, 58, 63	11, 12, 14, 15, 43

Name	Disclosure Information	Presentations	E-Posters
Smith, Lachlan	JOR: Spine: Editorial or governing board; PLOS One: Editorial or governing board; Submitted on: 04/24/2018	43	
Smith, Zachary	No Conflicts to Disclose; Submitted on: 03/10/2018	67	
Smucker, Joseph	Back Bay Life Science Advisors: Paid consultant; Baxter/Apatech: Research support; Biostructures, LLC: Research support; Medtronic Sofamor Danek: Paid presenter or speaker; Research support; Theorem Clinical Research: Paid consultant; Watermark Research Partners, Inc.: Paid consultant; Submitted on: 04/19/2018	79	
Snowden, Ryan	No Conflicts to Disclose; Submitted on: 10/02/2018	79	
Snyder, Daniel	No Conflicts to Disclose; Submitted on: 10/02/2018	4	
Soma, Kazuhito	No Conflicts to Disclose; Submitted on: 04/26/2018		20
Soroceanu, Alexandra	No Conflicts to Disclose; Submitted on: 04/26/2018	17, 22, 54, 63	
Spector, Leo [M]	Cervical Spine Research Society: Board or committee member; Lumbar Spine Research Society: Board or committee member; Nuvasive: Other financial or material support; Paid presenter or speaker; Stryker: Paid consultant; Paid presenter or speaker; Synthes: Other financial or material support; Submitted on: 10/02/2018	21	
Spiker, William R. [PC, M]	DePuy, A Johnson & Johnson Company: Research support; K2M: Paid consultant; Nexus Orthopaedics: Paid consultant; NEXXT Orthopaedics: Paid consultant; Synthes: Research support; Submitted on: 06/01/2018	20	
Spina, Nicholas	DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Submitted on: 04/18/2018	20	
Srinivasan, Aditya	No Conflicts to Disclose; Submitted on: 06/22/2018	13	
Steele, Portia	No Conflicts to Disclose; Submitted on: 04/20/2018	66	
Stein, Daniel	No Conflicts to Disclose; Submitted on: 04/24/2018	28	
Steinberger, Jeremy	No Conflicts to Disclose; Submitted on: 04/23/2018	4	
Steinhaus, Michael	No Conflicts to Disclose; Submitted on: 10/31/2018	28	

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Name	Disclosure Information	Presentations	E-Posters
Steinmetz, Michael RC, M	AANS/CNS Section on Disorders of the Spine and Peripheral Nerves: Board or committee member; Biomet: IP royalties Counicl of State Neurosurgical Societies: Board or committee member; Elseveir: Publishing royalties, financial or material support; Globus Medical: Paid consultant; Paid presenter or speaker; Intellirod: Paid presenter or speaker; Stryker: Paid presenter or speaker; World Neurosurgery and Operative Neurosurgery: Editorial or governing board; Submitted on: 06/01/2018	57	
Stekas, Nicholas	No Conflicts to Disclose; Submitted on: 04/25/2018	17, 54	
Stephens, Byron	AO Spine: Board or committee member; Spine: Editorial or governing board; Stryker: Other financial or material support; Submitted on: 03/28/2018		30
Stone, Marcus	No Conflicts to Disclose; Submitted on: 04/25/2018	36	
Su, Brian PC	Cervical Spine Research Society: Board or committee member; North American Spine Society: Board or committee member; Stryker: Paid consultant; Submitted on: 07/10/2017		
Suda, Kota	No Conflicts to Disclose; Submitted on: 04/24/2018	89	35
Sugawara, Ryo	No Conflicts to Disclose; Submitted on: 10/11/2018	25	
Sun, Yu S	No Conflicts to Disclose; Submitted on: 04/22/2018		
Suzuki, Akinobu	No Conflicts to Disclose; Submitted on: 04/21/2018	52	
Suzuki, Satoshi	No Conflicts to Disclose; Submitted on: 04/16/2018	23	
Takahashi, Ikuko	No Conflicts to Disclose; Submitted on: 04/24/2018		44
Takahashi, Shinji	No Conflicts to Disclose; Submitted on: 10/03/2018	52	
Takahashi, Yuichiro	No Conflicts to Disclose; Submitted on: 04/26/2018	23	
Takahata, Masahiko	Asahikasei Pharma: Paid presenter or speaker; Chugai Pharma: Research support; Daiich-Sankyo: Paid presenter or speaker; Research support; DePuy, A Johnson & Johnson Company: Research support; Submitted on: 04/23/2018	77, 89	

Name	Disclosure Information	Presentations	E-Posters
Takenaka, Shota	No Conflicts to Disclose; Submitted on: 04/26/2018	26	
Takeshita, Katsushi	Eli Lilly: Paid presenter or speaker; Shionogi & Co., Ltd: Paid presenter or speaker; Submitted on: 10/19/2018	25	
Tallarico, Richard	Stryker Spine: Paid consultant; Vertiflex: Research support; Submitted on: 04/24/2018	3	
Tamai, Koji	No Conflicts to Disclose; Submitted on: 10/02/2018	52, 78	
Tan, Lee [S]	No Conflicts to Disclose; Submitted on: 06/01/2018	81	
Tanaka, Hisashi	No Conflicts to Disclose; Submitted on: 04/26/2018	26	
Tanaka, Sakae	Amgen Co: Paid consultant; Bristol-Myers Squibb: Paid consultant; Chugai Pharmaceutical Co. Ltd.: Paid presenter or speaker; Chugai Pharmaceutical Co., Ltd: Paid consultant; Daiichi Sankyo Co. Ltd.: Paid consultant; Paid presenter or speaker; Eli Lilly: Paid presenter or speaker; Janssen Pharmaceutical K.K.: Paid consultant; Kyocera Medical Corporation: Paid Consultant; Msd K.K.: Paid Consultant; Ono Pharmaceutical Co., Ltd: Paid Consultant; Teijin Pharma Limited: Paid consultant; Submitted on: 04/21/2018		20
Tanenbaum, Joseph	No Conflicts to Disclose; Submitted on: 10/02/2018	57	
Tanimoto, Yuji	No Conflicts to Disclose; Submitted on: 04/22/2018		17
Tarazona, Daniel	No Conflicts to Disclose; Submitted on: 10/03/2018	2, 30, 38, 82	26
Tatara, Yasunori	No Conflicts to Disclose; Submitted on: 10/04/2018	64	
Terai, Hidetomi	No Conflicts to Disclose; Submitted on: 04/17/2018	52	
Tesdahl, Eric	SpecialtyCare: Employee; Submitted on: 04/25/2018		16
Tetreault, Lindsay	No Conflicts to Disclose; Submitted on: 04/22/2018	29	
Theodore, Nicholas	DePuy, A Johnson & Johnson Company: IP royalties; Research support; Globus Medical: IP royalties; Paid consultant; Stock or stock Options; Submitted on: 04/24/2018	42	
Theologis, Alexander	No Conflicts to Disclose; Submitted on: 04/30/2018	18	
Tobert, Daniel	No Conflicts to Disclose; Submitted on: 10/02/2018		57

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Name	Disclosure Information	Presentations	E-Posters
Toole, Thomas	No Conflicts to Disclose; Submitted on: 10/02/2018	3	
Tortolani, Paul [RC]	Cervical Spine Research Society: Board or committee member; Globus Medical: IP royalties; Paid consultant; Innovasis: IP royalties; Paid consultant; J. of spinal Deformity: Editorial or governing board; Spineology: Paid consultant; Research support Surgical Neurology International: Editorial or governing board; Submitted on: 04/25/2018		
Toth, Jeffrey	Cytophil, Inc.: Paid consultant; Medtronic Sofamor Danek: Research support; Submitted on: 04/18/2018		39
Toyoda, Hiromitsu	No Conflicts to Disclose; Submitted on: 04/19/2018	52	
Traynelis, Vincent [M]	Journal of Spinal Disorders and Techniques: Editorial or governing board; Medtronic: IP royalties; Paid consultant; Medtronic Sofamor Danek: IP royalties; Paid consultant; Neurosurgery: Editorial or governing board; Spine: Editorial or governing board; Spine Surgery Today: Editorial or governing board; Surgical Neurology International Spine: Editorial or governing board; World Neurosurgery: Editorial or governing board; Submitted on: 05/01/2016		
Tribus, Clifford [RC, PC]	Amedica and Spineology: Stock or stock Options; Cervical Spine Research Society: Board or committee member; Clinical Spine Surgery: Editorial or governing board; Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board; Lumbar Spine Research Society: Board or committee member; McGraw-Hill: Publishing royalties, financial or material support; Medtronic: Research support Scoliosis Research Society; AAOS: Board or committee member; Spine: Editorial or governing board; Spineology: IP royalties; Paid consultant; Stryker: IP royalties; Other financial or material support; Paid consultant; Paid presenter or speaker Zimmer: IP royalties; Paid consultant; Submitted on: 07/09/2017		

Name	Disclosure Information	Presentations	E-Posters
Truumees, Eeric [PC]	AAOS: Board or committee member; AAOS Now: Editorial or governing board; American Orthopaedic Association: Board or committee member; Dova Pharmaceuticals: Research support; Journal of Bone and Joint Surgery - American: Editorial or governing board; Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board; Medtronic Sofamor Danek: Research support North American Spine Society: Board or committee member; Publishing royalties, financial or material support; Pfizer: Research support; Relievant: Research support; Spine: Editorial or governing board; Stryker: Research support; The Spine Journal: Editorial or governing board; Vertex Pharmaceuticals: Research support; Submitted on: 05/28/2018		
Tsuji, Osahiko	No Conflicts to Disclose; Submitted on: 04/24/2018	23, 89	17, 23, 35, 52
Tsuji, Takashi	Eli Lilly: Paid presenter or speaker; Medtronic: Research support; Nuvasive: Research support; Pfizer: Paid presenter or speaker; Stryker: Research support; Submitted on: 04/23/2018		19, 38
Tuchman, Alexander	No Conflicts to Disclose; Submitted on: 04/25/2018	81	
Turnbull, Helen [SP]	No Conflicts to Disclose; Submitted on: 11/19/2018		
Udo-inyang, Inyang	No Conflicts to Disclose; Submitted on: 05/29/2018		32
Ukon, Yuichiro	No Conflicts to Disclose; Submitted on: 04/23/2018	69	
Ushio, Shuta	No Conflicts to Disclose; Submitted on: 04/23/2018		25
Utter, Andrew	No Conflicts to Disclose; Submitted on: 10/02/2018	36	

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Name	Disclosure Information	Presentations	E-Posters
Vaccaro, Alexander [M]	Advanced Spinal Intellectual Properties: Stock or stock Options; Aesculap: IP royalties; Atlas Spine: IP royalties; Paid consultant; Avaz Surgical: Stock or stock Options; Bonovo Orthopaedics: Stock or stock Options; Clinical Spine Surgery: Editorial or governing board; Computational Biodynamics: Stock or stock Options; Cytonics: Stock or stock Options; DePuy, A Johnson & Johnson Company: Paid consultant; Dimension Orthotics LLC: Stock or stock Options; Electrocore: Stock or stock Options; Elsevier: Publishing royalties, financial or material support; Flagship Surgical: Stock or stock Options; FlowPharma: Stock or stock Options; Franklin Bioscience: Stock or stock Options; Gerson Lehrman Group: Paid consultant; Globus Medical: IP royalties; Paid consultant; Stock or stock Options; Guidepoint Global: Paid consultant; Innovative Surgical Design: Paid consultant; Stock or stock Options; Insight Therapeutics: Stock or stock Options; Jaypee: Publishing royalties, financial or material support; Medtronic: IP royalties; Paid consultant; none: Other financial or material support; Nuvasive: Paid consultant; Stock or stock Options; Orthobullets: Paid consultant; Paradigm Spine: Stock or stock Options; Parvizi Surgical Innovations: Stock or stock Options; Prime Surgeons: Stock or stock Options; Progressive Spinal Technologies: Stock or stock Options; Replication Medica: Stock or stock Options; Spine Journal: Editorial or governing board; Spine Medica: Stock or stock Options; SpineWave: IP royalties; Paid consultant; Spinology: Stock or stock Options; Stout Medical: Paid consultant; Stock or stock Options; Stryker: IP royalties; Paid consultant; Taylor Franics/Hodder & Stoughton: Publishing royalties, financial or material support; Thieme: Publishing royalties, financial or material support; Vertiflex: Stock or stock Options; Submitted on: 10/08/2018	2, 30, 38, 41, 82	26
Vaishnav, Avani	No Conflicts to Disclose; Submitted on: 10/03/2018		49
van Zwet, Erik	No Conflicts to Disclose; Submitted on: 04/26/2018	7	
Vanston, Susan	No Conflicts to Disclose; Submitted on: 04/24/2018		30

Name	Disclosure Information	Presentations	E-Posters
Varthi, Arya	No Conflicts to Disclose; Submitted on: 04/23/2018	1	27
Vasquez-Montes, Dennis	No Conflicts to Disclose; Submitted on: 11/02/2018	80, 84	6, 13, 37
Vega, Andrew	No Conflicts to Disclose; Submitted on: 04/20/2018	78	
Ver, Mikhail Lew	No Conflicts to Disclose; Submitted on: 05/15/2018	66	
Vira, Shaleen	No Conflicts to Disclose; Submitted on: 04/18/2018	84	6, 13, 37
Vleggeert-Lankamp, Carmen	Aesculap/B.Braun: Research support; Cervical Spine Research Society: Board or committee member; Medtronic: Research support; Submitted on: 04/24/2018	7, 34	
Volkmar, Alexander	No Conflicts to Disclose; Submitted on: 10/02/2018	48, 51	45
Wanebo, John	Biomet: IP royalties; Submitted on: 04/27/2018	44	
Wang, Hui	No Conflicts to Disclose; Submitted on: 04/24/2018		1
Wang, Jeffrey [M]	Amedica: IP royalties American Orthopaedic Association: Board or committee member; AO Foundation: Board or committee member; Biomet: IP royalties bone biologics: Stock or stock; Options Cervical Spine Research Society: Board or committee member; Clinical Spine Surgery: Editorial or governing board; electrocore: Stock or stock Options; expanding ortho: Stock or stock Options; Fziomed: Stock or stock Options; Global Spine Journal: Editorial or governing board; Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board; North American Spine Society: Board or committee member; pearldiver: Stock or stock Options; Seaspine: IP royaltie; Society of Brain Mapping and Therapeutics: Board or committee member; surgitech: Stock or stock Options; Synthes: IP royalties; The Spine Journal: Editorial or governing board; Submitted on: 10/02/2018	78	
Wang, Jian	No Conflicts to Disclose; Submitted on: 04/27/2018	90	
Wang, Jianxi	No Conflicts to Disclose; Submitted on: 10/03/2018	53	

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Name	Disclosure Information	Presentations	E-Posters
Wang, Marjorie	AANS ex officio until May 2018: Board or committee member; Abbott: Stock or stock Options; Biomet: Paid consultant; Elsevier: Editorial or governing board; World Neurosurgery section editor: Editorial or governing board; Submitted on: 04/14/2018	61	
Wang, Shenglin	CSRS-Asia Pacific Section: Board or committee member; Submitted on: 04/21/2018		10
Warner, Eric	No Conflicts to Disclose; Submitted on: 10/05/2018	82	
Warth, Ryan	Musculoskeletal Transplant Foundation: Research support; Springer: Publishing royalties, financial or material support; Submitted on: 10/03/2018	13	
Watanabe, Kei	No Conflicts to Disclose; Submitted on: 04/25/2018	71	44
Watanabe, Kota	No Conflicts to Disclose; Submitted on: 04/12/2018	23, 89	19, 38, 52
Watanabe, Masahiko	No Conflicts to Disclose; Submitted on: 06/06/2018		19, 38
Watanabe, Yoshiyuki	Canon Medical Corp: Paid presenter or speaker; Dai Nippon Printing Co.,Ltd: Research support; Japan College of Radiology: Board or committee member; Submitted on: 04/29/2018	26	
Weber, Kenneth	No Conflicts to Disclose; Submitted on: 04/26/2018	67	
Weisenthal, Benjamin	No Conflicts to Disclose; Submitted on: 03/25/2018	76	
Wick, Joseph	No Conflicts to Disclose; Submitted on: 04/23/2018	47	
Wilent, William	American Society of Neurophysiological Monitoring: Board or committee member; Submitted on: 04/24/2018		16
Wilson, Jason	No Conflicts to Disclose; Submitted on: 04/24/2018	41	
Wilson, Jefferson	Stryker: Paid consultant; Submitted on: 03/18/2018	29, 50	56
Witham, Timothy	DePuy, A Johnson & Johnson Company: Paid consultant; Eli Lilly: Research support; The Global Spine Journal: Editorial or governing board; Submitted on: 10/05/2018	42	
Witiw, Christopher	No Conflicts to Disclose; Submitted on: 04/22/2018	50	56
Wolinsky, Jean-Paul PC	Siemens: Paid consultant; Submitted on: 10/02/2018	42	

Name	Disclosure Information	Presentations	E-Posters
Woods, Barrett	Altus: IP royalties NEXXT Spine: Paid consultant Precision Spine: Paid consultant Stryker: Paid consultant Titan: Paid consultant; Submitted on: 10/02/2018	2, 30, 38, 82	26
Xia, Yuanxuan	No Conflicts to Disclose; Submitted on: 04/24/2018	42	
Xiong, Wei	No Conflicts to Disclose; Submitted on: 04/23/2018		22
Xu, Guohua	No Conflicts to Disclose; Submitted on: 04/24/2018	87	
Yabu, Akito	No Conflicts to Disclose; Submitted on: 04/17/2018	52	
Yagi, Mitsuru	No Conflicts to Disclose; Submitted on: 10/08/2018	23	
Yamada, Tsuyoshi	No Conflicts to Disclose; Submitted on: 10/02/2018	86	
Yamane, Junichi	No Conflicts to Disclose; Submitted on: 04/22/2018	23	52
Yamazaki, Akiyoshi	Alphatec Spine: Paid consultant; Submitted on: 04/25/2018		44
Yamazaki, Masashi	No Conflicts to Disclose; Submitted on: 04/26/2018		28, 41
Yang, Haisong	No Conflicts to Disclose; Submitted on: 04/23/2018	6	
Yang, Jingyan	No Conflicts to Disclose; Submitted on: 04/24/2018	28	
Yang, Seung Heon	No Conflicts to Disclose; Submitted on: 04/24/2018	34	53
Yang, Xiaoyu	No Conflicts to Disclose; Submitted on: 10/09/2018	34	
Yew, Andrew	No Conflicts to Disclose; Submitted on: 04/19/2018	11	
Yi, Seong	No Conflicts to Disclose; Submitted on: 04/23/2018	73	
Yoon, S. Tim RC	AOSpine: Board or committee member; Biomet: Research support; European Spine Journal: Editorial or governing board; International Society for the Study of the Lumbar Spine: Board or committee member; Meditech Advisor: IP royalties; Meditech Advisors: Stock or stock Options; Medyssey: Stock or stock Options; Phygen: Stock or stock Option;s Spine: Editorial or governing board; Stryker: IP royalties; The Spine Journal: Editorial or governing board; Submitted on: 06/23/2018	41	

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Name	Disclosure Information	Presentations	E-Posters
Yoshii, Toshitaka	American Journal of Tissue Engineering & Stem Cell: Editorial or governing board; International Journal of Orthopedics and Rehabilitation: Editorial or governing board; Medtronic Sofamor Danek: Research support; Olympus biomaterial: Research support; Submitted on: 10/02/2018	86	25, 47
Yoshikawa, Hideki	No Conflicts to Disclose; Submitted on: 04/23/2018	69	
Yu, Elizabeth	AAOS: Board or committee member; Limiflex: Research support; North American Spine Society: Board or committee member; Submitted on: 04/18/2018	40, 72	
Yu, Yan	No Conflicts to Disclose; Submitted on: 10/05/2018	32	
Yuasa, Masato	No Conflicts to Disclose; Submitted on: 04/25/2018	86	25
Yun, Chawon	No Conflicts to Disclose; Submitted on: 10/03/2018		4
Zakaria, Hesham	No Conflicts to Disclose; Submitted on: 04/25/2018	74	
Zigler, Jack	Aesculap/B.Braun: Paid consultant; Centinel Spine: Paid consultant; Coluna: Editorial or governing board; DePuy, A Johnson & Johnson Company: Paid consultant; Expanding Orthopaedics, Safe Orthopaedics, Spinal Kinetics: Stock or stock Options; ISASS: Board or committee member; Journal of ISASS: Editorial or governing board; K2M: IP royalties; Orthofix, Inc.: Paid consultant; Simplify: Paid consultant; Zimmer: IP royalties; Submitted on: 04/16/2018	37	
Zoega, Bjorn SP	Cervical Spine Research Society: Board or committee member; Submitted on: 11/05/2018		

CERVICAL SPINE RESEARCH SOCIETY

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Podium Presentation Abstracts

Presentation #1

Does the Duration of Cervical Radicular Symptoms Impact Outcomes Following Anterior Cervical Discectomy and Fusion?

Bryce A. Basques, MD, Chicago, IL
Philip K. Louie, MD, Chicago, IL
Michael Nolte, MD, Chicago, IL
Jannat M. Khan, BS, Chicago, IL
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Objective: There is no clear indication of when surgical outcomes become less effective in the setting of acute versus chronic symptoms from cervical nerve root compression. The main objective of this study was to assess whether the duration of symptoms has an effect on clinical outcomes, specifically resolution of radicular symptoms, in patients undergoing an anterior cervical discectomy fusion (ACDF) for radiculopathy**.**

Materials/Methods: We performed a retrospective cohort analysis of patients who underwent an ACDF for radiculopathy (6 months minimum follow-up). Patients were divided into four non-exclusive groups: radicular symptoms for less than six months, six months or greater, less than one year, and those with symptoms for one year or greater. Radiographic assessments included: C2-C7 lordosis, T1 angle, levels fused, sagittal vertical axis (SVA), fusion mass lordosis, proximal and distal adjacent segment lordosis, and adjacent segment degeneration (ASD). Neck Disability Index (NDI) scores and Visual Analog Scales (VAS) scores for the neck and arm were obtained. Bivariate and multivariate regressions were subsequently used to compare clinical outcomes between procedure groups. Multivariate analyses controlled for differences in baseline patient characteristics.

Results: 380 consecutive patients (mean follow-up 28.2 months) were included. Patients with radicular symptoms for six months or greater presented with significantly higher pre-operative VAS-neck scores ($p<0.01$), but also experienced greater improvement in preoperative to final VAS-neck ($p= 0.005$) scores compared to patients who experienced symptoms for less than 6 months. Patients with radicular symptoms for 1 year or greater experienced greater pre-operative and final VAS-neck ($p<0.001$), VAS-arm ($p=0.021$) and NDI ($p<0.01$) scores compared to patients who experienced symptoms less than 1 year. There were no significant differences in risk of radiographic adjacent segment degeneration, fusion, subsidence, or reoperation between patient groups on either side of the 6-month or 1-year duration of symptoms (DOS) threshold.

Conclusions: The present study found that patients with a DOS of one year or more before surgery compared to those who had symptoms for less than one year, experienced a similar amount of clinical outcome improvement after ACDF. However, these patients initially presented with and continued to have more severe pain and disability post-operatively. Patients presenting with symptoms for 6 months or greater had similar outcomes to those with symptoms less than 6 months.

Presentation #1 (cont.)

Table 1. Demographics

	Pain < 6 mo	Pain > 6 mo	All patients	p-value	Pain < 1 yr
Overall	118	262	380		198
Age	49.5 ± 12.3	50.1 ± 11.1	50.1 ± 11.1	0.767	50.4 ± 11.8
Female sex	50.85%	49.43%	49.87%	0.291	47.47%
BMI	27.2 ± 6.4	30.81	29.0 ± 6.4	0.162	28.8 ± 6.8
Smoking	16.10%	22.14%	20.26%	0.176	17.68%
Diabetes	13.56%	9.58%	10.82%	0.248	12.18%
ASA >=3	14.41%	19.47%	17.89%	0.226	19.19%
Number of levels				0.311	
1	33.90%	32.06%	32.4%		33.3%
2	49.15%	46.18%	47.1%		46.5%
3	15.25%	21.37%	19.5%		19.2%
4	1.69%	0.38%	0.9%%		1.0%

ASA = American Society of Anesthesiologists Physical Status Classification System

BMI = body mass index kg/m^2

Presentation #1 (cont.)

Table 2. Comparing clinical outcomes

					Multivariate				Multivariate	
	Radicular symptoms	Pain < 6 mo	Pain > 6 mo	All patients	Beta	p-value	Pain < 1 yr	Pain > 1 yr	Beta	p-value
Preoperative										
VAS neck		4.8 ± 4.0	7.9 ± 2.5	7.1 ± 3.3	**3.14**	**<0.001**	6.1 ± 3.7	8.1 ± 2.3	**2.75**	**<0.001**
	Pain	6.2 ± 3.9	7.9 ± 2.3		**-2.67**	**0.009**	6.4 ± 3.5	8.1 ± 2.5	**-2.55**	**0.012**
	Sensory	7.0 ± 3.4	7.4 ± 2.7		0.51	0.617	6.9 ± 3.4	7.8 ± 2.6	-0.99	0.323
	Weakness	4.7 ± 4.1	6.1 ± 3.4		1.68	0.097	4.7 ± 3.9	6.7 ± 3.2	**-2.56**	**0.019**
VAS arm		5.6 ± 3.9	5.6 ± 3.7	5.6 ± 3.7	0.01	0.991	5.0 ± 3.8	6.2 ± 3.6	**1.91**	**0.021**
	Pain	6.2 ± 3.8	4.9 ± 3.7		1.65	0.102	5.6 ± 3.9	5.5 ± 3.6	0.13	0.891
	Sensory	5.5 ± 3.8	5.6 ± 3.6		-0.03	0.963	5.5 ± 3.8	5.8 ± 3.4	-0.34	0.732
	Weakness	5.9 ± 3.9	6.2 ± 3.9		-0.77	0.586	5.1 ± 3.4	6.1 ± 3.7	-1.73	0.089
NDI		42.8 ± 21.7	48.6 ± 20.1	47.0 ± 20.6	-1.23	0.223	41.0 ± 19.5	52.8 ± 20.1	**-3.12**	**<0.001**
	Pain	41.5 ± 20.3	50.9 ± 20.2		**-2.25**	**0.027**	41.1 ± 19.1	56.1 ± 19.8	**-3.76**	**<0.001**
	Sensory	46.6 ± 21.0	47.7 ± 20.5		-0.25	0.804	45.2 ± 20.4	51.4 ± 20.8	-1.57	0.120
	Weakness	45.2 ± 20.4	52.5 ± 20.9		-1.55	0.123	45.3 ± 20.1	55.1 ± 21.6	-1.87	0.064
Final										
VAS neck		1.5 ± 2.1	2.3 ± 2.5	2.1 ± 2.4	-1.59	0.115	1.5 ± 2.0	2.7 ± 2.6	**1.22**	**0.025**
	Pain	1.6 ± 2.1	2.3 ± 2.5		-1.41	0.161	1.6 ± 2.0	2.8 ± 2.7	**-2.52**	**0.013**
	Sensory	1.6 ± 2.3	2.4 ± 2.4		-1.71	0.091	1.7 ± 2.2	2.8 ± 2.5	**-2.26**	**0.026**
	Weakness	2.2 ± 2.3	1.7 ± 2.5		0.75	0.454	2.0 ± 2.3	2.1 ± 2.7	-0.12	0.905
VAS arm		1.2 ± 1.9	1.9 ± 3.0	1.7 ± 2.7	-1.08	0.282	0.9 ± 1.7	2.5 ± 3.3	**1.42**	**0.017**
	Pain	1.8 ± 2.1	1.9 ± 3.0		-1.31	0.192	1.0 ± 1.9	2.6 ± 3.3	**-3.10**	**0.003**
	Sensory	1.4 ± 2.4	1.9 ± 2.9		-0.93	0.351	1.2 ± 2.2	2.5 ± 3.2	**-2.36**	**0.020**
	Weakness	1.6 ± 2.6	1.8 ± 3.0		-0.27	0.781	1.5 ± 2.5	2.3 ± 3.3	-1.06	0.290

Presentation #1 (cont.)

NDI	18.0 ± 17.1	22.0 ± 21.2	20.81 ± 20.1	0.9	0.369	14.4 ± 15.8	27.5 ± 22.0	**-3.54**	**0.002**		
Pain	18.5 ± 18.3	22.3 ± 21.0		-0.94	0.351	15.8 ± 17.2	28.1 ± 21.7	**-3.19**	**0.002**		
Sensory	20.7 ± 19.1	20.9 ± 20.9		-0.04	0.961	17.9 ± 18.3	26.1 ± 22.0	**-2.00**	**0.040**		
Weakness	21.8 ± 19.7	16.9 ± 21.1		1.02	0.306	20.5 ± 19.5	22.1 ± 23.3	-0.28	0.777		
Change preoperative to final											
VAS neck	3.3 ± 4.7	5.8 ± 3.2	5.1 ± 3.8	**-2.91**	**0.005**	4.6 ± 4.2	5.7 ± 3.4	1.72	0.058		
Pain	4.2 ± 4.4	5.9 ± 3.3		**-2.02**	**0.041**	4.9 ± 4.0	5.7 ± 3.5	-0.90	0.369		
Sensory	4.5 ± 4.5	5.8 ± 2.9		-1.61	0.112	5.0 ± 4.1	5.5 ± 3.1	-0.57	0.571		
Weakness	4.9 ± 3.9	6.0 ± 3.6		-1.18	0.241	5.0 ± 3.8	6.0 ± 4.0	-0.89	0.373		
VAS arm	4.4 ± 4.2	4.0 ± 3.8	4.1 ± 3.9	-0.47	0.642	4.2 ± 4.0	4.0 ± 3.8	0.63	0.456		
Pain	3.5 ± 4.1	4.4 ± 3.6		-1.08	0.284	3.8 ± 3.9	4.4 ± 3.7	-0.68	0.497		
Sensory	4.9 ± 4.1	3.3 ± 3.4		1.92	0.067	4.5 ± 4.1	3.3 ± 3.2	1.43	0.157		
Weakness	4.1 ± 3.9	4.1 ± 3.6		-0.03	0.977	4.1 ± 3.5	3.7 ± 3.5	0.42	0.677		
NDI	28.6 ± 28.2	27.4 ± 22.0	27.7 ± 23.7	-0.22	0.828	29.3 ± 23.3	26.1 ± 24.3	1.77	0.592		
Pain	25.5 ± 26.1	29.5 ± 26.1		-0.77	0.443	27.4 ± 23.3	28.7 ± 24.2	-0.24	0.804		
Sensory	28.5 ± 26.7	27.4 ± 20.5		0.21	0.831	29.0 ± 24.2	25.7 ± 22.4	0.63	0.531		
Weakness	25.22 ± 23.1	26.2 ± 23.4		-0.24	0.792	26.6 ± 23.0	34.4 ± 26.0	-1.17	0.244		

VAS = Visual Analog Scale score. NDI = Neck Disability Index score

Presentation #1 (cont.)

Table 3. Sagittal parameters preoperatively and postoperatively

	Pain < 6 mo	Pain > 6mo	All patients	Multivariate		Pain < 1 yr	Pain > 1 yr	Multivariate	
				Beta	p-value			Beta	p-value
Preoperative									
C2-7 Lordosis (deg)	2.2 ± 12.0	5.4 ± 10.8	4.4 ± 11.0	**-2.40**	**0.017**	4.4 ± 12.0	4.4 ± 10.8	0.46	0.694
SVA (mm)	28.0 ± 11.0	27.2 ± 11.3	27.4 ± 11.2	-0.62	0.535	28.5 ± 11.3	26.3 ± 11.0	-1.45	0.200
Fusion seg lordosis (deg)	-1.0 ± 8.45	0.4 ± 6.7	0.0 ± 7.31	-1.71	0.089	0.0 ± 7.87	-0.1 ± 6.7	0.11	0.892
T1 slope (deg)	24.8 ± 8.3	26.2 ± 8.3	25.8 ± 8.3	-1.07	0.287	26.1 ± 8.7	25.5 ± 7.8	-0.36	0.758
Proximal lordosis (deg)	1.6 ± 8.3	2.0 ± 8.0	1.9 ± 8.1	-0.38	0.699	1.6 ± 7.4	2.2 ± 8.8	0.67	0.421
Distal lordosis (deg)	3.7 ± 4.4	3.7 ± 4.6	3.7 ± 4.5	-0.02	0.987	3.6 ± 4.6	3.8 ± 4.5	0.13	0.828
Immediate postoperative									
C2-7 Lordosis (deg)	5.8 ± 9.4	8.2 ± 10.2	7.5 ± 10.5	**-2.18**	**0.03**	7.1 ± 9.8	7.9 ± 10.3	1.10	0.276
SVA (mm)	29.3 ± 10.1	30.0 ± 11.1	29.8 ± 10.8	-0.56	0.575	30.4 ± 11.0	29.1 ± 10.6	-0.26	0.803
Fusion seg lordosis (deg)	6.0 ± 6.1	6.5 ± 5.6	6.3 ± 5.8	-0.86	0.390	6.1 ± 5.9	6.6 ± 5.6	0.50	0.384
T1 slope (deg)	26.8 ± 7.7	28.4 ± 7.4	27.9 ± 7.5	-1.44	0.151	27.6 ± 7.8	28.1 ± 7.3	0.73	0.476
Proximal lordosis (deg)	1.2 ± 8.5	1.5 ± 8.7	1.4 ± 8.6	-0.32	0.754	1.3 ± 8.1	1.4 ± 9.2	0.42	0.622
Distal lordosis (deg)	2.4 ± 5.2	2.6 ± 4.6	2.5 ± 4.8	-0.26	0.790	2.5 ± 5.0	2.5 ± 4.6	-0.09	0.890
Final									
C2-7 Lordosis (deg)	7.7 ± 10.0	9.9 ± 10.2	9.2 ± 10.1	**-2.01**	**0.045**	8.8 ± 10.0	9.6 ± 10.2	1.07	0.303
SVA (mm)	26.3 ± 10.7	27.7 ± 10.6	27.2 ± 10.7	-1.13	0.257	27.2 ± 10.5	27.3 ± 10.9	1.23	0.214
Fusion seg lordosis (deg)	5.3 ± 6.2	6.1 ± 5.7	5.9 ± 5.9	-1.21	0.226	5.7 ± 6.2	6.0 ± 5.5	0.30	0.614
T1 slope (deg)	27.4 ± 6.8	28.8 ± 7.8	28.4 ± 7.5	-1.35	0.179	27.8 ± 7.0	29.0 ± 8.0	1.46	0.144
Proximal lordosis (deg)	2.0 ± 8.3	2.3 ± 8.4	2.2 ± 8.3	-0.33	0.737	2.0 ± 7.7	2.5 ± 9.0	0.77	0.355
Distal lordosis (deg)	3.4 ± 5.5	3.7 ± 4.9	3.6 ± 5.1	-0.37	0.709	3.6 ± 5.4	3.6 ± 4.8	-0.31	0.639

*Odds ratio represents odds of ASD per one-unit increase in each sagittal parameter

SVA - Sagittal Vertical Axis

Presentation #1 (cont.)

Table 4. Change in parameters at different time points

	Pain <6 mo	Pain >6 mo	All patients	Multivariate		Pain < 1 yr	Pain > 1 yr	Multivariate	
				Beta	p-value			Beta	p-value
Change Preoperative to Postoperative									
Lordosis (deg)	3.5 ± 8.6	2.8 ± 7.7	3.0 ± 8.0	0.69	0.492	2.7 ± 8.0	3.5 ± 8.1	0.75	0.381
SVA (mm)	2.0 ± 7.9	2.8 ± 7.8	2.5 ± 7.8	-0.86	0.389	2.0 ± 7.9	3.0 ± 7.6	1.06	0.222
Fusion seg lordosis (deg)	6.9 ± 7.4	6.1 ± 6.1	6.3 ± 6.5	1.04	0.297	5.9 ± 6.8	6.8 ± 6.1	0.53	0.415
T1 slope (deg)	2.2 ± 6.0	2.3 ± 5.3	2.3 ± 5.5	-0.11	0.910	2.1 ± 5.6	2.5 ± 5.4	0.20	0.812
Proximal lordosis (deg)	-0.3 ± 3.9	-0.6 ± 4.0	-0.5 ± 4.0	-0.63	0.530	-0.3 ± 4.0	-0.7 ± 3.9	-0.31	0.463
Distal lordosis (deg)	-1.5 ± 4.9	-1.1 ± 4.1	-1.2 ± 4.3	-0.60	0.547	-1.0 ± 4.6	-1.4 ± 4.0	-0.29	0.622
Change Postoperative to Final									
Lordosis (deg)	1.9 ± 5.7	1.6 ± 5.5	1.6 ± 5.6	0.47	0.641	1.6 ± 5.5	1.7 ± 5.7	-0.12	0.831
SVA (mm)	-3.6 ± 7.0	-2.7 ± 7.5	-3.0 ± 7.3	-1.04	0.299	-3.5 ± 7.6	-2.4 ± 6.9	1.35	0.082
Fusion seg lordosis (deg)	-0.6 ± 3.9	-0.4 ± 3.6	-0.5 ± 3.7	-0.50	0.619	-0.4 ± 3.8	-0.6 ± 3.5	-0.22	0.568
T1 slope (deg)	0.2 ± 4.0	-0.6 ± 6.4	-0.3 ± 5.8	0.89	0.375	-0.6 ± 6.5	0.0 ± 4.8	0.78	0.376
Proximal lordosis (deg)	0.9 ± 3.4	0.9 ± 4.0	0.9 ± 3.8	-0.15	0.878	0.7 ± 4.1	1.2 ± 3.5	0.46	0.246
Distal lordosis (deg)	1.1 ± 4.0	1.1 ± 3.9	1.1 ± 3.9	0.23	0.820	1.1 ± 3.9	1.1 ± 4.0	-0.23	0.662
Change Preoperative to Final									
Lordosis (deg)	5.5 ± 8.1	4.4 ± 7.8	4.8 ± 7.9	1.16	0.246	4.4 ± 8.1	5.2 ± 7.7	0.56	0.516
SVA (mm)	-1.6 ± 7.9	0.2 ± 8.1	-0.4 ± 8.1	-1.83	0.067	-1.1 ± 7.7	0.5 ± 8.5	1.94	0.026
Fusion seg lordosis (deg)	6.2 ± 7.9	5.6 ± 6.1	5.8 ± 6.8	0.74	0.459	5.5 ± 7.5	6.2 ± 5.8	0.29	0.666
T1 slope (deg)	2.2 ± 6.4	2.1 ± 7.1	2.1 ± 6.9	0.06	0.955	1.5 ± 7.9	2.8 ± 5.6	1.70	0.124
Proximal lordosis (deg)	0.6 ± 4.7	0.4 ± 4.6	0.5 ± 4.6	0.46	0.647	0.4 ± 4.9	0.5 ± 4.3	0.13	0.798
Distal lordosis (deg)	-0.4± 4.9	-0.1 ± 4.2	-0.2 ± 4.4	-0.45	0.651	0.03 ± 4.7	-0.4 ± 4.1	-0.49	0.406

*Odds ratio represents odds of ASD per one-unit increase in each sagittal parameter

Presentation #1 (cont.)

Table 5. Comparison of ASD, reoperations, fusion, and subsidence

				Multivariate				Multivariate	
	Pain <6 mo	Pain >6 mo	All patients	OR	p-value	Pain < 1 yr	Pain > 1 yr	OR	p-value
Any ASD	18.64%	20.61%	20.00%	0.44	0.658	17.17%	23.08%	1.48	0.135
Proximal	11.86%	16.03%	14.74%	1.06	0.291	11.62%	18.31%	1.68	0.435
Distal	10.17%	8.78%	9.21%	-0.43	0.665	9.09%	9.34%	1.09	0.817
Proximal and Distal	3.39%	4.20%	3.95%	0.37	0.708	3.54%	4.40%	1.29	0.644
Reoperations	1.69%	5.73%	4.47%	1.63	0.098	2.53%	6.59%	2.62	0.079
Fusion	96.61%	98.09%	97.63%	0.87	0.386	97.98%	97.25%	0.77	0.702
Subsidence	2.54%	6.87%	5.53%	1.64	0.101	5.05%	6.04%	1.11	0.825

*Odds ratio represents odds of ASD per one-unit increase in each sagittal parameter

ASD = Radiographic evidence of Adjacent Segment Degeneration

Subsidence as measured by a decrease in intervertebral disc height of ≥2mm from immediate post-operative radiographs to final followup radiographs.

Presentation #2

Does Duration of Preoperative Radiculopathy Symptoms Impact Postoperative Outcomes and Reoperations After an ACDF?

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Introduction: Most literature evaluating the effect of duration of symptoms (DOS) on clinical outcomes after cervical spine surgery is regarding myelopathy, demonstrating that longer DOS negatively affects postoperative health-related quality of life (HRQOL) outcomes. However, there is limited data on the relationship of duration of cervical radiculopathy symptoms on outcomes following surgery.

Methods: A retrospective study was performed to identify patients with cervical radiculopathy who underwent an ACDF and determine the effects of duration of symptoms (DOS) on HRQOL outcomes and reoperation rates. Patients were grouped based on DOS into three categories: (1) less than 6 months; (2) 6 months to 2 years; (3) more than 2 years. Patients who underwent surgery for trauma, tumor, infection, or revision, and patients with less than one year of clinical follow-up were excluded. Outcomes evaluated included preoperative and postoperative SF-12 PCS, SF-12 MCS, NDI, VAS arm pain, VAS neck pain, and reoperations. Multivariate analyses were performed to determine the independent effect of DOS on postoperative HRQOL outcomes, while controlling for factors such as age, gender, BMI, smoking, diabetes, number of levels fused, and preoperative HRQOL scores.

Results: A total of 216 patients were included with a mean follow-up of 16.0 (range 12.0-46.1) months. The mean age was 51.9 (range 23-84) years old, and the mean BMI was 29.4 (range 18.8-54.9). The average number of levels fused was 2.01 (range 1-4). There were 86 patients with symptoms for less than 6 months, 61 patients with symptoms for 6 months to 2 years, and 69 patients with symptoms for more than 2 years. The three groups were similar in terms of age, gender, BMI, smoking status, diabetes, and number of levels fused.

There were no differences in preoperative HRQOL scores between the three groups at baseline (Table 1). Postoperatively, patients with a longer duration of symptoms had significantly worse outcomes in every HRQOL outcome metrics except for the SF-12 MCS (Table 1). Furthermore multivariate analysis demonstrated longer duration of symptoms predicted lower postoperative PCS (Beta -1.696, p=0.031) and MCS (-1.991, p=0.027), and higher postoperative NDI (Beta 4.746, p=0.002), neck pain (Beta 0.733, p=0.001), and arm pain (Beta 0.700, p=0.001).

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #2 (cont.)

Overall, there was an 8.3% (n=18) rate of reoperation, which on average occurred 20.0 months (7 days-46.4 months) after surgery. There were 8 (9.3%), 5 (8.2%), and 5 (7.2%) reoperations among patients with less than 6 months, 6 months to 2 years, and more than 2 years of symptoms, respectively, with no difference among the three groups (p=0.899).

Conclusion: While all cohorts demonstrated improvements in HRQOL outcome metrics, patients should be counseled that delaying surgical intervention for more than six months might result in inferior results, because patient with a longer duration of cervical radiculopathy symptoms had worse postoperative function, disability, and pain scores at a minimum of one-year follow-up. However, longer duration of symptoms did not result in a difference in reoperation rates.

Table 1. HRQOL outcomes by Duration of Symptoms

	Less than 6 months		6 months to 2 years		More than 2 years			
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	ANOVA p-value	Multivariate Analysis p-value
Preop PCS	34.25	7.97	33.26	7.60	32.91	7.63	0.538	
Postop PCS	43.49	11.71	39.73	9.92	39.43	11.09	0.039*	0.031*
Preop MCS	45.21	12.17	45.66	11.92	45.68	13.48	0.965	
Postop MCS	50.32	10.75	47.83	11.70	47.01	12.41	0.179	0.027*
Preop NDI	41.38	19.46	43.05	19.21	44.72	18.17	0.552	
Postop NDI	21.21	22.30	27.11	21.89	31.27	23.29	0.021*	0.002*
Preop Neck pain	6.07	2.64	5.44	2.94	6.09	2.59	0.302	
Postop Neck pain	2.56	2.78	3.41	2.78	3.93	3.07	0.012*	0.001*
Preop Arm pain	5.43	3.08	5.45	2.89	4.82	3.39	0.406	
Postop Arm pain	2.18	2.79	2.96	2.84	3.50	3.04	0.018*	0.001*

Table 1. Comparison of mean and standard deviation between patients with symptoms for less than 6 months, 6 months to 2 years, and more than 2 years using ANOVA analysis. Multivariate analysis used to control for confounding variables and determine the effect of duration of symptoms on postoperative HRQOL outcomes.

Presentation #3

Effect of Postoperative Increase in Disc Height on Clinical Outcomes in Anterior Cervical Discectomy and Fusion Patients

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Introduction: Anterior cervical discectomy and fusion (ACDF) has been widely used to treat cervical degenerative disc pathology. It is believed that, in addition to direct surgical decompression, inserting a solid graft/spacer into the disc space allows for further neurological decompression. There is also a belief that over decompression from large grafts can cause postoperative neck pain; however, there is little clinical data to support this. The purpose of this study was to find the correlation between a postoperative increase in intervertebral disc height (IVD) and postoperative neck pain with NDI scores in ACDF patients.

Methods: Review of the control arm of a prospectively collected IDE study comparing ACDF to M6C Disc arthroplasty. Anterior and posterior postoperative disc height changes at the IVD level after graft insertion (6 weeks, 3 months, 6 months, 1-year, 2-year) were measured. The change in postoperative neck pain and NDI scores were measured at 6 weeks, 3 months, 6 months and 1 year follow-ups. A stepwise analysis was made to compare changes in postoperative neck pain and NDI scores with disc height change, for both anterior and posterior disc height change separately by using an ANOVA test.

Results: Patients with a posterior disc height change of ≤2mm (n=60) had a statistical improvement in postoperative neck pain scores at 6 weeks (from preoperative = 7.2 to postoperative = 3, $p<0.001$), 3months (from preoperative = 7.3 to postoperative = 2.1, $p<0.001$), 6 months (from preoperative = 7.2 to postoperative = 2.4, $p<0.001$) and 1 year (from preoperative = 7.4 to postoperative = 2.6, $p<0.001$). No significant improvement was noticed in patients with posterior disc height change >2mm (n=6), at 6 weeks (from preoperative = 4.5 to postoperative = 2.4, $p=0.117$), 6 months (from preoperative = 4.5 to postoperative = 3.2, $p=0.06$) and 1 year (from preoperative=4.5 to postoperative=3.2, $p=0.16$), except for 3 months (from preoperative = 4.5 to postoperative e= 2.3, $p=0.04$). By direct comparison, the mean improvement in posterior neck pain score was statistically less in patients with posterior disc height >2mm at 6weeks ($p= 0.06$, 2 vs. 4.2), 6 months ($p=0.02$, 1.2 vs. 4.7), and 1 year ($p=0.06$, 1.4 vs. 4.6) compared to patients with ≤2mm, respectively. (Table 1/ Graph 1) No correlation was seen between anterior disc height change and improvement in postoperative neck and NDI scores.

Conclusion: Greater than 2mm increase in postoperative IVD height had significantly less improvement in postoperative neck pain scores. While distraction may allow for indirect decompression, surgeons should use caution with a potential concern for less neck pain improvement.

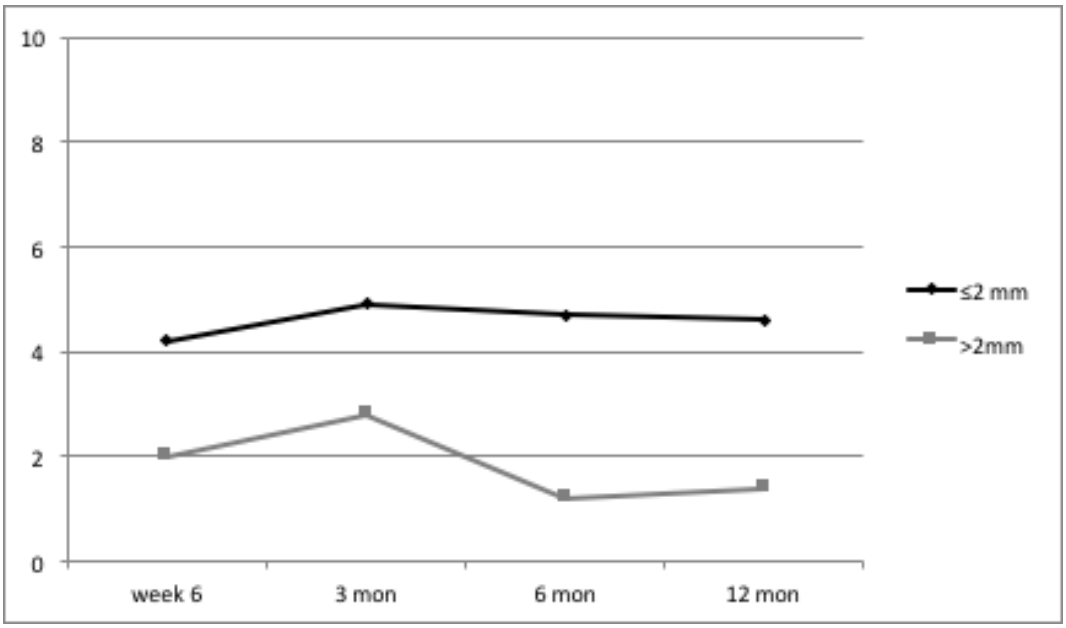
Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #3 (cont.)

Table 1: Posterior IVD Height Change versus Improvement in Neck Pain Scores

IVD height change	**n**	**Improvement in Neck pain scores from Preoperative**			
		6 weeks	**3 months**	**6 months**	**12 months**
≤2 mm	58	4.2 (p<0.001)	4.9 (p<0.001)	4.7 (p<0.001)	4.6 (p<0.001)
>2mm	6	2 (p=0.117)	2.8 (p=0.04)	1.2 (p=0.06)	1.4 (p=0.16)
P value (comparing difference in improvement between groups)		0.06	0.17	0.02	0.06

Graph 1: Posterior IVD Height Change versus Improvement in Neck Pain Scores



Presentation #4

Disparities in Outcomes by Payer Groups for Patients Undergoing Anterior Cervical Discectomy and Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a common procedure used for the treatment of cervical radiculopathy and myelopathy. Disparities in outcomes based on insurance payer have been well documented in the scientific literature, but no such analysis exists for patients undergoing ACDF.

Methods: Patients at a single institution were queried with the Current Procedural Terminology (CPT) codes 22554, 22551, and 63075 as having undergone ACDF from 2006-2016. Exclusion criteria consisted of any patient who underwent a posterior cervical fusion during the same hospitalization. Patients were assigned to one of five insurance categories: uninsured, managed care, commercial indemnity insurance, Medicare, and Medicaid, with patients in the commercial indemnity group serving as the reference for all comparisons. Multivariable logistic regression equations for various outcomes with the exposure of payer were created, controlling for age, sex, ASA Class, and the patient's Elixhauser Comorbidity Index. A Bonferroni correction was utilized, such that alpha=0.0125.

Results: 2,393 patients underwent ACDF from 2006-2016, with 638 in the commercial plan group, 1,138 managed care plan, 156 Medicaid, 445 Medicare, and 16 uninsured. Medicare patients were significantly older than the commercial plan group (64.13 vs. 48.87, $p<0.0125$). Managed care (47.56% vs. 54.53%, $p=0.005$) and Medicaid (38.67% vs. 54.53%, $p=0.0005$) groups had significantly fewer males than the commercial group. Based on ASA Class, the Medicaid ($p=0.0006$) and Medicare ($p<0.0001$) were significantly sicker than those with commercial plans; however, this finding was only confirmed using the Elixhauser Comorbidity Index in the Medicare ($p<0.0001$) group, while the difference was insignificant ($p=0.2$) in the Medicaid group.

The Medicaid patients had higher rates of prolonged extubation (7.69% vs. 2.19%, $p=0.0005$) and prolonged LOS (50.64% vs. 35.42%, $p=0.0005$). Upon unadjusted analysis, this difference remained for prolonged extubation (OR: 4.67; 98.75% CI: 0.99 – 22.11; $p=0.01$), but differences in prolonged LOS became nonsignificant. Medicaid patients also had higher adjusted rates of non-home discharge (OR: 1.68; 98.75% CI: 1.05 – 2.68, $p=0.006$). Unadjusted analysis showed that Medicare patients had higher rates of prolonged extubation (5.39% vs. 2.19%, $p=0.005$), non-home discharge (15.08% vs. 3.34%, $p<0.0001$), and prolonged LOS (49.21% vs. 35.42%, $p<0.0001$), but only the difference in prolonged LOS persisted during adjusted analysis (OR: 2.12; 98.75% CI: 1.00 – 4.48, $p=0.0125$).

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Presentation #4 (cont.)

The Medicaid cohort had higher rates of 30- (7.69% vs. 1.88%, p=0.0001) and 90-day (10.26% vs. 2.82%, p<0.0001) ED visits, both of which persisted in the adjusted analysis (30 day OR: 4.39; 98.75% CI: 1.52 – 12.66; p=0.0005; 90 day OR: 3.71; 98.75% CI: 1.50 – 9.15; p=0.0003). While the Medicare patients initially had higher rates of 30- (3.82% vs. 1.10%, p=0.003) and 90-day (8.99% vs. 3.29%, p<0.0001) readmissions, these differences did not persist in the adjusted analysis.

Conclusions: Medicare and Medicaid patients had higher rates of non-home discharge and unexpected post-operative ED visits compared to other insurance groups. Further studies are needed to identify areas for targeted quality improvement measures and more rigorous postoperative care-planning to alleviate these disparities.

Presentation #5

Posterior Foraminotomy vs. Anterior Decompression and Fusion in Patients with Cervical Degenerative Disc Disease with Radiculopathy – Five-Year Outcomes from the National Swedish Spine Register

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Background: The long-term efficacy of posterior foraminotomy compared with anterior decompression and fusion (ACDF) for the treatment of cervical degenerative disc disease with radiculopathy has not previously been investigated in a population-based setting. Swespine is a national register using validated instruments with prospectively collected data. 90% of the spine clinics in Sweden are affiliated and the register completeness is 75%.

Methods: All patients in the national Swespine register since January 1st, 2006 with cervical degenerative disc disease and radiculopathy were eligible for the study. Follow-up information was obtained up to November 15th, 2017. We compared, using of propensity score matching, patients treated with posterior foraminotomy with patients who underwent ACDF. The primary outcome was the Neck Disability Index (NDI), a patient-reported function score that ranging from zero to 100%, with higher scores indicating greater disability and a minimal clinically important difference of >15%. Secondary outcomes were EQ-5D and pain scores for the neck and arm. Reoperations were also accounted for.

Results: A total of 4,368 patients (2,136/2,232 women/men) met the inclusion criteria of whom 647 had undergone posterior foraminotomy and 3,721 had undergone ACDF. After propensity score matching, 421 patients with a mean age of 52 years remained in each group. Scores on the NDI were approximately halved in both groups after 5 years, but without a significant mean difference in NDI (2.1%; 95% CI, -5.1 to 9.3; P=0.57) between the groups. There were no differences between the groups in EQ-5D nor in pain scores for the neck and arm. Secondary surgeries on the index level were more frequent in the foraminotomy-group, 6%, compared with the ACDF-group, 1%, P<0.001. Preserved motion on the index level did not prevent secondary surgeries due to adjacent segment pathology, 2% each group.

Conclusion: In patients with cervical degenerative disc disease and radiculopathy posterior foraminotomy did not result in a clinically important difference in outcomes after 5 years compared with ACDF; although, secondary surgeries were more frequent in the foraminotomy group. These results reflect a national setting and not just a few clinics or surgeons.

Presentation #6

In-Situ Decompression to Spinal Cord During Anterior Controllable Antedisplacement Fusion Treating Degenerative Kyphosis with Stenosis: Surgical Outcomes and Analysis of C5 Nerve Palsy Based on 49 Patients

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Objective: To observe outcomes of anterior controllable antedisplacement fusion (ACAF) in the treatment for degenerative kyphosis with stenosis (DKS) and analyze the probability of C5 nerve palsy.

Methods: In the period from 2016 to 2017, a consecutive cohort of adults with DKS underwent ACAF. All these patients were performed cervical plain films, CT and MRI. The operation duration, blood loss and hospital stay was estimated. Radiologic assessment included kyphotic correction, decompression width and spinal canal area. Postoperative curvature of spinal cord was observed on sagittal MRI. The JOA scoring system was used to evaluate the neurological status. C5 nerve palsy and other complications were all recorded.

Results: Fourty-nine patients were included in the study. There was significant kyphosis correction after operation (-19.4° vs. 3.5°, $P<0.01$). On cross-sectional CT images, the mean decompression width and spinal canal area was 19.0mm and 218.5 mm^2. On sagittal MRI, the spinal cord curvature was classified into five types, type I-lordosis, type II-straight with no shifting, type III-straight with shifting, type IV-sigmoid, and type V-kyphosis. After ACAF, the spinal cord is kept in good curvature with no shifting in all patients. No patient presented with C5 nerve palsy. The mean postoperative JOA score was significantly better than preoperation (14.9 vs. 9.0 points, $P<0.01$), with a mean improvement rate of 79.8%.

Conclusions: ACAF provides an in-situ decompression and good curvature to the spinal cord. Accordingly, it attains good neurological recovery and lower incidence of C5 nerve palsy when it is used in the treatment for DKS.

Presentation #6 (cont.)

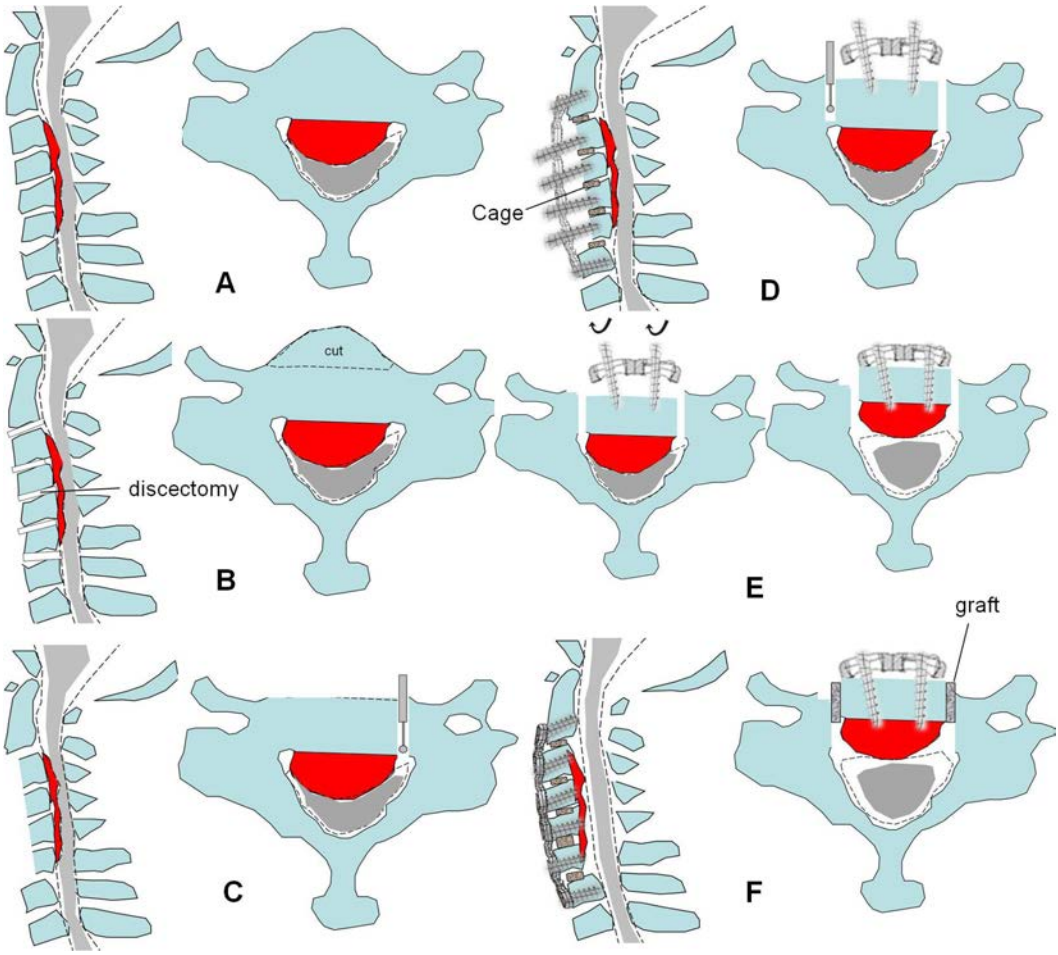

Fig.1. ACAF surgical technique (DKS with OPLL). A. Spinal cord compression because of DKS with OPLL from C3 to C6. B. Discectomy from C2/3 to C6/7 (left) and cutting of the anterior part of the vertebrae according to the thickness of the ossified mass (right). C. Anterior part of C3, C4, C5 and C6 was cut (left) and on the left side of the vertebra, creating a groove about 3 mm wide to the posterior wall of the vertebrae from C6 to C3 (right). D. Filling the intervertebral space from C6/7 to C2/3 with a cage filled with autologous bone fragments and placing an anterior plate on C7 and C2 as well as a screw in the central (C3, C4, C5 and C6) vertebrae (left) and then creating groove on the right side from C6 to C3 (right). E. Axial views of before (left) and after (right) tightening of the screw in the middle vertebra (C3, C4, C5 and C6). F. Sagittal (left) and transverse (right) views of the spinal canal showing good volume of the spinal canal with well spinal cord morphology and curvature.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #7

Subgroup Analysis on the Efficacy of Anterior Cervical Discectomy with or without Interbody Fusion or Arthroplasty in the Treatment of Cervical Radiculopathy: Combined Clinical Results of Two Randomised Controlled Trials

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Introduction: The cervical disc prosthesis was introduced to decrease neck disability after anterior discectomy. Several randomized controlled trials (RCTs) were performed to compare outcome of a prosthesis implant (ACDA) to the most common alternative: implanting a cage (ACDF). Numbers of patients in RCTs are generally small and therefore the results of two RCTs with comparable set up were combined. Both RCTs also included a group of patients in which no intervertebral device was implanted (ACD). As a result of the larger sample size in the combined dataset subgroup analysis for BMI, age, gender and smoking could be performed.

Methods: Both the NECK trial (LUMC; activC ®) and the Procon trial (RadboudUMC; Prodisc®) included patients with radicular signs and symptoms in one or both arms due to a single level cervical intervertebral disc herniation and/or an osteophyte in accordance with MRI findings. Both studies chose Neck Disability Index as the primary outcome variable, and subscales of the SF36 and McGill pain score as secondary outcome parameters. Variables were analysed at baseline and at 2 years post-operatively. Subgroup analysis was performed for gender, age ≤ 40 and > 40, BMI ≤ 30 and > 30 and smoking/non-smoking. To account for the correlation between repeated measurements Generalized Estimating Equations (GEE) were used. Study type was added as a fixed effect to correct for differences between the two studies.

Results: Data from 109 patients from the NECK trial and 142 patients from the Procon trial were combined, creating a total study population of 251 patients. 83 patients were allocated into ACD, 83 patients into ACDF and 85 patients into ACDA. The mean age was 45,02 (SD ±7,525; range 18 to 70). The NDI decreased comparably in all treatment arms from 44.31-46.62 to 21.9 ± 3.1 (ACD), 22.5 ± 3.6 (ACDF) and 22.7 ± 4.3 (ACDA) . Treatment effect differences were 0.56 (CI -4.12 to 5.24; ACDF vs ACD), 0.76 (CI -4.45 to 5.96; ACDA vs ACD) and 0.20 (CI -5.29 to 5.68 ACDP vs ACDF) on a 100-point scale. In all three comparisons the treatment effect never exceeded the Minimal Clinical Important Difference (MCID) of 15% (**figure 1**). Results for the secondary outcome scales were comparable.

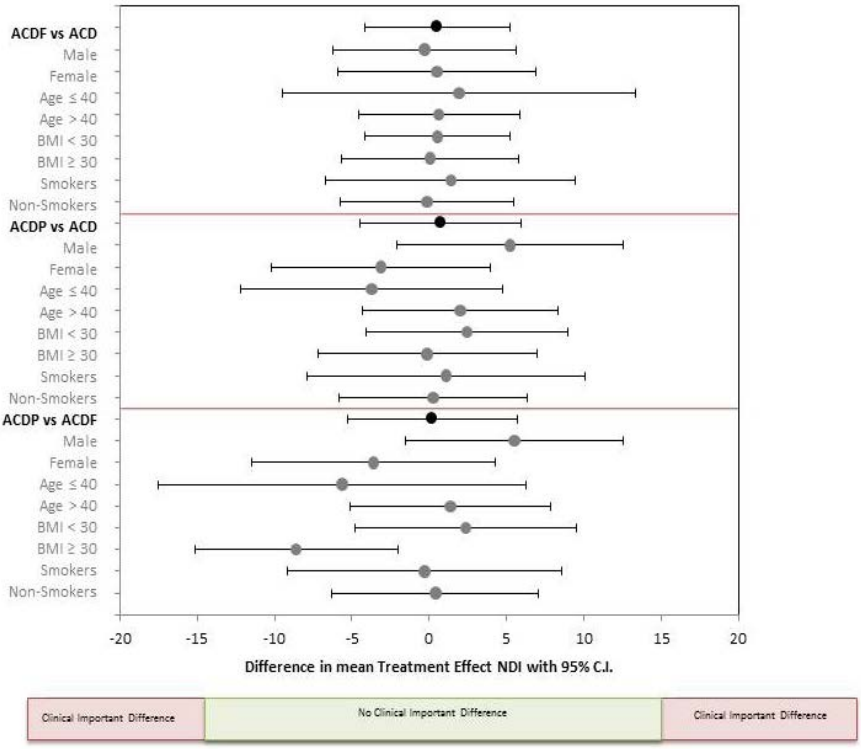
Subgroup analysis for gender, age, BMI and smoking demonstrate small differences in treatment effect almost exclusively without exceeding MCID borders (**figure 1**). Considering NDI, only the maximal lower limit of the confidence interval of age ≤ 40 reached the MCID of 15%; the interval is however wide and the majority of the interval is in between the 15% difference limit.

Conclusion: Combining the results of two RCTs results allows the conclusion that there is no difference in treatment effect of ACD, ACDF and ACDA. Even subgroup analysis does

Presentation #7 (cont.)

not indicate a certain type of patient that would benefit more from one particular treatment strategy. Remarkably, the ACD clinical results are similar to ACDF and ACDA results. Single level anterior discectomy without implanting an intervertebral device is therefore a solid alternative to ACDF or ACDP.

Figure 1. NDI Treatment Effects after 2 years



Presentation #8

A Comparison of Three Different Positioning Techniques on Surgical Corrections and Post-Operative Alignment in Cervical Deformity Surgery

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Introduction: Cervical deformity surgery involves various methods to achieve sagittal alignment objectives. Instrumentation type, surgical approaches, interbody grafts and osteotomies can be used to achieve surgical goals. Furthermore, patient positioning may impact ultimate sagittal correction. To our knowledge, the effect of different patient positioning methods on sagittal alignment correction after cervical deformity surgery has not been studied. The purpose was to examine the differences in sagittal alignment correction between three positioning methods used in cervical deformity surgery.

Methods: A review of a prospective multicenter cervical deformity database was performed. Inclusion criteria were: pre- and post-op lateral radiographs, intraop positioning data, posterior approach (with and without anterior) and UIV at C6 or above. Patients with Grade 5, 6 or 7 osteotomies were excluded. Positioning groups were Mayfield (M), Bivector traction (BV) and Halo (H). Pre- and post-op sagittal parameters were analyzed. Segmental changes were analyzed using the Fergusson method. Significance was defined as a=0.05.

Results: 80 (58% female) of 153 potential subjects were included. Mean age was 60.6±10.5 (range 31-83) and mean BMI 29.2±8.0 (17-58). Positioning groups were 48M, 20BV, and 12H. No differences existed in baseline demographics, baseline cervical sagittal radiographic parameters, primary vs revision, UIV levels or postoperative alignment between groups. Mean cohort postoperative C2-C7 lordosis was 7.8°±14 and C2-C7 SVA was 34.1mm±15. BV had the largest number of levels fused (BV 13.8, H 8.9, M 8.9, P<0.004). There was no difference in pre-post difference of T1S, C2-C7 lordosis, C2-C7 SVA, TS-CL, C2-T3 lordosis or C2-T3 SVA between groups (P>0.05). No difference in pre-op sagittal flexibility existed between groups (P>0.05). There was no difference in postop alignment parameters between groups (P>0.05). A trend toward smaller postop C2-T3 SVA (mm) was observed in H, however, failed to reach significance (H 58, BV 73, M 84, P=0.053) Examining all groups, the majority of segmental correction was achieved at C4-5-6 (Mean 6.9°±11) with no differ-

Presentation #8 (cont.)

ence between groups (*P*>0.05). M had larger segmental correction at C3-4-5 than H and BV, but was not significantly different (M 7.4°, H 1.9°, BV 0.6°, *P*=0.054). Alternatively, BV had significantly more segmental correction at C7-T1-T2 (BV 4.2°, M 0.3°, -1.7°, *P*<0.027) [Figure 1]. No significant correlations existed between number of levels fused and segmental correction (Pearson *r*, *P*>0.05).

Conclusions: Patient positioning does not appear to affect the amount of correction or ultimate alignment in cervical deformity procedures. All positioning methods achieve the majority of segmental correction through C4-5-6 and BV appears to have the largest corrective abilities at the cervico-thoracic junction. These findings are important to consider when planning cervical deformity procedures.

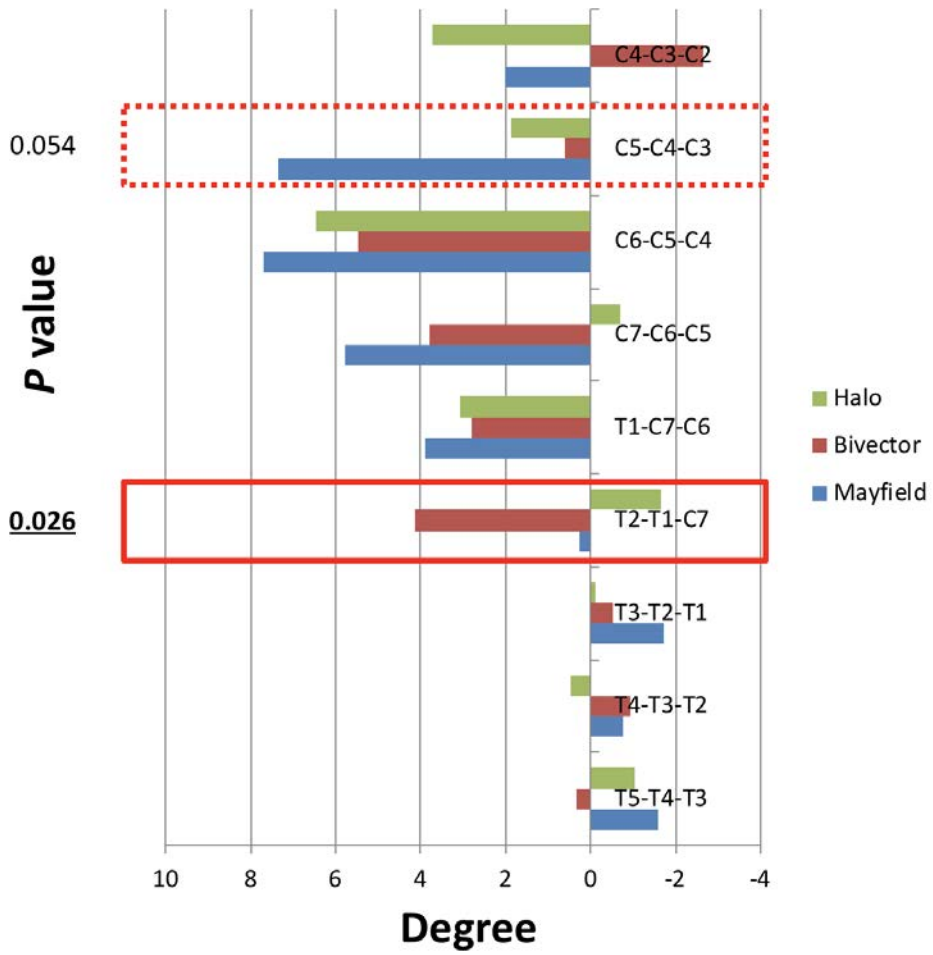

Figure 1: Comparison of segmental correction between the three different intra-operative position.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #9

The Effect of Local Versus Intravenous Steroids on Dysphagia and Dysphonia Following Anterior Cervical Discectomy and Fusion (ACDF): 1-Year Data from a Single-Blinded, Prospective, Randomized Control Trial

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Background: Dysphagia and dysphonia are the most common post-operative complaints following anterior cervical discectomy and fusion (ACDF). While most post-surgical dysphagia is mild and transient, severe dysphagia can have profound effects on overall health and surgical outcomes. Severe dysphagia places the patient at higher risk for dehydration, aspiration, and death. The purpose of this study was to compare the efficacy of local to intravenous (IV) steroid administration during ACDF on post-operative dysphagia and dysphonia.

Methods: This was a single-blinded, prospective, and randomized clinical trial. 75 patients undergoing ACDF with cervical plating were randomized to 3 groups: control (no steroid), IV steroid (10mg of IV dexamethasone during closure), or local steroid (40mg of local triamcinolone). Patient-reported outcomes measures were collected for dysphagia, dysphonia, and neck pain post-operatively for 1-year.

Results: Patient demographics were not significantly different (**Table 1**). Day 1 post-operative patient outcomes scores showed significantly lower scores in dysphonia (p=0.015) and neck pain (p=0.034) in the local steroid group compared to the control and IV steroid groups. At 2 weeks post-operative, the local steroid cohort showed significantly decreased incidence in severe dysphagia (Bazaz: moderate/severe, p=0.050; Eat-10:severe dysphagia, p=0.027) compared to the control and IV steroid groups (**Table 1, Figure 1**). Both steroid groups had significantly less severe dysphagia when compared to the control group at the 6-week and 3-month time points. At 1-year post-operative, both steroid groups had significantly reduced dysphagia rates (p=0.014) when compared to the control group.

Conclusion: Both local and intravenous steroid administration after cervical plating in ACDF surgery yield better patient-reported outcomes for dysphagia when compared to controls. This is particularly evident in the reduction of patients reporting fewer severe dysphagia symptoms after ACDF with local steroid application during the first 2 post-operative weeks. Future studies should attempt to stratify dysphagia when reporting outcomes related to anterior cervical surgery.

Presentation #9 (cont.)

Table 1: Dysphonia, Dysphagia, & Neck Pain Patient Reported Outcomes After ACDF by Treatment Arm

	Control Group	IV Steroid Group	Local Group	p - value
Pre-operative				
Patients (#)	21	25	29	
Gender	Male: 11 Female: 10	Male: 14 Female: 11	Male: 15 Female: 14	
Age (avg. years)	54.0	51.6	55.6	0.522
Number of Levels Fused	1-Level: 12 (57.1%) 2-Level: 8 (38.1%) 3-Level: 1 (4.8%)	1-Level: 12 (48.0%) 2-Level: 13 (52.0%) 3-Level: 0 (0.0%)	1-Level: 14 (48.3%) 2-Level: 12 (41.4%) 3-Level: 3 (10.3%)	0.351
Bazaz: mild/moderate/severe (%)	4.8%	0.0%	6.9%	0.495
Bazaz: moderate/severe (%)	0%	0%	0%	N/A
Eat-10: dysphagia (%)	9.5%	16.0%	10.3%	0.820
Eat-10: severe dysphagia (%)	0%	0%	0%	N/A
Abnormal VHI-10 (%)	4.8%	4.0%	3.4%	1.000
VAS: neck pain (median [IQR])	8.0 [6.0, 9.0]	8.0 [6.0, 9.0]	7.0 [4.0, 9.0]	0.328
NDI (mean % [SD])	40 [19]	34 [18]	35 [19]	0.597
1 Day Post-op				
Patients (#)	21	25	28	
Bazaz: mild/moderate/severe (%)	61.9%	44.0%	50.0%	0.494
Bazaz: moderate/severe (%)	33.3%	24.0%	7.1%	0.053
Eat-10: dysphagia (%)	76.2%	68.0%	60.7%	0.552
Eat-10: severe dysphagia (%)	38.1%	32.0%	17.9%	0.273
Abnormal VHI-10 (%)	9.5%	20.0%	0.0%	***0.015**
VAS: neck pain (median [IQR])	7.0 [6.50, 9.00]	6.0 [3.00, 9.00]	6.00 [3.00, 7.00]	***0.034**
NDI (mean % [SD])	27 [14]	28 [16]	27 [18}	0.955

Presentation #9 (cont.)

2 Weeks Post-op				
Patients (#)	20	25	29	
Bazaz: mild/moderate/severe (%)	30.0%	16.0%	13.8%	0.392
Bazaz: moderate/severe (%)	15.0%	16.0%	0.0%	***0.050**
Eat-10: dysphagia (%)	50.0%	48.0%	27.6%	0.188
Eat-10: severe dysphagia (%)	20.0%	16.0%	0.0%	***0.027**
Abnormal VHI-10 (%)	15.0%	16.0%	3.4%	0.225
VAS: neck pain (median [IQR])	6.0 [5.00, 8.00]	4.0 [3.00, 6.00]	4.0 [3.00, 6.00]	***0.037**
NDI (mean % [SD])	31 [20]	24 [15]	20 [16]	0.152
6 Weeks Post-op				
Patients (#)	21	23	29	
Bazaz: mild/moderate/severe (%)	28.6%	17.4%	6.9%	0.116
Bazaz: moderate/severe (%)	23.8%	8.7%	0.0%	***0.009**
Eat-10: dysphagia (%)	38.1%	34.8%	17.2%	0.226
Eat-10: severe dysphagia (%)	28.6%	0.0%	0.0%	***<0.001**
Abnormal VHI-10 (%)	9.5%	8.7%	3.4%	0.608
VAS: neck pain (median [IQR])	5.0 [3.00, 8.00]	4.0 [2.00, 5.50]	5.0 [3.00, 7.00]	0.270
NDI (mean % [SD])	23 [19]	21 [15]	24 [19]	0.844
3 Months Post-op				
Patients (#)	20	23	29	
Bazaz: mild/moderate/severe (%)	15.0%	13.0%	13.8%	1.000
Bazaz: moderate/severe (%)	15.0%	0.0%	0.0%	***0.019**
Eat-10: dysphagia (%)	20.0%	8.7%	6.9%	0.318
Eat-10: severe dysphagia (%)	10.0%	0.0%	0.0%	**0.074**
Abnormal VHI-10 (%)	10.0%	4.3%	0.0%	0.183
VAS: neck pain (median [IQR])	4.5 [1.75, 7.00]	3.0 [1.00, 4.00]	3.0 [2.00, 5.00]	0.238
NDI (mean % [SD])	14.6 [40]	11.1 [23.3]	10 [23.5]	0.703

Presentation #9 (cont.)

6 Months Post-op				
Patients (#)	19	24	29	
Bazaz: mild/moderate/severe (%)	15.8%	8.3%	13.8%	0.741
Bazaz: moderate/severe (%)	5.3%	0.0%	0.0%	0.264
Eat-10: dysphagia (%)	21.1%	8.3%	13.8%	0.526
Eat-10: severe dysphagia (%)	0.0%	0.0%	0.0%	N/A
Abnormal VHI-10 (%)	9.5%	8.7%	3.4%	0.608
VAS: neck pain (median [IQR])	5.0 [3.00, 8.00]	4.0 [2.00, 5.50]	5.0 [3.00, 7.00]	0.270
NDI (mean % [SD])	23 [19]	21 [15]	24 [19]	0.844
1 Year Post-op				
Patients (#)	19	23	29	
Bazaz: mild/moderate/severe (%)	14.3%	0%	3.4%	0.094
Bazaz: moderate/severe (%)	4.8%	0.0%	3.4%	0.739
Eat-10: dysphagia (%)	23.8%	0%	6.9%	***0.014**
Eat-10: severe dysphagia (%)	9.5%	0.0%	0.0%	0.076
Abnormal VHI-10 (%)	9.5%	4.0%	0.0%	0.186
VAS: neck pain (median [IQR])	4.0 [1.00, 6.00]	2.0 [1.00, 4.00]	1.0 [1.00, 5.00]	0.653
NDI (mean % [SD])	22.2 [33.6]	4.0 [18]	6.0 [26]	0.263

*indicates that the p-value reached clinical significance ($p < 0.05$) set value for significance)

**** P-values shown are related to a 3-way analysis**

IQR, Interquartile range; SD, standard deviation; % indicates present of patients in given cohort with abnormal patient reported outcomes, (Eat-10 dysphagia score > 3, Eat-10 severe dysphagia score > 15, Abnormal VHI-10 score > 11, Bazaz: mild/moderate/severe indicates that a Bazaz Classification of mild, moderate, or severe dysphagia considered abnormal, Bazaz: moderate/severe indicates that a Bazaz Classification of moderate or severe dysphagia considered abnormal)

Presentation #9 (cont.)

Figure 1: Graphical Representation of Patient Outcomes

Presentation #10

What are the Important Predictors of Postoperative Functional Recovery in Patients with Cervical OPLL? Results of a Multivariate Analysis

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Introduction: Ossification of the posterior longitudinal ligament (OPLL) is defined by pathological ossification within the posterior longitudinal ligament. OPLL can reduce the space available for the spinal cord, cause myelopathy and radiculopathy. Several factors related to the morphology, severity and distribution of OPLL have been defined using computed tomography (CT), radiography, and magnetic resonance imaging (MRI). These include the classification system proposed by the Japanese Ministry of Health, Labor and Welfare (continuous, segmental, mixed or circumscribed), the shape of ossification (hill- or plateau- shaped), the extent of OPLL relative to a K-line (positive or negative), and the canal occupying ratio. These factors may be associated with myelopathy severity, influence treatment decisions, and predict functional outcomes. It is unclear, however whether these factors affect functional outcomes following cervical decompression surgery because of few studies conducting multivariate analysis regarding functional recovery in cases with OPLL. The purpose of this study was to investigate the association between various features of cervical OPLL and postoperative functional recovery using multivariate analysis.

Methods: This was a retrospective cohort study of 142 OPLL patients who had undergone laminoplasty; 135 had complete radiographical data and were followed up for ≥2 years. The following OPLL characteristics were compared between patients with “good” and “poor” outcomes [Japanese Orthopedic Association (JOA) recovery rate ≥50% and <50%, respectively]: number of ossified levels, OPLL classification, ossification shape, K-line, canal-occupying ratio, and increased MRI signal intensity. Presence of diabetes mellitus (DM), C2-7 lordotic angle and C2-7 sagittal vertical axis (SVA) were also compared. Risk factors associated with poor surgical outcomes were identified by stepwise multivariate logistic regression analysis. A p <0.05 was considered to be a statistically significant difference.

Results: Pre- and postoperative (2 years following surgery) JOA scores were 10.6 ± 2.9 and 14.1 ± 2.2 respectively, indicating significant improvement following laminoplasty ($p<0.001$). The average JOA recovery rate was 53.4 ± 34.7%, with 81 (60.0%) and 54 (40.0%) patients in the better and poorer neurological outcome groups, respectively. The canal occupation ratio of OPLL equal to or less / greater than 60% were 117 (86.7%) and 18 (13.3%) patients, respectively. In the comparison between patients with better and poor JOA recovery rates, an occupying ratio greater than 60% was significant ($p<0.003$), whereas age, gender, presence of DM, number of ossification levels, K-line state (+/-), JOA welfare classification, shape (hill- or plateau-shaped), cervical alignment and increased signal intensity change on MRI were not significant factors. In the stepwise logistic regression analysis, an occupation ratio greater than 60% was identified as a significant factor for poor postoperative neurological outcome [relative risk: 4.82, 95% confidential interval: 1.61-14.46, $p=0.005$].

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #10 (cont.)

Conclusions: This multivariate analysis demonstrated a large size OPLL (occupying ratio > 60%) was associated with a risk of poor neurological recovery roughly 5 times greater **(Figure 1 and 2)**, and anterior approach or posterior decompression with fusion surgery should therefore be considered.

Figure 1

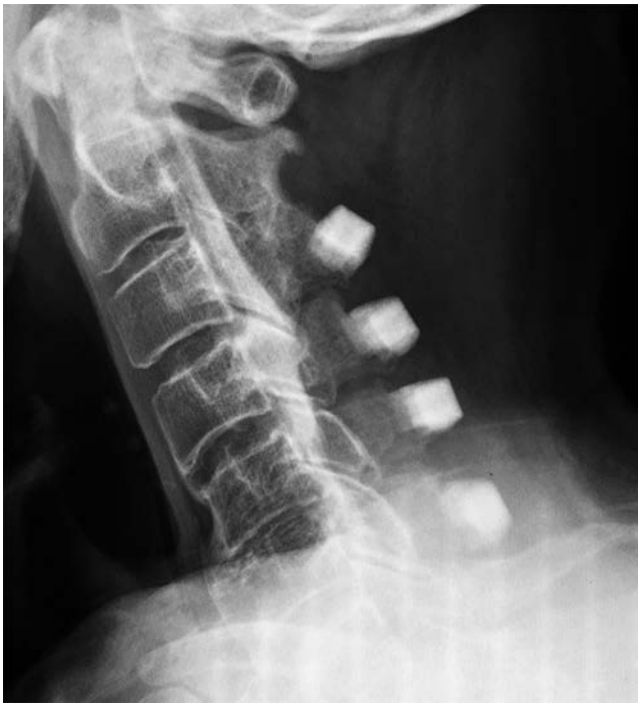
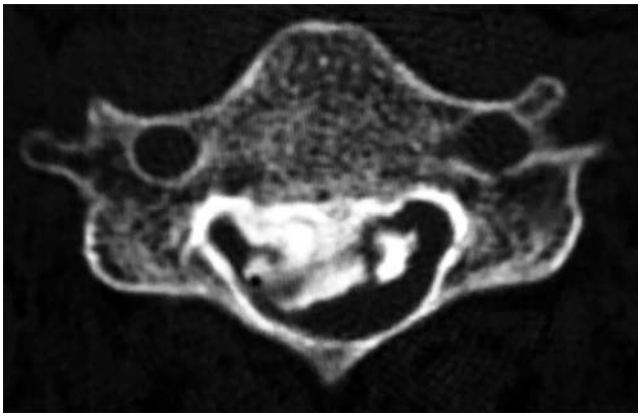


Figure 2



Presentation #11

Quantitative Risk Factor Analysis of Post-Operative Dysphagia After Anterior Cervical Discectomy and Fusion (ACDF) Using the Eating Assessment Tool-10 (EAT-10)

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Introduction: Anterior cervical discectomy and fusion (ACDF) is one of the most common spinal operations performed in the United States[1]. Dysphagia is a common post-operative complication in patients undergoing ACDF[2]. The Eating Assessment Tool-10 (EAT-10) is a self-administered, symptom-specific 10-item clinical instrument to document dysphagia symptom severity[3]. This study aims to analyze the risk factors contributing to dysphagia after ACDF using EAT-10 as a quantitative measure of dysphagia.

Methods: This IRB approved study utilized a retrospective chart review of 163 patients from July 2013 to October 2017 who underwent ACDF at a single institution and prospectively completed EAT-10 surveys pre and postoperatively. Exclusion criteria included patients with documented pre-operative dysphagia or scores ≥ 3 on their pre-operative EAT-10 questionnaire indicating an abnormal score at baseline. EAT-10 scores were collected preoperatively and at postoperative day 1, postoperative day 14, 1 month, 3 month, 6 months and 12 months after surgery. Preselected risk factors were abstracted from the patients chart. Univariate analyses was performed to identify candidate variables that had a statistical correlation ($p<0.1$) with abnormal EAT-10 scores (≥3) at each time point. Two tailed t-test was used for continuous variables and chi squared test was used for categorical variables. Multivariate logistic regression was then utilized to identify risk factors that were independently correlated with abnormal EAT-10 scores at each time point with significance set to $p < 0.05$.

Results: Female gender, younger patients and increased OR time was associated with increased rates of dysphagia in the early postoperative period (Table 1). History of obstructive sleep apnea, history of asthma, increased ASA score and a larger number of spinal levels included in the surgery were correlated with increased dysphagia in the later postoperative periods. Female gender was the only risk factor that was positively correlated with increased rates of dysphagia in multiple times points across the early and late postoperative periods. Patients with mild dysphagia at post-op day 1 had their average EAT-10 scores normalize by post-op week 2, whereas patients with severe dysphagia did not demonstrate normalize their average EAT-10 scores until post-op month 6 (Figure 1).

Conclusions: Dysphagia is a well-known, common complication in patients undergoing ACDF. This is the first study to our knowledge utilizing the EAT-10 questionnaire to quantify the degree each potential risk factor poses to dysphagia development at multiple postoperative time points. Factors associated with longer-term dysphagia seem to be more associated with pre-existing medical co-morbidities of the patients. Understanding risk factors that may correlate with increased rates of dysphagia has the potential to improve preoperative patient counseling, setting of patient expectations, and identify patients that may benefit from intraoperative steroids. Postoperatively, utilization of the EAT-10 questionnaire can stratify

Presentation #11 (cont.)

patients with mild and severe dysphagia as these patient populations have differing time courses for recovery. Quantitative scoring also allows a more granular method of tracking dysphagia improvement and may prove beneficial in reassuring patients in the outpatient setting.

Sources:

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Time	*OR*	*95% CI*	*P-value*
Post-Op 1 Day			
Age	1.04	1.01-1.07	0.007
Female Gender	2.98	1.46-6.09	0.003
OR Time	1.02	1.01-1.03	0.016
Post-Op 2 Weeks			
Use of Topical Steroids	0.35	0.17-0.73	0.022
Post-Op 6 Weeks			
Hx of TIA/Stroke	5.83	1.02-32.23	0.047
Hx of Post-op Nausea/vomiting	3.92	1.09-14.05	0.036
Surgical Side (Right)	0.20	0.04-0.95	0.043
C5-C6 involvement	0.33	0.13-0.81	0.015
Post-Op 3 Months			
Hx of OSA	6.60	1.63-26.70	0.008
Hx of Asthma	7.10	1.61-31.27	0.010
Post-Op 6 Months			
Female Gender	3.53	1.05-11.87	0.042
Post-Op 12 Months			
Female Gender	10.45	1.10-99.39	0.041
Levels of Surgery	4.51*	1.12-18.20	0.034
ASA Score	7.97*	1.57-40.40	0.012

*Represents each unit increase

Table 1. Risk factor analysis across multiple time points post-operatively.

Presentation #11 (cont.)

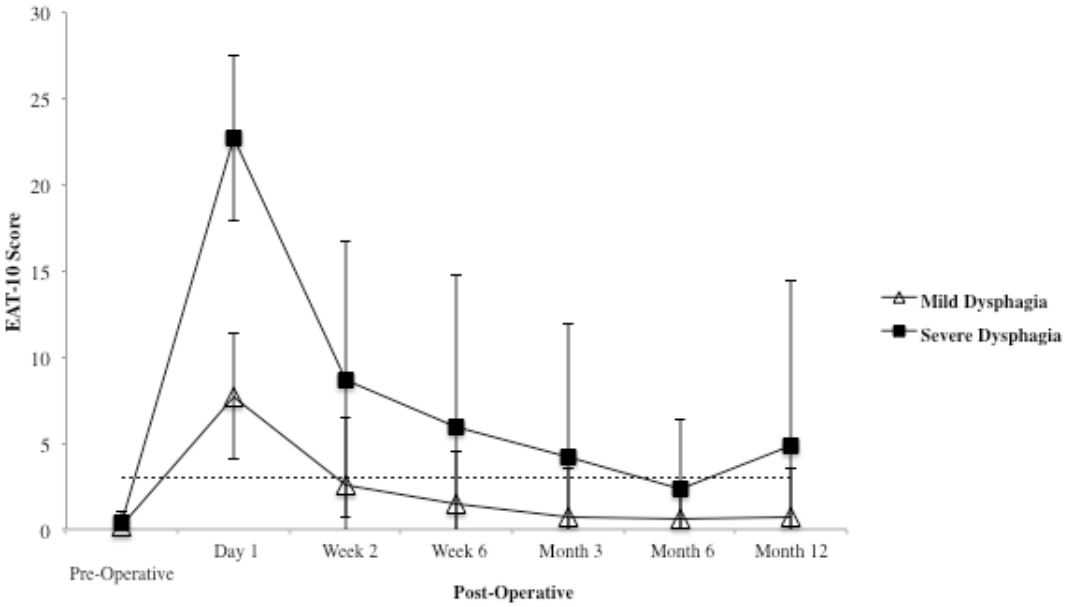

Figure 1. Mean EAT-10 Scores for patients with mild and severe dysphagia over multiple post-operative time points.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #12

Reoperation for Late Neurological Deterioration After Laminoplasty in Cases with Degenerative Cervical Myelopathy: Comparison Between Cervical Spondylosis and Ossification of Posterior Longitudinal Ligament

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Introduction: Cervical laminoplasty is a standard technique for patients with cervical myelopathy attributable to multilevel spinal stenosis caused by cervical spondylosis (CSM) or ossification of the posterior longitudinal ligament (OPLL). The surgical outcomes over 10 years has been reported to be satisfactory. While reoperation for late neurological deterioration following laminoplasty was sometimes experienced, little information is available in the existing reports on long-term follow up after laminoplasty. The purpose of this study was to investigate the rate needing reoperation of cervical laminoplasty and elucidate the reasons of neurological deterioration by comparing CSM and OPLL.

Methods: This was a retrospective cohort study of patients with cervical French-door laminoplasty for cervical myelopathy that included 623 patients, with an average follow-up duration of 6.1 years (range 2-15 years). The clinical results were evaluated using the Japanese Orthopaedic Association (JOA) score. Reoperations for late neurological deterioration was investigated and other reoperation for infection, epidural hematoma, wound dehiscence and C5 palsy at immediate postoperative period was excluded from the current analysis. Kaplan-Meier survival analysis was performed for the estimation needing reoperation, and the difference requiring reoperation was investigated between CSM and OPLL by using log rank test.

Results: The primary diagnosis was CSM and OPLL in 522 (83.8%) and 101 (16.2%) patients. The preoperative JOA score (9.9 ± 3.2 points) was recovered at 1 year post-surgery (13.5 ± 2.5 points) and maintained at 10 years post-surgery (13.3 ± 2.3 points). During the follow-up period, 10 patients required reoperation (1.6%): 1.3% in CSM and 3.0% in OPLL. There was no significant difference regarding the rate needing reoperation between CSM and OPLL by using log rank test ($p = 0.38$). The mean duration of reoperation was 4.7 ± 3.2 years following primary surgery in patients with CSM. The predicted risk of reoperation in CSM was 0.6% (95% CI 0.52%–0.68%) at 5 years and 2.4% (95% CI 2.37%–2.43%) at 10 years. The reasons of reoperation were C5 palsy due to new-onset disc herniation in 5 cases, severe radiculopathy in 1 case and restenosis due to instability after laminoplasty in 1 case. Anterior discectomy and fusion was performed in cases with C5 palsy or radiculopathy, while laminectomy was performed in the remaining 1 case. On the other hand, the predicted risk of reoperation in OPLL was 0.1% (95% CI 0.08%–0.12%) at 4 years, and the period at reoperation was longer in OPLL (the mean duration of reoperation: 10.0 ± 5.7 years, $p=0.13$) compared with CSM. The reason of reoperation was enlargement of OPLL in all 3 cases, whose OPLL was categorized in continuous type. Posterior laminectomy and fusion was performed in all cases.

Presentation #12 (cont.)

Conclusions: Although clinical outcome following laminoplasty was favorable in majority of cases, reoperation for late neurological deterioration was needed in 1.3%. The timing of reoperation was earlier in CSM and majority of reasons was C5 palsy. On the other hand, the reoperation was performed later in OPLL and enlargement of OPLL was the main cause.

Presentation #13

Complications After Instrumented Posterior Occipitocervical Fusion for Upper Cervical Spine Trauma

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Introduction: Traumatic injuries involving the upper cervical spine are complex injuries with a variety of treatment challenges that require a multi-disciplinary approach. OCF remains the treatment of choice for unstable craniocervical junction injuries and can be successful in carefully selected patients; however, both orthopaedic and medical complications following this procedure are less-well documented despite their potentially devastating consequences. The purposes of this study were to (1) evaluate the types and frequencies of orthopaedic and medical complications following OCF and (2) to identify potential predisposing risk factors for these complications.

Materials/Methods: After IRB approval, the medical records of 32 consecutive patients who underwent OCF for traumatic injuries from 2010-2016 were retrieved for review. Demographic data, comorbidities, smoking status, injury diagnoses, concomitant injuries, surgical procedural data, postoperative bracing information, and postoperative radiographic studies were reviewed as part of this study. Preoperative, intraoperative, and postoperative complications along with fusion rates were evaluated for each patient. Three patients who died very soon after their surgeries due to traumatic brain injuries (TBIs) were excluded from statistical analysis, but were included in complications reporting. Pearson correlations coefficients were performed to identify statistical relationships between single independent and dependent variables. Multiple logistic regressions (ridge and probit regressions) were performed to identify independent risk factors for the occurrence of complications after OCF. Regression coefficients are reported adds odds ratios (ORs). Two-tailed p-values of <0.05 were considered statistically significant.

Results: Twenty-nine consecutive patients (14 male, 15 female) with a mean age of 52.7 years (range, 12-95 years) and a mean body mass index (BMI) of 28.1 kg/m^2 (range, 14.6-41.9 kg/m^2) who underwent OCF for traumatic upper cervical spine injuries were included. Additional demographic information along with injury types and surgical variables are provided in **Table 1**. Thirteen of 29 patients (44.8%) experienced a total of 21 complications during the course of their treatment (**Table 2**). Complications included airway compromise/dysphagia (8 cases; 61.5%), infection (6 cases; 46.1%), loss of fixation (3 cases; 23.1%), and cardiovascular events (4 cases; 30.8%). Statistically significant correlations were identified between the occurrence of at least one complication and the polytraumatic injuries (R=0.48), complete spinal cord injuries (R=0.37), lower ISS scores (R=0.48), and postoperative halo placement (R=0.51; p=0.009, 0.044, 0.008, and 0.004 respectively). Postoperative airway compromise was significantly correlated with unstable type 2 odontoid fractures (R=0.47; p=0.009). Multiple logistic regression revealed a significant relationship between lower ISS scores and the occurrence of any complication (OR=1.60; p=0.043); however, postoperative Halo placement was found to be significantly associated with post-

Presentation #13 (cont.)

operative dysphagia/airway compromise (OR=1.62; p=0.028) independent of ISS scores.

Conclusion: Thirteen of 29 patients (44.8%) experienced a total of 21 complications, and airway compromise was the most frequent (8/13 patients; 61.5%). Although lower ISS scores were significantly correlated the occurrence of any complication, postoperative halo placement was specifically found to be an independent predictor of postoperative airway compromise or dysphagia independent of ISS scores. Future comparative studies should closely evaluate the relationships between halo placement, injury severity, and the types of complications encountered thereafter.

Table 1: Summary of patient demographics, injury types, and surgical variables.

Total number of patients, n	32
Male gender, n (%)	17 (31.2)
Mean Age (SD)	52.7 (23.7)
Mean BMI (SD)	28.1 (6.7)
Presence of DM, n (%)	5 (15.6)
Presence of HTN, n (%)	10 (31.3)
Smokers, n (%)	6 (20.0)
Mechanisms of Injury	
MVC, n (%)	18 (56.3)
Fall from standing, n (%)	14 (43.8)
Injury Severity Scores	
Mean ASA Class (range, SD)	3.3 (1-4, 0.8)
Mean ISS (range, SD)	39.7 (27-75, 16.6)
Mean GCS (range, SD)	10.5 (3-15, 5.4)
ASIA Status, n (%)	
ASIA Grade A	6 (18.8)
ASIA Grade B	1 (3.1)
ASIA Grade C	4 (12.5)
ASIA Grade D	1 (3.1)
ASIA Grade E	20 (62.5)

Injury Types, n (%)	
Atlantoaxial Instability	3 (9.4)
C-2 Body Fracture, unstable	4 (12.5)
Occipitocervical Dissociation	13 (41.0)
Odontoid Fracture, Type 2, Unstable	6 (18.8)
Odontoid Non-Union[a]	4 (12.5)
Subaxial Extension-Distraction Injury	2 (6.3)
Traumatic Brain Injuries	3 (9.4)
Surgical Variables (range, SD)	
Mean Operative Time, minutes	203.5 (110-618, 94.3)
Mean Blood Loss, mL	134.4 (20-700, 121.4)
Mean Levels of Instrumentation	4.3 (3-9, 0.5)
Fixation Hardware, n (%)	
Interlaminal Screws	10 (31.3)
Pars Screws	15 (46.9)
Pedicle Screws	3 (9.4)
Bone Graft Usage, n (%)	
Autograft (Iliac Crest)	15 (46.9)
Allograft	17 (53.1)
DBM	5 (15.6)
Cancellous	18 (56.3)
Commercial Type I Collagen Scaffold	5 (15.6)

[a] Each odontoid non-union occurred following non-operative treatment for acute odontoid fractures.

Table 2: Summary of adverse events within 90 days of surgery.

Adverse Event	**Total, n (%)**[†]	**With Halo, n**	**With Hard Collar, n**	**No Brace, n**
Airway Compromise[a]	8 (61.5)	6	1	1
Infection[b]	6 (46.1)	4	1	1
Loss of Fixation[c]	3 (23.1)	1	0	2
Cardiovascular Event[d]	4 (30.8)	0	2	2
Death[e]	*3*	*1*	*0*	*2*
Totals	**21**	**12**	**4**	**6**

[†] No postoperative complications were identified for patients who were placed in a soft collar postoperatively.

[a] Airway compromise (including those with dysphagia) most commonly occurred due to postoperative laryngeal/pharyngeal edema; those with airway compromise were re-intubated in most cases (one case required emergency cricothyroidotomy).

[b] Two patients developed sepsis for reasons unrelated to the cervical spine injury or proce-

Presentation #13 (cont.)

dure (blunt abdominal trauma with subsequent asplenia). Pneumonia was the most common source of postoperative infection related to cervical spine trauma in this cohort.

[c] For one patient, hardware removal was performed at 14 months after the index procedure due to symptomatic hardware loosening, at which point the fusion mass was found to be completely healed. Two other patients were found to have asymptomatic screw cut-out at postoperative follow-up, although successful fusion was achieved without any further complications. All other patients who survived their injuries were found to have fused successfully through radiographic evaluation.

[d] There was one pulmonary embolism, 3 cardiac arrests (each due to neurologic compromise resulting from the cervical spine injury), and one stroke involving the right middle cerebral artery.

[e] All three patients died as a result of traumatic brain injuries sustained at the time of their initial injuries; therefore, these cases were excluded from the analysis of postoperative complications.

Presentation #14

Predicting the Occurrence of Post-Operative Distal Junctional Kyphosis in Cervical Deformity Patients

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Introduction: Distal junctional kyphosis (DJK) development after cervical deformity (CD) corrective surgery is a growing concern for surgeons and patients. Few studies have investigated baseline and procedural risk factors that predict the occurrence of DJK. The aim of this study was to predict DJK development after CD corrective surgery using predictive modeling.

Methods: Retrospective review of a prospective multicenter CD database. Patients>18yr meeting at least one of the following radiographic criteria: cervical kyphosis (C2-7 Cobb angle >10°), cervical scoliosis (coronal Cobb angle >10°), positive cervical sagittal imbalance (C2-C7 sagittal vertical axis >4cm), or horizontal gaze impairment (chin-brow vertical angle >25°). DJK was defined as the development of an angle <-10° from the end of fusion construct to the 2nd distal vertebra, as well as a change in this angle by <-10° from baseline to post-operative. Baseline demographic, clinical and surgical information were used to predict the occurrence of DJK using generalized linear modeling both as one overall model and as sub-models using 1) baseline demographic and clinical predictors and 2) surgical predictors.

Results: 117 CD patients (60.7±10.6 years, 61.4% female, BMI: 29.8±8.5kg/m^2) undergoing cervical deformity surgery were included (7.2±3.6 levels, 16.3% three-column osteotomy use, Approach: 45.3% Posterior, 19.7% Anterior, 35% Combined). At any post-operative visit up to 1-year, 23.1% of CD patients developed DJK. There was no difference in early to late post-operative alignment in any parameters. DJK was predicted with high accuracy with a combined model using baseline demographic, clinical, and surgical factors by the following factors: pre-operative neurologic deficit, use of transition rod, and C2-C7 lordosis <-12°, TS-CL >31° and cSVA>54mm (AUC=87%). In the model using only baseline demographic and clinical predictors of DJK, presence of comorbidities (most commonly diabetes, hypertension, and depression), presence of baseline neurologic deficit, and high pre-operative C2-T3 angle were included in the final model (AUC=87%). The final model using only surgical predictors for DJK included (AUC=81%): combined approach (OR: 7.9, CI: 1.7-37.1), posterior UIV below C4 (OR: 0.59, CI: 0.33-1.1), use of transition rod (OR: 2.8, CI: 0.8-10.2),

Presentation #14 (cont.)

lack of anterior corpectomy (OR: 0.5, CI: 0.2-1.1), more than three posterior osteotomies (OR: 1.4, CI: 1.1-1.8), and performance of a three-column osteotomy (OR: 2.9, CI: 0.8-11.3).

Conclusions: DJK was predicted with high accuracy using a combination of neurologic, surgical, and primarily radiographic factors, most markedly three-column osteotomy use, combined approach, TS-CL>31° and cSVA>54mm. Pre-operative assessment and consideration should be given to these factors that are predictive of DJK to mitigate poor outcomes.

Presentation #15

Therapeutic Outcomes for Dropped Head Syndrome

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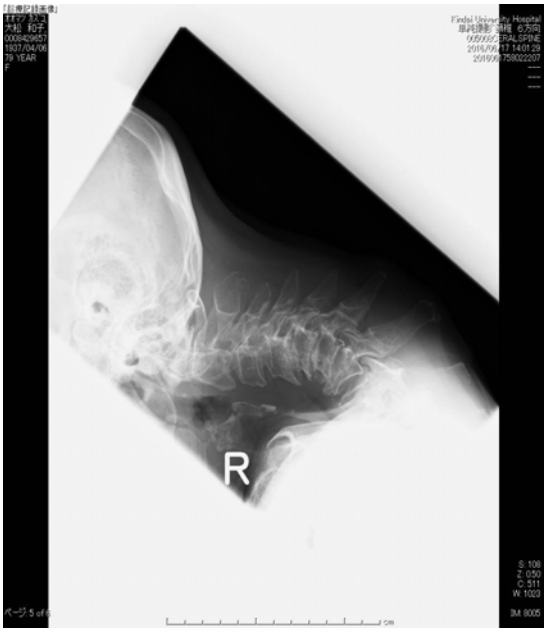
Purpose: Dropped head syndrome (DHS) is a rare clinical entity which is defined as a chin-on-chest deformity in the standing or sitting position, resulting from sagittal imbalance of the cervical region. DHS is reported to be accompanied by various types of neuromuscular diseases, however, defined diagnosis is occasionally difficult to obtain. Moreover, therapeutic outcome including non-operative and operative treatment is unknown. In the present study, we reported the clinical and radiological outcomes of these treatments for DHS.

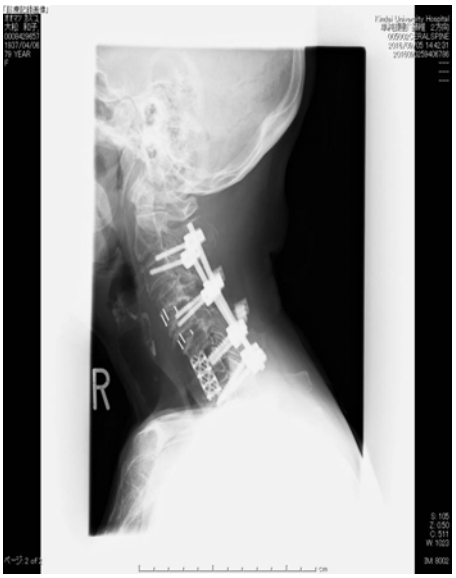
Materials/Methods: Thirty-one DHS patients [3 male and 28 female, with an average age of 75.2 years (range 35–88)] with a main complaint of horizontal gaze disorder were enrolled in this study. As non-operative treatment, soft collar was applied for 3 months, and pain killer was prescribed for the cases with neck pain. Consultant to neurologist was also considered. When non-operative treatments failed, we indicated the surgical intervention to the patients, and eleven cases who agreed with surgery underwent correction surgery using cervical pedicle screw. Four cases underwent posterior reconstruction surgery, and seven with rigid kyphosis required anterior release, cage insertion, and posterior fixation **(Figure)**. Spino-pelvic lateral radiographs in the standing position were taken of all patients. Parameters such as C2-7 angle, C2-7 SVA, and T1 slope were measured, and the parameter changes between pre- and post-operative radiographs were also examined. Complications such as spinal cord injury, C5 palsy, proximal/distal junctional kyphosis (PJK, DJK) non-union, and difficulty of swallowing were investigated.

Results: Non-operative treatments were effective on eight of 31 patients. All of 11 patients who underwent correction surgery were able to gaze horizontally after surgical intervention. No spinal cord injury was observed. Three transient C5 palsy, one DJK, and one transient difficulty of swallowing were found. No non-union was observed. Pre-/post-operative C2-7 angle (degree) and C2-7 SVA (mm) were; -35.9±21.1/8.6±7.6 and 56.7±20.4/27.6±17.0 respectively, and these changes showed statistical significance. On the other hand, Pre-/post-operative T1 slope (degree) was 23.4±19.3/27.1±9.8, and the change did not reach to statistical significance.

Conclusions: In the present study, we have indicated that non-operative treatment was successful in 26% of the patients. Because of the older age of the patients, several patients did not agree with surgical intervention, however, surgery brought good clinical and radiological outcomes with fewer complications **(Figure)**.

Presentation #15 (cont.)





Figure

Presentation #16

Postoperative Cervical Kyphosis After Correction of Adult Thoracolumbar Deformity: Is it Permanent?

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Introduction: Several studies have been reported with regard to cervical kyphosis after correction of adult spinal deformity, resulting from an effort to maintain upright alignment and horizontal gaze. However, there was a lack of evidence for postoperative cervical kyphosis after deformity correction. The aim of this study is to evaluate changes of postoperative cervical kyphosis during follow-up periods and to verify differences of cervical kyphosis according to the amount of correction in lumbar lordosis or sagittal balance.

Methods: A retrospective chart review was performed in our institution. Total 122 patients (female=102, mean age=69.2) with degenerative lumbar kyphosis who underwent thoracolumbar deformity correction with a minimum of 2-years follow-up were analyzed. Cervical, thoracic and lumbar lordosis or kyphosis were measured pre- and post-operatively. To evaluate influencing factors for change of cervical alignment, the patients were divided according to postoperative lumbar lordosis and sagittal alignment. The patients were categorized into 3 groups by postoperative pelvic incidence–lumbar lordosis (PI–LL<–10°:n=50, –10°< PI–LL<10°:n=43, PI–LL>10°:n=29) and C7 plumb line(C7PL<0 mm:n=29, 0<C7PL<50 mm:n=60, C7PL>50 mm:n=33), respectively. Cervical alignment was compared among each group. All parameters were measured at preoperative, immediately postoperative, and last follow-up periods. Correlation analyses among all parameters were also performed.

Results: Mean preoperative LL (1°) significantly improved immediately after surgery (–59°) and was maintained at the last follow-up (–54°). Mean preoperative C7PL (167 mm) significantly improved immediately after surgery (2 mm) and was maintained until the last follow-up (36 mm). Preoperative cervical lordosis and thoracic kyphosis changed from –21° and 3° to –10° and 21° immediately after surgery and slightly changed at the last follow-up (–16° and 25°). At the last follow-up, mean cervical lordosis showed no significant differences according to postoperative PI–LL (<–10°:–15.6±13.5°, –10°-10°:–14.6±12.1°, >10°:–18.7±11.8°) (p=0.375), but there were significant differences for cervical lordosis according postoperative C7PL (<0mm:–15.0±12.8°, 0-50mm:–15.0±11.1°, >50mm:–24.8±13.6°) (p=0.035). The patients with sagittal imbalance (C7PL>50mm) showed significantly higher cervical lordosis than other patients. In correlation analysis, cervical lordosis was not correlated with thoracic kyphosis immediately after the surgeries, but with thoracic kyphosis at the last follow-up.

Conclusion: Cervical kyphosis seems to deteriorate temporarily immediately after correction of adult thoracolumbar spinal deformity, but improves during the follow-up period. Particularly, postoperative cervical kyphosis was influenced by postoperative sagittal vertical axis, but not by amount of lumbar lordosis correction.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #16 (cont.)

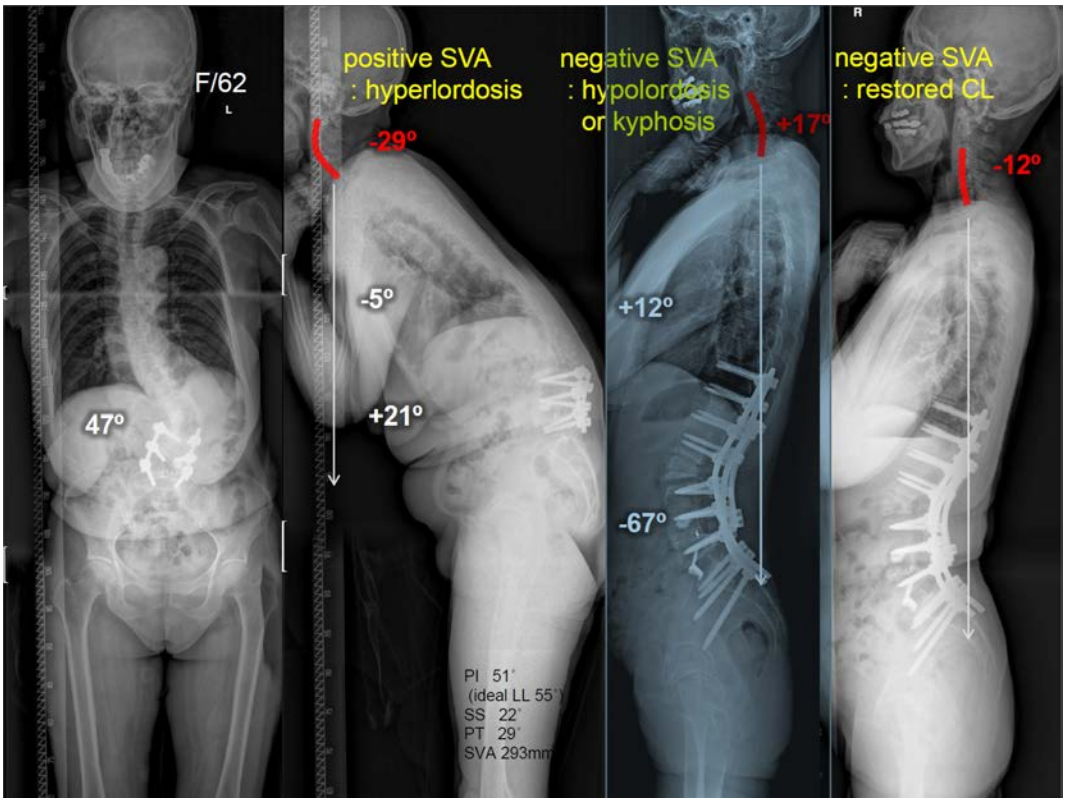

Figure 1. A representative case. A 62-year old female patient with adult spinal deformity shows immediate postoperative cervical kyphosis (kyphosis: 17°), but this cervical kyphosis was changed into a lordotic curvature at the last follow-up (lordosis: -12°).

Presentation #17

Surgical Outcomes in Rigid vs. Flexible Cervical Deformities

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Introduction: Cervical deformity patients have been shown to have severe disability and poor health status. Little is known about how patients with fixed cervical deformity compare to those with flexible malalignment in disability and surgical outcomes. This study aims to elucidate disability and surgical outcomes in patients with rigid deformities of the cervical spine.

Methods: A prospective database of operative CD patients was analyzed. Inclusion criteria were cervical kyphosis>10°, cervical scoliosis>10°, cSVA>4cm or chin-brow vertical angle>25°. Patients were categorized as having rigid CD if they had <10° change in CL between flexion and extension and were compared to flexible CD in terms of HRQL and surgical factors. Patients were subanalyzed based on the apex of their deformity: in the cervical (C) or the cervico-thoracic (CT) region.

Results: 127 patients met inclusion criteria including 32 rigid and 95 flexible CD patients. For the entire cohort, rigid CD was associated with worse pre-op alignment by TS-CL, T1S, cSVA, C2S, and cSVA ($p<.01$). Post-operatively, rigid CD had increased C2S (29.1 vs 22.2°) at 3 months and increased cSVA (47.1 vs 37.5) at 1 year ($p<.05$) compared to flexible CD. Rigid CD patients had more posterior levels fused (9.5 vs 6.3), less anterior levels fused (.01 vs 2.0), greater EBL (1036.7 vs 698.5), more use of 3CO (40.6% vs 12.6%), larger total osteotomy grade (6.5 vs 4.5) and mean osteotomy grade (3.3 vs 2.1) per level ($p<.05$). Rigid patients with C deformities had less anterior levels fused, more use of 3CO and decreased op-time ($p<.05$). For CT patients there were no differences in surgical parameters. There were no significant differences in baseline or postoperative HRQL, the rate of DJK or the rate of major and minor complications between rigid and flexible CD. For both rigid and flexible CD patients there were significant improvements from baseline to 1 year in NSR Neck (-2.4,

Presentation #17 (cont.)

-2.7), NDI (-8.4, -13.3), mJOA (0.1, 0.6), and EQ5D (0.01, 0.05) ($p<0.05$).

Conclusions: Patients with cervical deformity (CD) can have severe disability. Among 127 CD patients, deformities were classified as rigid or flexible. Rigid CD patients had worse baseline alignment but had similar impact on health-related quality of life (HRQL) measures. Patients with rigid deformities required longer fusions and higher osteotomy grades but they achieved similar improvements in HRQL without higher rates of complications. Patients with rigid cervical deformities have worse baseline cervical malalignment but are equally disabled when compared to those with flexible deformities. Rigid cervical deformities require greater osteotomy grades and more levels fused resulting in longer operative times and more blood loss. Despite more extensive surgeries, rigid cervical deformity patients have equivalent HRQL improvements.

Figure 1

Table: Rigid vs. Flexible Cervical Deformity

Surgical Parameters	Rigid (N = 32)	Flexible (N = 121)	p-Value
Mean Op Time	483.41	484.89	0.98
Mean EBL (mL)	1036.72	698.54	0.04
Mean Ant Levels Fused	1	2.05	0.01
Mean Post Levels Fused	9.53	6.32	<0.01
Mean # of Osteotomies	6.53	4.5041	0.033
Mean Osteotomy Grade	3.29	2.08	<0.01
3-Column Osteotomy (%)	40.6	12.6	<0.01
ReOperation Required (%)	12.50%	11.60%	0.89
DJK Incidence (%)	14.30%	24.20%	0.41
Minor Complications (%)	12.50%	9.50%	0.625
Major Complications (%)	3.10%	5.30%	0.622
HRQL Improvement			
	Rigid (N = 32)	Flexible (N = 121)	p-Value
NSR Neck Change (baseline to 1Y)	-2.4	-2.7	0.67
NDI Change (baseline to 1Y)	-8.4	-13.3	0.25
mJOA Change (baseline to 1Y)	0.11	0.62	0.44
EQ5D Change (baseline to 1Y)	0.01	0.05	0.051

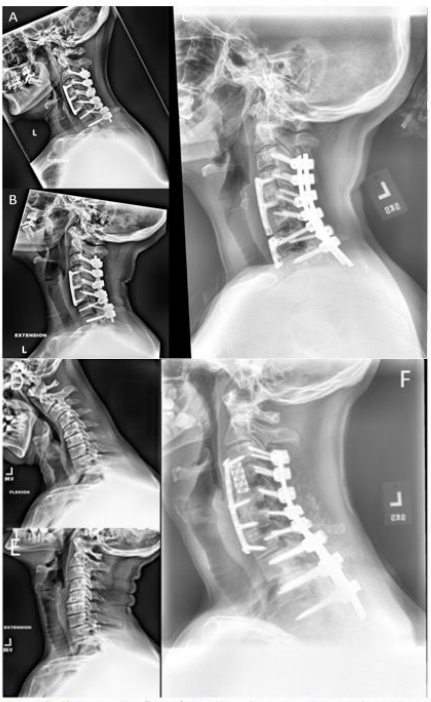

Figure 1 (A-C): Preoperative flexion/extension and postoperative x-rays in a patient with a rigid cervical deformity requiring a PSO at T1. (D-F): Preoperative flexion/extension and postoperative x-rays in a patient with a flexible cervical deformity requiring anterior/posterior fusion C3-T3.

Presentation #18

Cervical and Cervicothoracic Sagittal Alignment by Roussouly Thoracolumbar Subtypes in Asymptomatic Volunteers

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Introduction: Appropriate sagittal spinal alignment are dictated by a harmonious relationship between the cervical, thoracic, and lumbar spines. Comprehension of cervicothoracic alignment with respect to variations in thoracolumbar alignment is limited. This study aims to compare radiographic sagittal cervical alignment parameters of asymptomatic volunteers based on Roussouly's thoracolumbar sagittal alignment subtypes.

Methods: 120 asymptomatic adults were recruited. Radiographic measurements: PI, PT, SS, LL, orbital tilt, orbital slope, occipital slope, occipital incidence, occiput-C2 lordosis, C2-7 lordosis, CBVA, T1 slope, cervicothoracic alignment, T2-5 kyphosis, and C2-C7 SVA. Each patient was classified into one of four Roussouly types. Cervical alignment parameters were analyzed and compared between groups.

Results: Presented in Table 1. 87 individuals [male-23; female-64; avg age 49±16 years (22-77 years)] were included for analysis. The four groups were not different for age, gender, and BMI. As expected, lumbopelvic parameters were slightly different across the Roussouly types, fitting with the definition (PI, SS, PT, LL). Average values for all patients included: O-C2 lordosis (-28±9^0), CBVA (-1±9^0), C2-7 lordosis (-11±14^0), C2-7 SVA (21±9mm), T1 slope (25±9^0), C6-T4 angle (5±8^0), T2-5 angle (16±7^0), thoracic kyphosis (47±13^0). No sagittal radiographic alignment measurements of the cervical spine and cervicothoracic junction were different between groups.

Conclusions: In asymptomatic volunteers, sagittal alignment parameters of the axial and subaxial cervical spine, cervicothoracic junction, and thoracic spine based on variations in thoracolumbar sagittal alignment were not different when sagittal profiles were classified as proposed by Roussouly. These data may guide surgical correction of cervical and cervicothoracic deformities to ensure horizontal gaze and good overall sagittal plane alignment.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #18 (cont.)

	All	Roussouly Type				*p*
		I	II	III	IV	
N	87	8	47	19	13	
Gender Male Female	23 64	4 4	14 33	3 16	2 11	0.21
Age (yrs)	49 ± 16 (22-77)	37 ± 12 (23-60)	47 ± 17 (22-76)	52 ± 15 (28-77)	55 ± 16 (28-76)	0.07
BMI	27 ± 6 (19-45)	26 ± 6 (19-38)	27 ± 5 (19-45)	28 ± 6 (20-38)	27 ± 8 (20-41)	0.86
Thoracolumbar Parameters						
PI	49 ± 12 (22-88)	35 ± 8 (22-43)	44 ± 6 (31-54)	60 ± 4 (55-67)	64 ± 9 (56-88)	<0.01
SS	34 ± 8 (18-65)	22 ± 3 (18-25)	31 ± 4 (25-43)	38 ± 4 (26-43)	46 ± 9 (22-65)	<0.01
PT	15 ± 7 (-2-35)	13 ± 8.2 (-2-22)	12 ± 6 (0-27)	22 ± 5 (15-30)	18 ± 7 (11-35)	<0.01
LL	-58 ± 11 (-81- -32)	-52 ± 14 (-79- -39)	-55 ± 10 (-75- -32)	-61 ± 11 (-74- -36)	-67 ± 11 (-81- -43)	<0.01
TK	47 ± 13 (11-77)	45 ± 14 (23-68)	45 ± 12 (11-67)	50 ± 12 (35-70)	49 ± 15 (15-77)	0.45
Cervical/Cervicothoracic Parameters						
Orbital Tilt (deg)	68 ± 9 (43-96)	67 ± 8.1 (56-78)	70 ± 10 (44-99)	69 ± 7 (49-77)	68 ± 8 (55-84)	0.71
Occipital Slope (deg)	10 ± 9 (-11-30)	12 ± 6 (4-22)	8 ± 9 (-11 - 26)	11 ± 9 (-4-30)	13 ± 10 (-3-29)	0.21
Occipital Incidence (deg)	81 ± 8 (61-101)	84 ± 7 (73-100)	80 ± 9 (61-99)	82 ± 8 (72-101)	82 ± 8 (68-95)	0.38
Orbital Slope (deg)	19 ± 8 (-9-46)	18 ± 6 (12-28)	18 ± 9 (-9 – 46)	19 ± 7 (10-41)	21 ± 7 (11-35)	0.77
O-C2 (deg)	-28 ± 9 (-52- -6)	-32 ± 4.6 (-36 - -21)	-27 ± 9 (-52- -6)	-28 ± 9 (-42 - -8)	-31 ± 6 (-43- -22)	0.23
CBVA (deg)	-1 ± 9 (-28-33)	2 ± 8 (-10-14)	-2 ± 10 (-28 – 33)	-2 ± 6 (-10-12)	-1 ± 8 (-19-10)	0.73
C2-7 lordosis (deg)	-11 ± 14 (-43-21)	-12 ± 13 (-23 -18)	-9 ± 14 (-41 - 21)	-14 ± 13 (-32 - 16)	-15 ± 16 (-43-13)	0.33
C2-7 SVA (mm)	21 ± 9 (-2-49)	18 ± 7.1 (12-31)	21 ± 10 (-2 – 49)	21 ± 9 (8-40)	20 ± 9 (8-40)	0.84
T1 slope (deg)	25 ± 9 (0-52)	23 ± 7 (10-30)	23 ± 9 (0-52)	27 ± 7 (15-39)	26 ± 11 (8-44)	0.40
CT jxn (C6-T4) (deg)	5 ± 8 (-18-23)	1 ± 9 (-13-16)	7 ± 7 (-13 -23)	5 ± 7 (-5-21)	4 ± 12 (-18-20)	0.27
T2-5 (deg)	16 ± 7 (2-34)	18 ± 8 (9-30)	15 ± 7 (2-31)	18 ± 7 (8-34)	17 ± 8 (3-28)	0.53

Presentation #19

Can the American College of Surgeons Risk Calculator Predict 30-Day Complications After Cervical Spine Surgery?

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Introduction: Surgical risk calculators exist in many fields[1-3] and may assist in the identification of patients at increased risk for complication and readmissions. Risk calculators may allow for improved outcomes, an enhanced informed consent process, and management of modifiable risk factors. The American College of Surgeons (ACS) NSQIP risk calculator was developed from a cohort of over 1.4 million patients, using 2,805 unique CPT codes.[4] The risk calculator uses 21 patient predictors (e.g., age, ASA class, BMI, HTN) and the planned procedure (CPT code) to predict the chance that patients will have any of 12 different outcomes (e.g. death, any complication, serious complication, reoperation) within 30-days following surgery. The purpose of this study is to determine if the ACS NISQIP risk calculator can predict 30-day complications after cervical fusion.

Methods: A retrospective chart review was performed on patients that underwent primary cervical fusion between Jan 2009-2015 at a single-institution, utilizing cervical fusion CPT codes (22554, 22590, 22595, 22600). Patients without 30 days post-operative follow-up were excluded. Descriptive statistics were calculated for the overall sample, anterior v. posterior fusion, and single v. multi-level fusion. Logistic regression models were fit with actual complication occurrence as the dependent variable in each model and ACS estimated risk as the independent variable. The c-statistic was used as the measure of concordance for each model. ROC curves were plotted to visually depict the predictive ability of the estimated risks. Acceptable concordance was set at $c > 0.80$. All analyses were conducted using SAS v9.4.

Results: A total of 404 patients (207 anterior, 197 posterior) were included in the analysis. Age, BMI, gender and number of levels fused are described in Table 1. Logistic regression results for the overall sample can be seen in Table 1 and Figure 1. Because there were no deaths, no models were fit for mortality. Only “Any complication” and “SNF/Rehab Admission” met the criteria for $c>0.80$ for acceptable concordance between ACS prediction and actual occurrence.

Logistic regression results were performed on the anterior and posterior fusion groups separately. Prediction was better in the anterior group for “Any complication”, “SNF/Rehab admit”, and “Serious complication” than in the posterior group. While complications occurred at a higher rate in the posterior group, the ability of the risk calculator to predict complications was poorer. Logistic regression results comparing single-level and multi-level fusion group illustrated that prediction was better in the single-level group for “SNF/Rehab admit”, although prediction was still acceptable ($c>0.80$) in the multilevel group.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #19 (cont.)

Conclusion: The ACS risk-calculator only predicted complications in the categories of "any complication" ($p<0.0001$) and "discharge to skilled nursing facility" ($p<0.001$). However, the ACS risk calculator was unable to accurately predict specific complications on a more granular basis. The ACS risk calculator may be useful in the development of new institutional strategies for cervical spinal fusion but does not provide accurate information for individual patient care.

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Table 1. Patient characteristics & Logistic Regression Results

	Anterior (n=207)	Posterior (n=197)	Total Sample (n=404)
Age, years (n=65 missing)	51.5 (12.2) [21, 81]	62.0 (12.3) [29, 87]	55.6 (13.2) [21, 87]
BMI	29.0 (6.2) [15.6, 53.5]	29.7 (7.3) [17.8, 57.2]	29.3 (6.8) [15.6, 57.2]
Gender			
Female	104 (50.2%)	89 (45.2%)	193 (47.8%)
Male	103 (49.8%)	108 (54.8%)	211 (52.2%)
# levels of fusion (n=1 missing)			
1	69 (33.3%)	21 (10.7%)	90 (22.3%)
2	102 (49.3%)	22 (11.2%)	124 (30.8%)
3	32 (15.5%)	41 (20.9%)	73 (18.1%)
4	3 (1.4%)	43 (21.9%)	46 (11.4%)
5-6	1 (0.5%)	48 (24.5%)	49 (12.2%)
7-9	0	21 (10.7%)	21 (5.2%)

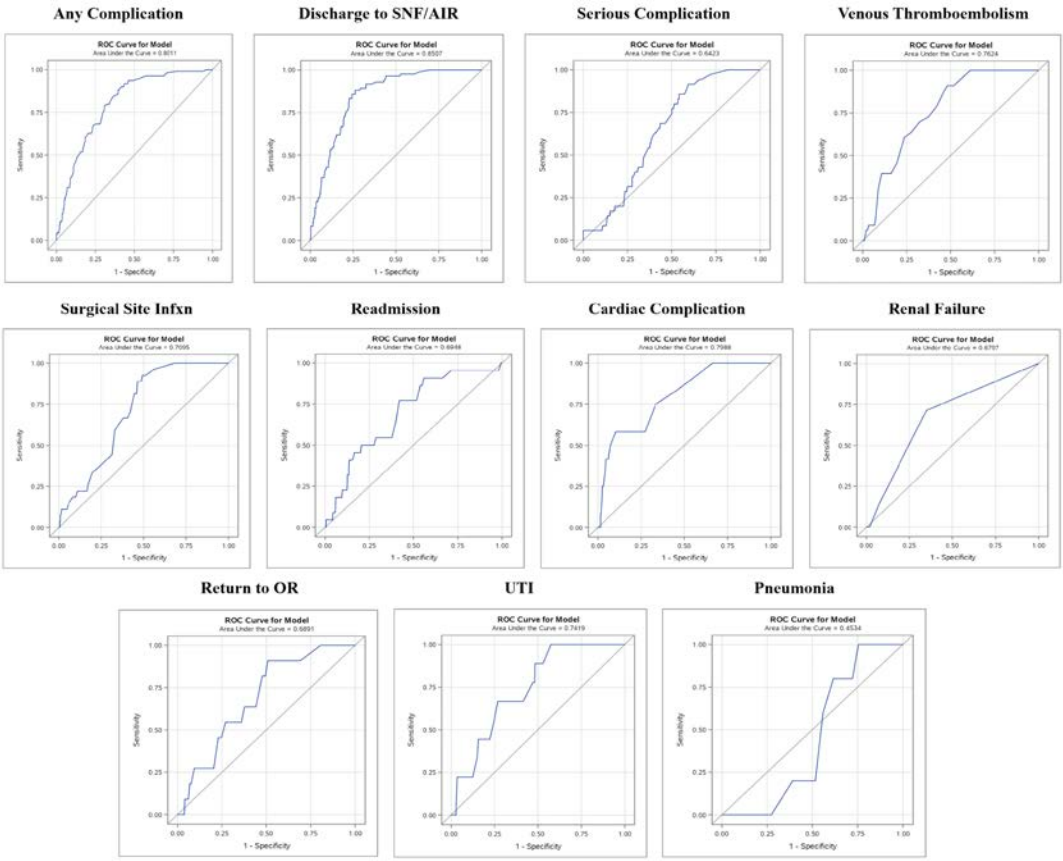
Presentation #19 (cont.)

Logistic regression results – All patients

	N (%) observed	OR (95% CI)	p-value	C-statistic
Any complication	**111 (27.5%)**	**1.24 (1.17, 1.31)**	**<0.0001**	**0.801**
SNF/Rehab admit	**84 (20.8%)**	**1.07 (1.05, 1.09)**	**<0.001**	**0.851**
Serious complication	35 (8.7%)	1.08 (1.01, 1.15)	0.0291	0.642
VTE	33 8.2%)	3.28 (1.89, 5.67)	<0.0001	0.762
Surgical site infection	27 (6.7%)	1.82 (1.29, 2.59)	0.0007	0.709
Readmit	22 (5.4%)	1.14 (1.04, 1.26)	0.0072	0.695
Cardiac	*12 (3.0%)*	*2.36 (1.37, 4.06)*	*0.0019*	*0.799*
Renal	*12 (3.0%)*	*1.23 (0.19, 8.06)*	*0.828*	*0.680*
Return to OR	*11 (2.7%)*	*1.45 (1.00, 2.11)*	*0.0520*	*0.689*
UTI	*9 (2.2%)*	*1.35 (1.00, 1.84)*	*0.0519*	*0.742*
Pneumonia	*5 (1.2%)*	*0.67 (0.15, 3.02)*	*0.6021*	*0.453*

Numbers in table are N (%) or Mean (SD) [min, max]

Figure 1: Cervical fusion Receiver Operating Characteristic (ROC) curves for each out-come measure



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Presentation #20

Difference in Patient Cohorts for Cervical Disc Arthroplasty (CDA) and Anterior Cervical Discectomy and Fusion (ACDF)

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Introduction: Cervical disc arthroplasty (CDA) and anterior cervical discectomy and fusion (ACDF) are two common procedures performed for a number of cervical disorders recalcitrant to conservative management. While the initial studies of CDA were randomized in nature, more recent studies have expanded indications for CDA and are non-randomized in nature. Studies that are non-randomized have the potential to be influenced by selection bias. This study aims to define the average differences in patients undergoing CDA and ACDF in a large national cohort in order to identify baseline cohort difference that may impact interpretation of future non-randomized studies.

Materials/Methods: We used AHRQ's National Inpatient Database (NIS) to identify patients undergoing CDA or ACDF coded using International Classification of Disease, 9th Revision, Clinical Modification (ICD-9-CM). Patients with spinal cord injury, congenital anomalies, and cancer, or spine fractures at other levels were excluded. Survey-weighted univariate analyses were used to compare the CDA and ACDF cohorts in terms of age, demographics, income, insurance status, and comorbidities. Two sets of multivariate regression models were run, a naïve model and one adjusting for differences in demographics/comorbidities/income, for cost and complications.

Results: An estimated 1,287,931 ACDFs and 22,579 CDAs were performed nationally between 2004 and 2014 according the sample captured by the NIS. Patients that underwent ACDF were on average older, with mean age of 53 years compared to 46.8 years in the CDA cohort ($p<0.01$). Demographics showed statistically significant differences with 9.2% of ACDF cohort identifying as black, compared to 6.9% in CDA cohort ($p<0.01$). ACDF cohort had 68.9% of patients with no comorbidities compared 79% of the CDA cohort ($p<0.01$). 23.9% of the ACDF cohort was in the highest income quartile compared to 29.4% of the CDA cohort ($p<0.01$). The ACDF cohort had 31.4% of patients that were insured under the Medicare or Medicaid, compared to 14.4% of the CDA cohort ($p<0.01$). Naïve regression models showed that CDA is less expensive with lower complication rates. Models adjusting for demographics and comorbidities show that CDA is more expensive with no statistically significant difference in complication rates.

Conclusion: Patients undergoing CDA tend to be younger, healthier, and more wealthy compared to patients that undergo ACDF. These are important factors to consider when interpreting results of non-randomized trials comparing the two procedures. Models that do not adjust for aforementioned factors would suggest that CDA may less expensive with lower complication rates, however once multivariate regression models are adjusted for those factors, CDA is the more expensive option with comparable complication rates compared to ACDF.

Presentation #21

Does Payer Type Affect Patient Satisfaction Scores?

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Introduction: Patient reported outcomes (PROs) have been traditionally collected for outcomes research. They are becoming increasingly important to how providers are being measured and reimbursed by payers and chosen by patients. PROs can help providers improve patient experience, increase referrals and reduce lawsuits. However concerns have been raised regarding the effect of payer type on patient satisfaction. The purpose of this study was to determine if payer type is associated with patient satisfaction.

Methods: At a large private orthopedic practice, patient satisfaction scores were routinely collected at all visits. Between December 2015 and December 2016, 2,768 patients presenting to our sub-specialty spine center completed a patient satisfaction survey. Patient age, sex, payer type (Medicaid, Medicare, Commercial and Workers Compensation) and satisfaction was queried from our institution's administrative database. Patient satisfaction was measured using the single question: "What is the likelihood that you would recommend this provider to your family and friends?" Patients rated their likelihood to recommend (L2R) on using a numeric rating scale from 0-10 with 10 being the most likely to recommend. Mean scores, Net Promoter (NP) category and NP score were analyzed. NP Methodology defines categories (scores 0-6 as detractors; 7-8 as neutral; and 9-10 as promoters) and NP score as number of detractors subtracted from the number of promoters divided by total number of respondents as a percentage. Wilcoxon Tests and Chi-Square Tests were used to determine differences between L2R and payer type.

Results: There were significant differences ($p<.0001$) in the likelihood to recommend scores between the different payer types and in the proportion of net promoters. Medicaid patients reported the highest average and NP scores (9.8 and 96.5) while workers compensation patients reported the lowest (9.1 and 74.8). Of the 2,764 patients with complete survey data, 143 were detractors, 2407 were promoters and 214 patients were neutral. See Table a. There was a significant difference in the proportion of NP categories between payer type. Medicaid had the highest percentage of net promoters (28/29, 96%) and workers compensation had the lowest percentage of net promoters (181/222, 81.5%; $p<0.0001$). See Fig 1.

Conclusion: Payer type does effect patient satisfaction scores. Medicaid patients had the highest L2R mean NRS and NP scores while Workers Compensation had the lowest L2R mean NRS and NP scores. This information can help inform providers about the effect of payer type on patient satisfaction as measured by Likelihood to Recommend.

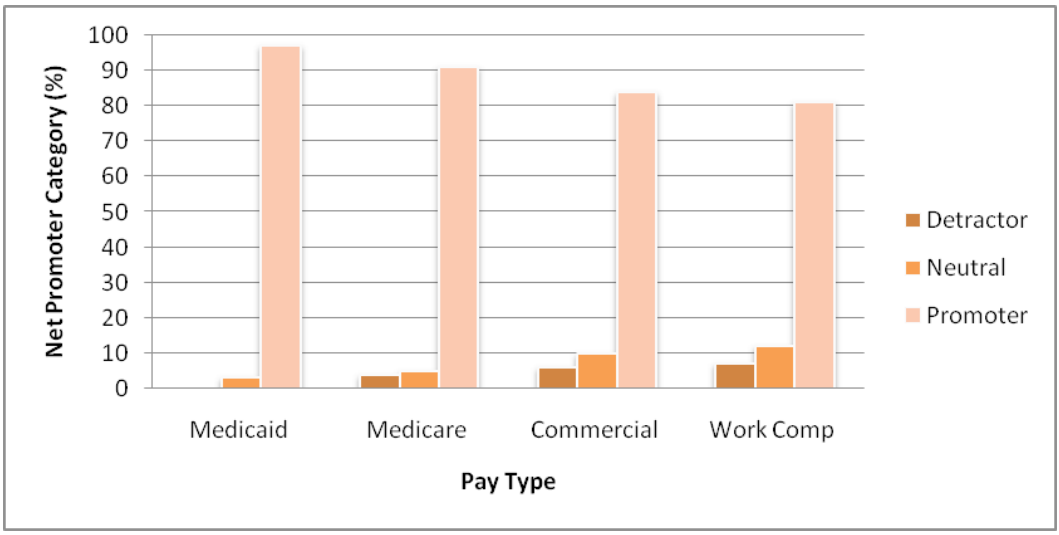
Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #21 (cont.)

Table A. L2R Numeric Rating Score and Aggregate NP Score

Payer Type	L2R Numeric Rating Score	Aggregate NP Score
Medicaid	9.8 (8-10)	96.5
Medicare	9.5 (0-10)	86.1
Commercial	9.3 (0-10)	78.8
WC	9.1 (0-10)	74.8

Figure 1. Net Promoter Category Percentage by Payer Type



Presentation #22

Development of a Novel Cervical Deformity Surgical Invasiveness Index

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Introduction: There has been a surgical invasiveness index for general spine surgery and adult spinal deformity, but a cervical deformity (CD) index has not been developed. The aim of this study was to develop a novel surgical invasiveness index for CD surgery that incorporates CD-specific parameters.

Methods: Retrospective review of a multicenter prospective CD database. CD was defined as at least one of the following: C2-C7 Cobb>10°, CL>10°, cSVA>4cm, CBVA>25°. Consensus from experienced spine and neurosurgeons selected weightings for each variable that went into the invasiveness index. Linear regression was used to predict operative time, EBL, and length of stay using the newly developed CD-specific invasiveness index, controlling for age, sex, and Charlson Comorbidity Index score. Binary logistic regression predicted high operative time (>338 minutes), high EBL (>600 cc), or high length of stay (>5 days) based on the median values of operative time, EBL and length of stay. Multivariable regression modeling was utilized to construct a final model incorporating the strongest combination of factors that would predict operative time, length of stay, and EBL. Significance was set at $P<0.05$.

Results: 85 CD patients with complete baseline demographic, clinical, and surgical details and 1-year data were included (61.35±10.7 years, 65.9% female). The variables included in the newly developed CD invasiveness index with their corresponding weightings were: history of prior cervical surgery (3), ACDF (2 per level), corpectomy (4 per level), levels fused (1 per level), implants (1 per level), posterior decompression (2 per level), Smith-Peterson osteotomy (2 per level), three column osteotomy (8 per level), fusion to upper cervical spine (2), absolute change in TS-CL, cSVA, T4-T12 thoracic kyphosis and SVA from baseline to 1-year follow-up (**Table 1**). The newly developed CD-specific invasiveness index strongly predicted a hospital length of stay greater than 5 days ($R^2=0.310$, $P<0.001$), high blood loss ($R^2=0.170$, $P=0.011$), and extended operative time ($R^2=0.207$, $P=0.031$). A second analysis was conducted using multivariable regression modeling to determine which combination of these factors included in the newly developed index were the strongest determinants of operative time, length of stay, and EBL. The final predictive model included the following

Presentation #22 (cont.)

factors: number of corpectomies, levels fused, decompression, combined approach, and absolute changes in SVA, cSVA and TK. This model predicted EBL (R^2=0.26), operative time (R^2=0.12), and length of stay (R^2=0.13).

Conclusions: Extended length of stay, operative time, and high blood loss were strongly predicted by the newly developed CD invasiveness index, incorporating surgical factors and radiographic parameters clinically relevant for patients undergoing cervical deformity corrective surgery.

Table 1. Surgical and radiographic components used to calculate the new cervical deformity invasiveness score.

Surgical Factors	***Points Assigned***
ACDF	2 points per level
Corpectomy	4 points per level
Levels Fused	1 point per level
Implants	1 point per implant
Posterior Decompression	2 points per level
Smith-Peterson Osteotomy	2 points per level
Three-Column Osteotomy	8 points per level
Fusion to upper cervical spine	2 points
Revision Status	3 points
Radiographic Factors	
Absolute change in cSVA	0.5 point per 1mm change
Absolute change in TS-CL	0.5 point per 1° change
Absolute change in Thoracic Kyphosis	0.5 point per 1° change
Absolute change in SVA	0.5 point per 1mm change

Presentation #23

A Clinical and Radiologic Study on Patients of Cervical Spondylotic Myelopathy with Anterior Cervical Spondylolisthesis Treated by Posterior Decompression Surgery: Retrospective Multicenter Study of 867 Cases

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Introduction: This multicenter study aimed to investigate the clinical and radiographic features of cervical spondylotic myelopathy (CSM) associated with anterior cervical spondylolisthesis (ACS).

Materials and Methods: Totally, 867 patients (582 males and 285 females, average age; 67.4 ± 11.8 years) with CSM who underwent posterior decompression surgery such as open-door laminoplasty, double-door laminoplasty, and selective laminectomy with a minimum follow-up of 1 year in 17 hospitals were included. ACS was defined as anterior slippage of ≥ 2 mm on a cervical radiograph taken in the neutral position. Clinical and radiographic features were compared between patients with ACS and those without ACS. Additionally, incidence and clinical features of the slippage progression, which is defined as postoperative change of anterior slippage ≥ 2 mm, were investigated. Student's t test and chi-square test were performed, and a p value < 0.05 was considered to be statistically significant.

Results: Preoperatively, 68 patients (7.8%) had ACS (average; 3.1 ± 1.0 mm, range; 2.0 - 6.0mm): C2 level, 3 patients; C3, 11; C4, 31; C5, 12; C6, 3; and C7, 8. Significant differences were found between ACS group and non-ACS group in age (74.0 vs. 66.8 years; p < 0.01), height (155.1 vs. 160.2 cm; < 0.01), body weight (55.2 vs. 61.0 kg; < 0.01), preoperative C2–C7 SVA (27.8 vs. 22.5 mm; < 0.01), preoperative JOA scores (9.8 vs 10.8 pts; < 0.01), and JOA recovery rate (53.9% vs. 41.6%; 0.02) (Table.1). There were 24 patients (2.8%) who developed postoperative progression of anterior slippage with average JOA recovery rate of 51.2 %. Among them, patients with preoperative ACS (n = 5, 7.4 %) had a significantly higher incidence of the slippage progression postoperatively (p = 0.04) (Table.2).

Conclusions: The incidence and the postoperative progression of ASD were observed in 7.8 % and 2.8% among the CSM patients, respectively. Our results suggest that develop-

Presentation #23 (cont.)

ment of ACS is more likely to occur among old and small patients who may not be able to compensate for sagittal imbalance such as larger C2-C7 SVA. Although presence of ACS increases risk of the postoperative further progression of slippage, it does not preclude indication of posterior decompression for CSM with ACS because, nevertheless, satisfactory outcomes can be obtained.

Table 1. Clincial and radiographic variables and cervical anterior spondylolisthesis

	ACS n (%) or mean ± SD	non-ACS n (%) or mean ± SD	p value
Gender	Male 40 (4.6%)	Male 547 (63.1%)	0.11
	Female 28 (3.2%)	Female 252 (29.1%)	
Age (y/o)	74.0 ± 10.5	66.8 ± 11.7	< 0.01*
Height (cm)	155.1 ± 9.4	160.2 ± 9.9	< 0.01*
Body weight (kg)	55.2 ± 10.0	61.0 ± 12.2	< 0.01*
BMI (kg/m^2)	22.8 ± 2.9	23.7 ± 3.6	0.06
Number of decompressed laminae	3.5 ± 1.0	3.5 ± 1.0	0.98
C2-C7angle (°)			
Neutral	12.9 ± 14.7	13.0 ± 12.9	0.98
Flex	-9.7 ± 15.3	-10.4 ± 12.4	0.71
Extension	23.8 ± 14.1	25.0 ± 13.3	0.49
Extension	20.4 ± 20.0	23.1 ± 13.5	0.34
ROM (°)	33.5 ± 15.1	35.4 ± 13.5	0.40
C2-C7 SVA (mm)	27.8 ± 14.9	22.5 ± 14.0	< 0.01*
Preoperative JOA (pts)	9.8 ± 3.2	10.8 ± 2.7	< 0.01*
Postoperative JOA (pts)	13.7 ± 2.4	13.6 ± 2.2	0.76
JOA recovery rate (%)	53.9 ± 26.5	41.6 ± 40.7	0.02*

ACS indicates anterior cervical spondylolisthesis; BMI, body mass index; EBL, estimated blood loss; ROM, range of motion; SVA, sagittal vertical axis; JOA, Japanese Orthopaedic Association.

Presentation #23 (cont.)

Table 2. Incidence and clinical result of patients among progression of cervical anterior spondylolisthesis

	Progression of ACS (+) n (%) or mean ± SD	Progression of ACS (-) n (%) or mean ± SD	p value
Gender	Male 17 (2.0%)	Male 570 (65.7%)	0.70
	Female 7 (0.8%)	Female 273 (31.5%)	
Presence of preoperative ACS	5 (7.4%)	19 (2.4%)	0.04*
Preoperative JOA (pts)	9.5 ± 3.2	10.8 ± 2.7	0.03*
Postoperative JOA (pts)	13.6 ± 2.0	13.6 ± 2.3	0.95
JOA recovery rate (%)	51.2 ± 21.3	42.4 ± 40.2	0.40

ACS indicates anterior cervical spondylolisthesis; JOA, Japanese Orthopaedic Association.

Presentation #24 – 1st Place Clinical Research Award Winner

Effect of Cervical Decompression Surgery on Spine and Lower Extremity Biomechanics in Adult Cervical Spondylotic Myelopathy Patients

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Introduction: Difficulties with balance and gait are one of the most common manifestations of cervical spondylotic myelopathy (CSM). Patients with CSM have a slower gait speed, prolonged double support duration, and reduced cadence compared to healthy controls. Surgical decompression was found to improve clinical outcomes, but conflicting results are noted when examining function. To our knowledge, there is no literature regarding spinal and lower extremity kinematics with very limited literature on the spatiotemporal gait parameters of patients with CSM before and after surgical intervention. The purpose of this study is to explore the level of functional compromise, both objectively and subjectively with patient-reported outcome measures, in patients with CSM. A secondary objective is to quantify the potential benefit of cervical decompression surgery on the biomechanics of the spine and lower extremities as evaluated by gait analysis.

Methods: This study was a non-randomized, prospective, concurrent control cohort study of patients with CSM before and after cervical decompression compared to a matched asymptomatic control group. Twenty-five subjects with symptomatic CSM underwent clinical gait analysis performed a week before (Pre) and 3 months after the surgery (Post). Clinical gait analysis was performed on 30 matched asymptomatic controls as well. Each subject performed a series of over-ground gait trials at a self-selected speed. Spine and lower extremity kinematics, spatiotemporal parameters, and clinical outcome were measured. A repeated measurement and one-way ANOVA were used.

Results: CSM patients demonstrated slower walking speed (p=0.006), reduced cadence (p=0.001), longer step time (p=0.013) wider step width (p=0.001; Table 1), greater ankle ROM (p=0.019), less hip ROM (p=0.050), increased pelvis (p=0.001), and lumbar spine (p=0.049) ROM compared to controls (Table 2). Postoperatively CSM patients demonstrated a faster walking speed (p=0.002), increased cadence (p=0.029), longer step length (p=0.015), narrower step width (p=0.004; Table 1), greater knee (p=0.043) and hip ROM (p=0.007), less pelvis (p=0.002), lumbar spine (p=0.035), and cervical spine (p=0.044) ROM (Table 2), and improved clinical outcomes (NDI, ODI, and VAS; p=0.001) compared to their pre-operative values. Post-surgical CSM patients did not presented with any differences compared to controls, beside pelvis ROM (p=0.019; Table 2).

Conclusion: This is the first study, both objectively and with patient-reported outcome measures, to quantify the benefits of cervical decompression surgery on the biomechanics and function of the spine and lower extremities before and after surgical intervention in a population of CSM patients. Preoperatively, CSM patients clearly demonstrated altered gait parameters compared to controls. However, following cervical decompression surgery,

Presentation #24 (cont.)

CSM patients exhibited improved gait pattern, spatiotemporal parameters, spine and lower extremity ROM, and even patient reported outcomes. Postoperatively, CSM patients did not demonstrate major differences in gait when compared to matched asymptomatic controls. This study not only provided a richer understanding of the gait pathology in cervical myelopathy, but uniquely showed that surgical intervention improves gait and function as measured by spatiotemporal parameters, spine and lower extremity ROM, and patient reported outcome measures. Identification of these key gait parameters can be used to help monitor and quantify postoperative recovery and rehabilitation protocols in cervical spondylotic myelopathy.

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Presentation #24 (cont.)

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Presentation #24 (cont.)

Table 1. Representative spatiotemporal data (cm; M±SD)

Variable	Pre	Post	Control	p-value		
				Pre-Control	Pre-Post	Post-Control
Walking Speed (m/s)	0.82±0.20	0.97±0.17	1.05±0.15	0.006	0.002	0.434
Cadence (step/min)	96.93±14.91	102.80 ±14.35	106.65 ±10.39	0.001	0.029	0.173
Step Time (s)	0.67±0.20	0.59±0.09	0.57±0.06	0.013	0.020	0.273
Single Support Time (s)	0.45±0.09	0.43±0.06	0.42±0.03	0.285	0.241	0.751
Double Support Time (s)	0.41±0.21	0.33±0.11	0.29±0.06	0.002	0.006	0.106
Step Length (m)	0.51±0.07	0.56±0.07	0.59±0.05	0.001	0.015	0.113
Step Width (m)	0.16±0.06	0.13±0.04	0.12±0.04	0.001	0.004	0.559

Table 2. Representative lower extremity and spine kinematic data (°; M±SD)

Variable	Pre	Post	Control	p-value		
				Pre-Control	Pre-Post	Post-Control
Sagittal Plane						
Ankle	26.73±8.90	24.54±7.67	21.77±6.17	0.019	0.134	0.145
Knee	23.36±13.94	30.27±10.36	25.45±9.14	0.506	0.043	0.073
Hip	33.06±7.69	37.12±3.39	36.18±4.21	0.050	0.007	0.373
Pelvis	4.20±2.06	3.28±1.36	2.54±0.86	0.001	0.002	0.019
Lumbar Spine	4.48±2.29	3.29±1.54	3.47±1.36	0.049	0.035	0.643
Cervical Spine	4.44±3.31	2.85±1.90	4.50±1.51	0.930	0.044	0.001
Head	4.95±2.80	3.99±2.02	4.61±1.65	0.577	0.073	0.210
Coronal Plane						
Ankle	7.81±4.64	5.32±3.06	3.55±1.81	0.001	0.006	0.010
Knee	14.03±5.29	10.14±3.76	8.73±11.70	0.069	0.001	0.021
Hip	9.87±2.01	9.82±2.84	9.43±2.29	0.454	0.913	0.574
Pelvis	6.44±2.40	5.89±2.58	6.60±2.37	0.813	0.270	0.296
Lumbar Spine	8.50±3.89	7.26±4.15	8.65±2.94	0.876	0.104	0.154
Cervical Spine	3.00±1.64	2.19±1.20	2.91±1.59	0.832	0.049	0.069
Head	3.54±2.55	3.25±1.78	3.06±1.62	0.404	0.332	0.681

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #25 – 3rd Place Clinical Research Award Winner

The Impact of K-Line (-) in the Neck-Flexion Position on Patient-Based Outcomes After Cervical Laminoplasty for Patients with Ossification of the Posterior Longitudinal Ligament

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Introduction: The concept of the K-line was proposed as a simple tool for making decisions about the surgical approach for patients with cervical myelopathy due to ossification of the posterior longitudinal ligament (OPLL). The K-line is reportedly a predictor of poor outcome due to insufficient decompression of the spinal cord after cervical laminoplasty. The K-line in the neck-flexion position has recently been proposed as a predictor of poor outcomes because laminoplasty is a motion-preserving surgery. However, the usefulness of the K-line has been demonstrated mainly based on the Japanese Orthopaedic Association (JOA) score, a physician-based outcome measure, and little is known of its efficacy for predicting patient-based outcome measures. The purpose of this study was to investigate whether K-line (-) in the neck-flexion position affects patient-based outcomes after cervical laminoplasty.

Materials/Methods: A retrospective analysis of prospectively collected data of 87 consecutive patients with cervical myelopathy due to OPLL who underwent double-door laminoplasty from 2008 to 2015 was performed. Ten patients were excluded because of comorbidities that impaired physical functions. Patients were categorized into two groups based on whether the OPLL did or did not exceed the K-line (K-line (-) group and K-line (+) group, respectively) on a preoperative neck-flexion radiograph (Fig. 1A). Outcome measures were assessed preoperatively and at 2-year follow-up. Patients rated the average pain intensities in the last month using an 11-point numerical rating scale (NRS) at the five anatomical areas shown in a body chart (Fig. 1B). Other patient-reported outcomes included EQ-5D and the Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). Patients also rated the degree of satisfaction with the outcome at the 2-year follow-up using a 7-point NRS. The objective functional outcome was assessed with the JOA score. Group comparisons were performed using the unpaired t-test or the Mann-Whitney U test.

Results: Sixty-eight patients completed 2-year follow-up (follow-up rate: 88%), with 22 (32%) K-line (-) and 46 (68%) K-line (+) patients. The two groups showed no significant differences in patient characteristics and baseline functions. At the 2-year follow-up, the pain NRS in both the upper and lower extremities was significantly higher in the K-line (-) group than in the K-line (+) group (Table 1). Other functional outcomes showed no significant differences, except for the cervical function domain of the JOACMEQ. However, with respect to postoperative changes of functional scores, patients in the K-line (-) group had significantly lower gains both in EQ-5D and the JOA score compared with those in the K-line (+) group. The degree of patient satisfaction with the outcome was also significantly lower in the K-line (-) group than in the K-line (+) group.

Presentation #25 (cont.)

Conclusion: K-line (-) in the neck-flexion position was significantly associated with higher pain intensity in the extremities, poorer functional recovery, and lower patient satisfaction with the outcome after cervical laminoplasty. These results indicate that insufficient decompression of the spinal cord in the neck-flexion position may interfere not only with the recovery of motor function, but also with recovery of neurogenic pain after cervical laminoplasty.

Figure 1

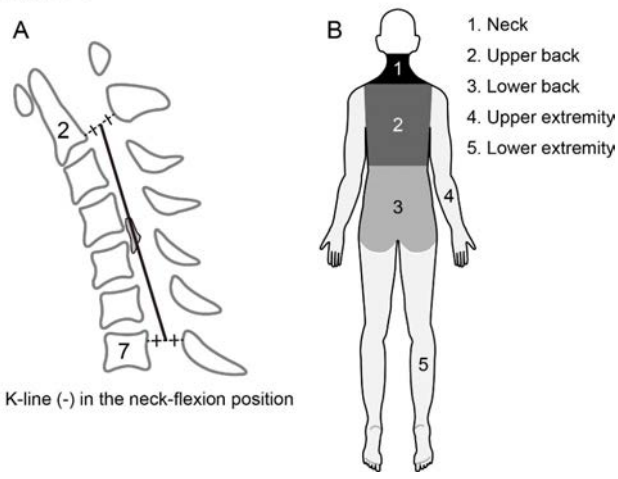

Table 1. Comparisons of functional outcomes between K-line (-) and K-line (+) groups at 2-year follow-up

Outcome	K-line (-) in the neck-flexion position (N =22)	K-line (+) in the neck-flexion position (N = 46)	P value
NRS for pain			
Neck	2	1	0.154
Upper back	1.5	0	0.107
Lower back	3.5	2	0.126
Upper extremity	**3**	**1**	**0.002**
Lower extremity	**4.5**	**3**	**0.009**
JOA score	13.1 ± 2.1	13.8 ± 2.3	0.226
EQ-5D	0.6 ± 0.1	0.7 ± 0.2	0.080
JOACMEQ			
Cervical spine function	**66.1 ± 25.8**	**78.9 ± 23.2**	**0.047**
Upper extremity function	70.0 ± 29.8	73.1 ± 25.7	0.094
Lower extremity function	74.2 ± 27.1	75.1 ± 21.6	0.879
Bladder function	51.8 ± 22.6	58.5 ± 22.1	0.741
Quality of life	65.5 ± 25.5	74.6 ± 21.3	0.135

Presentation #26

Brain Functional Connectivity Predicts for Neurological Improvement in Patients with Cervical Myelopathy – A Resting-State fMRI Study

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Introduction: Several radiographic prognostic factors (f.e. T2 high intensity area on MRI) for neurological recovery in patients with cervical myelopathy (CM) have been reported. However, none of these can fully predict the recovery partly because of the limited information from small area. We directed our attention on brain instead of cervical spine to explore a novel method for prognostic prediction based on imaging. Resting-state fMRI (rs-fMRI) is a method of functional brain imaging that can be used to evaluate regional interactions that occur without performing a task. The objective of this study was to explore preoperative brain biomarkers which predict postoperative neurologic recovery with rs-fMRI.

Methods: Twenty-eight CM patients (14 female, 14 male, mean age; 68 years) and 28 healthy matched control (HC) were included in this study. CM patients received rs-fMRI before and 6-month after surgery. Brain functional connectivity (FC) were compared between CM and HC groups and before and after surgery in the CM group with independent component analysis. Clinical outcomes including JOA score, 10-second test, and VAS were collected in the CM group, and correlation between pre-op FC and clinical improvement were also analyzed by Spearman's rank correlation coefficient. MRI conditions and software used for the analysis were as follows; MRI[3T]: GEGRE-EPI; TR/TE/FA;2000ms/30ms/90°; matrix size, 64 x 64; FoV, 220x220mm; software: Matlab R2016a, SPM12, Conn v.17c.

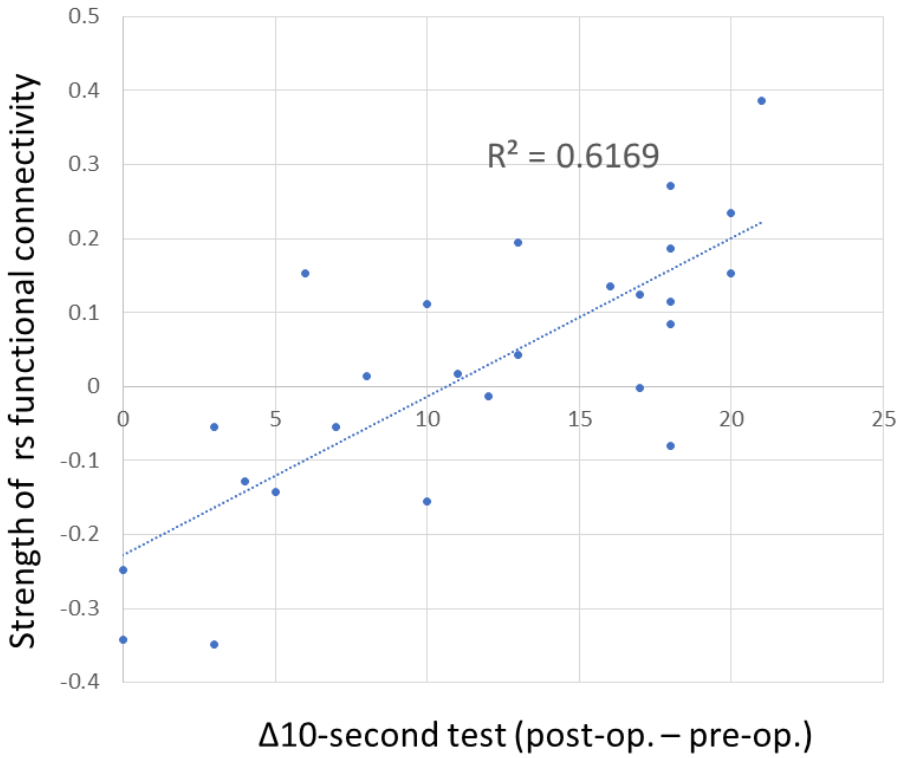
Result: Clinical outcomes were significantly improved after surgery (mean JOA score: pre-op/post-op; 10.8 ± 2.5 / 14.0 ± 2.0, mean 10-second test: pre-op/post-op; 16.1 ± 3.9 / 28.6 ± 7.9). Comparison of FCs between pre-op. CM and HC groups identified several significantly increased (f.e. FCs between cerebellum and posterior cingulate cortex, and between intraparietal sulcus and precuneus) or decreased (f.e. FCs between semsorimotor and cerebellum and between anterior insula and cerebellum) FCs in the CM group. Comparison between pre- and post-op. FC in the CM group demonstrated that the changes in FCs were observed not only the FCs where preoperative differences were observed but also the FCs where no preoperative difference was observed between the CM and HC groups. Correlation analysis between clinical outcome and pre-op FCs demonstrated that pre-op low FC between primary visual cortex and superior frontal gyrus (Fig.1) and pre-op. high FC between supramarginal gyrus and cuneus correlate with poor recovery in 10-second test.

Conclusions: Changes in brain FCs and correlations between the changes in FCs and clinical improvement by operation were investigated by rs-fMRI. Postoperative changes of

Presentation #26 (cont.)

FCs in CM patients included both the changes which decrease the preoperative differences in FCs with HC and the changes which increase de novo FCs between different regions. Significant positive and negative correlations between pre-op. FCs and clinical improvements were identified. Further establishment and validation of prediction formula is required, but FCs in brain can be a novel biomarker for cervical myelopathy.

Figure 1



Presentation #27

Multiparametric Quantitative Magnetic Resonance Imaging of the Cervical Spine to Measure Microstructure and Tissue Injury

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Introduction: Clinical diagnosis of myelopathy is sometimes challenging, as certain symptoms (e.g. fine motor dysfunctions, gait impairment) can be subjective and transient in nature. The diagnosis often requires a highly trained clinician, yet cases with diagnostic uncertainty are relatively common and often this diagnosis can be fairly delayed leading to significant impairment for patients. Conventional MRI imaging only provides limited information about the structure and integrity of the spinal cord and presence of compression is not highly specific for myelopathy as 8-25% healthy subjects may have this finding.

We describe a multi-parametric quantitative MRI protocol for microstructure analysis of the spinal cord to determine the precise degree of injury to the spine in the setting of degenerative cervical myelopathy (DCM). These techniques provides measures of demyelination, axonal injury and atrophy in the spinal cord which may provide enhanced accuracy for cases with diagnostic uncertainty.

Methods: 35 healthy controls and 56 DCM patients scanned under the multi-parametric MRI protocol were included in the analysis. Each patient underwent a battery of clinical assessments by an experienced physician for presence or absence of myelopathic signs/symptoms (mJOA, GRASSP, Berg Balance, GaitRite). Subjects underwent MRI acquisitions using our protocol in a 3T GE clinical scanner. The multi-parametric protocol combines MRI techniques including conventional MRI, Diffusion tensor imaging (DTI, ssEPI), Magnetization transfer (MT, SPGR with/without prepulse), T2* weighted imaging (T2*WI, MERGE with 3 echoes) covering C1-C7.

Image analysis was done using the Spinal Cord Toolbox (SCT) v.3.0. We calculated spinal cord cross-sectional area (CSA), fractional anisotropy (FA), MT ratio (MTR) and T2*W white matter to grey matter ratio (T2*W WM/GM) at the maximally compressed level (MCL), rostral (C1-C3) and caudal (C6-7) levels.

Statistical analysis performed using R (version 3.4.3). Diagnostic models developed using subject characteristics and MRI data using 1) logistic regression (LR) with backwards stepwise variable selection, 2) linear discriminant analysis (LDA), 3) principle component analysis followed by logistic regression (PCA-LR), 4) k-nearest neighbors (kNN) with various k values (3,5,7), and 5) a support vector machine (SVM) model using a radial basis function kernel and various values for cost=(1,10,100,1000), and gamma=1. Logistic regression models were limited to 4 degrees of freedom.

Results: 10 measures of tissue injury identified in our protocol showed good correlation with neurological disability (R^2= 0.55). All 5 diagnostic models showed good diagnostic accuracy for DCM, with the SVM model showing the highest performance (AUC=95.6%),

Presentation #27 (cont.)

outperforming LR (AUC=93.6%), PCA-LR (AUC=89.0%), LDA (AUC=87.9%), and kNN (k=5, AUC=84.6%).

Conclusions: We have established a reliable, clinically feasible qMRI protocol that can be used for diagnosis, detection of subclinical tissue injury and can be potentially be use for prediction of outcomes in DCM. Results show that supervised machine learning algorithms can achieve greater diagnostic accuracy than conventional statistical approaches.

Presentation #28

Minimal Clinically Important Difference and Substantial Clinical Benefit Using PROMIS CAT in Cervical Spine Surgery

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Introduction: The National Institutes of Health Patient Reported Outcomes Measurement Information System (PROMIS) allows for improved psychometric properties with reduced questionnaire burden through computer adaptive testing (CAT). Despite studies showing good correlation with "legacy" outcome measures, there is little literature available the clinical significance of changes in PROMIS scores.

Methods: Adult patients undergoing cervical spine surgery were prospectively enrolled. All patients were administered the PROMIS Physical Function (PF) and Pain Interference (PI) CATs, Neck Disability Index (NDI), Short Form 36 (SF-36) physical component scores (PCS) and mental component scores (MCS), and visual analog scale (VAS) for arm and neck pain. Outcome measures were administered via assessmentcenter.net in a random order at enrollment, 2-weeks after enrollment but prior to surgery and at 6-month follow up. Patients were included for analysis if they had a pre-operative diagnosis of myelopathy, radiculopathy or myeloradiculopathy and if they had completed the 6-month follow-up. The minimal clinically important difference (MCID) was calculated using a distribution-based method (one-half standard deviation of the change in outcome measures). The threshold for substantial clinical benefit (SCB) was calculated using an anchor-based method. The Health Transition Item of the SF-36 was utilized as an anchor with the cut-off values chosen using receiver operating characteristic (ROC) curve analysis to maximize sensitivity and specificity. Standard error of measurement (SEM) was also calculated.

Results: 139 patients (83 males) met the inclusion criteria, with an average age of 56.4 years. 36 patients had a preoperative diagnosis of myelopathy, 48 had a diagnosis of radiculopathy and 49 had a diagnosis of myeloradiculopathy. 102 patients had anterior procedures while 37 had a posterior approach. Patients demonstrated significant improvements in PROMIS PF, PROMIS PI, NDI, and SF-36 MCS and PCS pre- to post-operatively ($p < 0.001$; **Table 1**). The test-retest reliability of all tests was excellent (ICCs = 0.87-.094). Using these values, we calculated the SEM and MDC for all tests (**Table 2**). PROMIS, SF-36 and NDI scores were

Presentation #28 (cont.)

all correlated with our anchor question (|r| = 0.34-0.48, p<0.001). MCIDs were established at 8.5 for the NDI, 11.1 for the SF-36 PCS, 9.7 for the SF-36 MCS, 4.9 for PROMIS PI, and 4.5 for PROMIS PF. SCB was established at 13 for the NDI, 24 for the SF-36 PCS, 11.8 for the SF-36 MCS, 6.85 for the PROMIS PI, 6.75 for the PROMIS PF. The MCID were greater than the SEM for all measures.

Conclusions: To our knowledge, this is the largest study to date to report on the MCID and SCB using PROMIS in the cervical spine. We report an MCID of 4.9 for the PI and 4.5 for the PF with the SCB threshold being closer to 6.8 (6.85 for PROMIS PI and 6.75 for PROMIS PF). Our MCID were greater than the SEM for all measures. These data support the use of PROMIS in cervical spine patients and support the use of the CATs as a method to reduce questionnaire burden. Lastly, our results provide important context to PROMIS scores as their reporting becomes more widespread in the literature.

	Mean ± SD	SEM
PROMIS Physical Function		
Preoperative	41.4 ± 8.2	2.97
Postoperative Improvement	7.0 ± 8.9	-
PROMIS Pain Intensity		
Preoperative	60.9 ± 7.1	2.30
Postoperative Improvement	-8.7 ± 9.7	-
Neck Disability Index		
Preoperative	34.1± 19.1	4.40
Postoperative Improvement	-17.0 ± 17.1	-
VAS Neck Pain		
Preoperative	3.5 ± 2.5	0.55
Postoperative Improvement	-2.2 ± 2.3	-
VAS Arm Pain		
Preoperative	3.9 ± 2.5	0.56
Postoperative Improvement	-2.1 ± 2.6	-
SF-36 Mental Component Score		
Preoperative	62.0 ± 20.3	6.10
Postoperative Improvement	12.5 ± 19.4	-
SF-36 Physical Component Score		
Preoperative	53.3 ± 19.7	4.97
Postoperative Improvement	19.3 ± 22.2	-

SD = Standard Deviation; SEM = Standard Error of Measurement; PROMIS = Patient Reported Outcomes Measurement Information System; VAS = Visual Analogue Scale; SF-36 = Short Form-36

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Presentation #28 (cont.)

Table 2. MCID and SCB for Patient-Reported Outcome Measures

Outcome Measure	MCID	SCB Net Change (AUC)
PROMIS Physical Function	4.5	6.8 (0.73)
PROMIS Pain Interference	4.9	6.9 (0.78)
Neck Disability Index	8.5	13.0 (0.72)
VAS Neck Pain	1.2	2.5 (0.67)
VAS Arm Pain	1.3	2.5 (0.68)
SF-36 Mental Component Score	9.7	11.8 (0.67)
SF-36 Physical Component Score	11.1	24.1 (0.71)

MCID = Minimum Clinically Important Difference; SCB = Substantial Clinical Benefit; AUC = Area Under Curve; SD = Standard Deviation; PROMIS = Patient Reported Outcomes Measurement Information System; VAS = Visual Analogue Scale; SF-36 = Short Form-36

Presentation #29

Discordance Between Functional Outcome and Self-Reported Ratings of Health Status After Surgery for Degenerative Cervical Myelopathy

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Introduction: Surgery has been shown to improve functional outcomes for patients with Degenerative Cervical Myelopathy (DCM)[1]. However, in spite of functional gains experienced, a proportion of patients remain dissatisfied with their outcome post-operatively. Our goals were to: 1) determine the incidence of such discordance between functional outcome and self-rated measures of health status after surgery for DCM, and 2) determine which patient and disease related factors underlie such discordance.

Methods: Analyses were based on 479 surgically treated DCM patients prospectively enrolled in the AOSpine International Myelopathy study across 16 global sites. Outcome data was collected pre-operatively and at 1-year post-operatively. Descriptive analyses were conducted to evaluate the concordance between achieving change in functional status equal to, or greater than, the MCID of the modified Japanese Orthopedic Association (mJOA) scale (1-point for mild, 2-points for moderate and 3 points for severe DCM)[2] and self-reported ratings of health status at 1-year post-operatively. Change in self-reported health was assessed by asking participants to rate their general health status at 1-year post-operatively as compared to pre-operative status (much better, somewhat better, the same, somewhat worse, much worse). Concordance was defined as achieving the MCID and reporting general health as somewhat better or much better, whereas discordance was defined as achieving a MCID and reporting general health as the same, somewhat worse or much worse. Logistic regression analysis was used to determine important differences between patients with discrepancies between their clinical measures and self-reported ratings and those without.

Results: Of 401 patients with follow-up at 1-year, 55 patients (14%) were somewhat or much worse than pre-op, 82 (20%) were the same and 264 (66%) patients were somewhat or much better. Sixty-three patients (16%) demonstrated discordance at 1-year: 17 patients who reported to be somewhat or much worse, and 46 patients who reported to be the same, achieved the MCID of mJOA. In univariate analyses, smaller improvement in mJOA upper extremity scores ($p=0.071$), older age ($p=0.0073$), smoking ($p=0.082$) and lower total mJOA scores at 1-year ($p=0.087$), predicted discordance. Following multivariate analysis, older age and smaller improvement in mJOA upper extremity scores remained the most important predictors ($p<0.05$).

Conclusions: After surgery for DCM, older patients, as well as those with smaller improvements in postoperative upper extremity scores, tend to report worsened or unchanged general health status, in spite of experiencing clinically significant improvement in overall post-operative function.

References:

Fehlings MG, et al. JBJS, 2013.PMID: 2404855
Tetreault L, et al. Spine, 2015. PMID:26502097

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #30

Does Severity of Preoperative Myelopathy Symptoms Impact Health-Related Quality of Life in Cervical Spondylotic Myelopathy?

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Introduction: Cervical spondylotic myelopathy (CSM) is a progressive disease resulting in a stepwise deteroriation. However, while it is generally accepted that patients with moderate and severe myelopathy should undergo surgical treatment, the benefits of early surgical intervention for patients with mild myelopathy is often debated. The purpose of this study is to compare the health-related quality of life (HRQOL) outcomes after surgery between patients with mild myelopathy to those with moderate-to-severe myelopathy.

Methods: A retrospective review of 117 consecutive patients treated with anterior or posterior cervical surgery for CSM at a single large institute was conducted. Patients were classified based on the severity of their myelopathy symptoms as either mild (mJOA ≥ 15) or moderate-to-severe (mJOA < 15). Patients who were surgically treated for CSM and completed a preoperative mJOA survey were included. Those who underwent surgery for trauma, tumor, revision, or infection were excluded. Outcomes compared between the two groups included preoperative and postoperative SF12 (PCS and MCS), NDI, VAS arm pain, VAS neck pain, and mJOA scores. The recovery ratio (RR) was also calculated for each outcome in order to measure the amount of improvement while accounting for baseline scores and the maximal potential improvement. The RR is calculated as the difference between the postoperative and preoperative outcome divide by the difference between the optimal score and the preoperative score. Also, a multiple linear regression analysis was used to predict postoperative mJOA while controlling for factors such as age, BMI, gender, surgical approach, levels fused, and preoperative outcome scores.

Results: There were 57.3% (n=67) with mild myelopathy and 42.7% (n=50) with moderate-severe myelopathy. The average age was 55.8 ± 11.9 years, and the average BMI was 29.9 ± 6.4, and the mean follow-up was 19.0 (11.0-29.9) months. At baseline, the mild myelopathy group had significantly higher PCS and MCS, and significantly lower NDI, neck pain, and arm pain than did the moderate-to-severe group ($p<0.05$) (Table 1). The moderate-to-severe group had significant improvements in all six HRQOL outcomes. Similarly, the mild group had significant improvements in all outcomes except for MCS. Postoperatively, the mild myelopathy group had significantly higher PCS ($p=0.047$) and mJOA ($p<0.001$) scores than patients with moderate-severe myelopathy. There was no difference in the RR

Presentation #30 (cont.)

between the groups for all HRQOL outcomes except for mJOA, which was significantly higher in the moderate-to-severe group (0.57 vs 0.22, p=0.003). Both younger patients (p=0.011, β-coefficient= -0.057, 95% CI: -0.10, -0.013) and higher preoperative mJOA (p=0.003, β-coefficient=0.318, 95% CI: 0.115, 0.520) predicted a higher postoperative mJOA in the multiple linear regression.

Conclusion: Early surgical intervention when patients present with mild myelopathy should be strongly considered. Despite having higher function and lower pain preoperatively, patients with mild myelopathy had significant improvements in functional status and pain after surgery, and these results were similar when compared to those with more severe myelopathy symptoms. Furthermore, early surgical intervention will allow patients to maintain their higher functional status and less severe symptoms of myelopathy after surgery.

Comparison of HRQOL Outcomes by Myelopathy Severity

	Mild Myelopathy		Moderate-to-Severe Myelopathy		
	Mean	Standard Deviation	Mean	Standard Deviation	P-value
Preop PCS	36.9	8.3	31.4	7.7	<0.001*
Postop PCS	44.6	8.9	40.7	9.8	0.047*
RR PCS	.17	.20	.19	.22	0.758
Preop MCS	51.0	10.1	46.5	13.0	0.041*
Postop MCS	53.2	10.4	52.4	10.7	0.702
RR MCS	-.03	.46	.08	.43	0.218
Preop NDI	28.5	17.6	40.6	19.0	<0.001*
Postop NDI	16.0	18.0	19.8	17.6	0.302
RR NDI	.35	.61	.53	.36	0.109
Preop Arm pain	4.3	3.7	5.9	3.3	0.016*
Postop Arm pain	2.0	2.7	2.5	2.5	0.331
RR Arm pain	.36	.74	.49	.55	0.375
Preop Neck pain	3.9	3.4	4.8	3.2	0.046
Postop Neck pain	2.1	2.4	1.9	2.0	0.636
RR Neck pain	.27	.70	.46	.69	0.208
Preop mJOA	16.5	1.2	12.3	2.1	<0.001*
Postop mJOA	16.8	1.5	15.3	3.0	0.001*
RR mJOA	.22	.62	.57	.46	0.004*

Table 1. The mean and standard deviation for each preoperative and postoperative HRQOL outcomes is presented for both mild and moderate-to-severe myelopathy. The recovery ratio (RR) represents the amount of improvement for that outcome normalized for maximal potential improvement. Independent t-test were used to compare the means between the two severity groups. Statistical significance was determined when P-value ≤ 0.05.

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Presentation #31

Risk Factors Associated with Failure to Reach Minimal Clinically Important Difference in Patient-Reported Outcomes Following Anterior Cervical Discectomy and Fusion

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Introduction: The minimum clinically importance difference (MCID) represents a threshold for improvements in patient-reported outcomes (PROs) that patients deem important. No previous study has comprehensively examined risk factors for failure to achieve MCID after ACDF procedures for radiculopathic symptomatology. The objective of this study is to determine risk factors for failure to reach MCID for Neck Disability Index (NDI), Visual Analogue Scale (VAS) neck pain, and VAS arm pain in patients undergoing 1- or 2-level anterior cervical discectomy and fusion (ACDF) procedures.

Materials/Methods: A surgical registry of patients who underwent primary, 1- or 2-level ACDF from 2014-2016 was reviewed. Rates of MCID achievement for NDI, VAS neck pain, and VAS arm pain at final follow up were calculated based on published MCID values. Patients were then categorized into demographic and procedural categories. Bivariate regression was used to test for association of demographic and procedural characteristics with failure to reach MCID for each PRO. The final multivariate model including all demographic and procedural categories as controls was created using backwards, stepwise regression.

Results: 83, 84, and 77 patients were included in the analysis for VAS neck, VAS arm, and NDI, respectively. Rates of MCID achievement for VAS neck, VAS arm, and NDI were 55.4%, 36.9%, and 76.6%, respectively (**Table 1**). Upon bivariate analysis, patients with Charlson Comorbidity Index (CCI) ≥ 2 were less likely to achieve MCID for NDI than patients with CCI < 2 (p=0.025). Upon multivariate analysis, CCI ≥ 2 (p=0.025) was further associated with failure to reach MCID for NDI (**Table 2**).

Conclusions: The results of this study suggest that the majority of patients do not reach MCID for arm pain. Additionally, higher comorbidity burden as evidenced by higher CCI scores is a negative predictive factor for the achievement of MCID in neck disability following ACDF.

Presentation #31 (cont.)

Table 1. Unadjusted rates of MCID for Neck Disability Index (N=77)*

	n/N	Rate of MCID (%)	RR	95% CI	P-value†
Overall	59/77	76.6%			
Age					0.084
18-50 years	34/40	85.0%	Ref.	-	
>50 years	25/37	67.6%	0.79	0.61-1.03	
Sex					0.497
Female	24/33	72.7%	Ref.	-	
Male	35/44	79.6%	1.09	0.84-1.42	
Obesity					0.073
Non-obese (<30 kg/m^2)	42/50	84.0%	Ref.	-	
Obese (≥30 kg/m^2)	17/27	63.0%	0.75	0.55-1.03	
Insurance status					0.540
Non-WC	44/56	78.6%	Ref.	-	
WC	15/21	71.4%	0.91	0.67-1.23	
Current smoker					0.450
No	51/65	78.5%	Ref.	-	
Yes	8/12	66.7%	0.85	0.56-1.30	
Ageless CCI					**0.025**
<2	**55/65**	**81.54%**	**Ref.**	**-**	
≥2	**4/12**	**12.50%**	**0.39**	**0.17-0.89**	
Operative Duration					0.197
≤50 minutes	37/45	82.2%	Ref.	-	
>50 minutes	22/32	68.8%	0.84	0.64-1.10	
Number of Operative Levels					0.134
1	39/47	81.40%	Ref		
2	20/30	63.33%	0.80	0.60-1.07	

*Patients undergoing ACDF reaching Minimal Clinically Important Difference (MCID) for Neck Disability Index (NDI) with minimum 6-month follow-up
n = number reaching MCID
CCI = Charlson Comorbidity Index; BMI = Body Mass Index; WC = Worker's Compensation
Boldface indicate statistical significance
†p-value was calculated for each category using Poisson regression with robust error variance

Presentation #31 (cont.)

Table 2. Independent risk factors for failure to reach MCID

	RR	95% CI	p-value†
NDI			
Ageless CCI			0.025
<2	Ref.	-	-
≥2	0.39	0.17-0.89	
VAS Neck			
No factors identified	-	-	-
VAS Arm			
No factors identified	-	-	-

NDI = Neck Disability Index; VAS = Visual Analogue Scale
* The final multivariate model was selected using a backwards stepwise process initially including all variables and sequentially excluding variables with the highest p-value until all remaining variables had p<0.05. All models initially included age, sex, BMI, insurance status, smoking status, CCI, operative time, and number of operative levels. Only variables listed in this table remained following stepwise selection.
RR = relative risk; CI = confidence interval.
†p-value was calculated for each category using a backwards, stepwise regression model

Presentation #32

Evaluating Range of Motion During In-Vivo Dynamic Cervical Spine Motions in Spondylosis Patients

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Introduction: Cervical spondylosis refers to age related degenerative changes in the upper region of the spinal column. Symptoms caused by this degeneration can be classified into axial neck pain, cervical radiculopathy and cervical myelopathy (syndrome of long tract findings from spinal cord involvement). One of the most commonly prescribed treatments for cervical degenerative disorders is anterior cervical discectomy and fusion (ACDF). However, radiographic follow-up studies reveal that as many as 90% of treated patients develop progressive adjacent segment disease (ASD) with up to 25.6% requiring reoperation at an adjacent segment due to symptomatic ASD. Concerns for ASD have been the rationale for developing total disc replacement (TDR) through preserving index level motion capability. However, recent studies show that clinical outcomes and post-operative re-operation rate at adjacent segments is very similar between ACDF and TDR patient groups. One explanation for this is that the quality of motion being restored after TDR does not represent in-vivo physiological motion. However, there is still no consensus on the etiology of ASD because strong in-vivo data showing longitudinal changes in biomechanics is currently lacking. Previous studies have not investigated how disc degeneration can alter the loading conditions of the spine and cause aberrant motion in spondylosis patients. Therefore, in this study we investigated range of motion at the adjacent segment (C4-5) using a very accurate in-vivo imaging technique to better understand quantity and quality of motion in spondylosis patients. We then compared the data with healthy asymptomatic age and sex matched control subjects to separate the aging factor. The aim of this study was to investigate whether in-vivo range of motion can be used as a viable predictor of ASD.

Methods: This study was approved by our Institutional Review Board (IRB) and each participant signed an informed consent prior to participation. Ten asymptomatic subjects and 8 spondylosis patients without prior spinal disorders with an average age of 40.3 years old were recruited from one academic center. Subjects were tested using a combined dual fluoroscopic imaging system and MRI based 3D modeling technique (Figure 1). Specifically, the MR images were used to construct 3D models of the vertebrae from C3 to C7. The contours of the vertebrae were digitized using the 3D slicer modeling software. Next, to examine in-vivo motion using the dual fluoroscopic imaging modality, the cervical spine of each subject was imaged dynamically from a maximum extension to maximum flexion and from maximum left twist to maximum right twist motion of the neck in three trials. The in-vivo positions of the cervical vertebrae at different motion positions were reproduced to investigate the range of motion at the adjacent segment (C4-5) during the dynamic flexion–extension and twisting motions of the neck. C4-5 range of motion during three dynamic movement trials was determined using projection angles (Pxj, Pyi, Pzi). The maximum range of motion at C4-5 motion segment was determined by the most positive and most negative intervertebral rotations over the three analyzed trials for each movement. An unpaired two-sample t-test

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was used to determine if the mean ROM during each movement was significantly different between the healthy control subjects and the spondylosis patients.

Results: On average, the total angle range of motion at the adjacent segment (C4-5) was significantly reduced in the spondylosis group when compared with the healthy control subjects during dynamic extension-flexion and left-right twisting motions of the cervical spine. Specifically, the average angle ROM in healthy control subjects was 15.61 degrees with a standard deviation of 5.67 degrees during the dynamic extension-flexion movement of the neck. However, the average angle ROM was only 9.62 degrees with a standard deviation of 4.45 degrees in the spondylosis patient group during the dynamic extension-flexion movement of the neck (Fig 1B). Moreover, the average angle ROM in healthy control group was 8.34 degrees with a 2.36 degree standard deviation during the left-right twist motion of the neck. The spondylosis patient group only had a 2.58 degree angle ROM with a standard deviation of 3.02 degrees during the left-right twist movement of the neck (Fig 1A). The t-test showed that during both motions, the angle ROM was significantly different ($P < 0.05$) between the two groups.

Discussion: This study evaluated the angle range of motion at the adjacent segment (C4-5) in spondylosis patients and compared the results with the age and sex matched healthy control subjects during dynamic extension-flexion and left-right twisting motions of the cervical spine. The results indicated that during both motions, the angle ROM was significantly reduced in the spondylosis group when compared to the healthy control subjects. These results are consistent with previous findings and suggest that degenerated segment affects the adjacent segment motion. In-vivo and in-vitro tests have shown that adjacent segment experiences greater stresses which can lead to accelerated disc degeneration. The present study indicates that motion preservation devices should be segment specific and should take in consideration the angle range of motion of the adjacent segment in order to prevent further disc degeneration.

Significance: This study provides valuable baseline reference data for evaluating the effects of age and degeneration on the adjacent segment angle ROM during dynamic functional loading movements of the cervical spine. This data can be used as a reference in improving artificial disc designs so the artificial disc can restore the physiological range of motion at the index level without affecting adjacent segment kinematics.

References: [1] Wang S et al. Spine. 2011. [2] Wand S et al. J Biomech. 2009. [3] Anderst WJ et al. J Biomech. 2015. [4] Mummaneni PV et al. J Neurosurg Spine. 2007. [5] Ren C et al. Eur Spine J. 2014. [6] Brodke DS et al. J Bone Joint Surg Am. 2006

Presentation #32 (cont.)

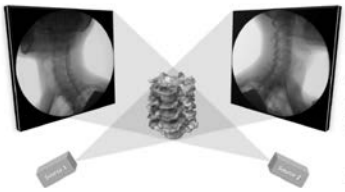

Figure 1. The virtual DIFS for reproduction of the in-vivo cervical vertebrae positions.

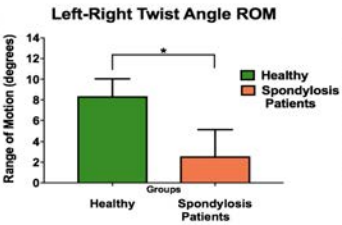

Figure 2A. Extension-Flexion Angle ROM in healthy and Spondylosis patients

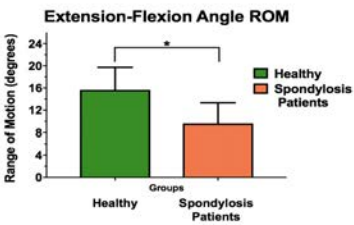

Figure 2B. Left-Right Twist Angle ROM in healthy and Spondylosis patients.

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Presentation #33

The Rate of Heterotopic Ossification Following Cervical Disc Arthroplasty: A Systematic Review and Comparison of Data

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Background: Heterotopic ossification (HO) is a potential complication of increasing clinical concern following cervical disc arthroplasty (CDA). While the investigational device exemption (IDE) studies have reported a relatively low rate of HO following CDA, several independent non-conflicted studies have suggested a significantly higher rate of HO.

Introduction: CDA is a well-established surgical modality for treatment of one- and two-level degenerative disc disease resulting in radiculopathy, myelopathy or myeloradiculopathy that has failed conservative treatment. Despite its proven mid-term clinical success, the potential for accelerated HO following CDA remains an active area of clinical concern. While the IDE studies report a relatively low rate of HO, several independent non-conflicted studies demonstrate higher rates of HO. While it remains unclear the clinical ramifications of HO development following CDA, high grade HO may restrict the desired motion preservation properties of CDA. The purpose of the current study is to perform a systematic review of the literature and determine the overall incidence of HO following CDA as well as per annum rates. As a secondary objective, we aim to compare the data obtained from the IDE studies vs independent studies to determine if an observation bias may exists amongst reported outcomes.

Methods: A MEDLINE literature search was performed using PubMed, the Cochrane Database of Systematic Reviews, and Embase from January 1980 to February 2018 using Medical Subject Heading queries for the terms: ((disc OR disk) AND (arthroplasty OR replacement OR prosthesis)) AND (ACDF OR discectomy OR fusion OR cervical OR arthrodesis) AND ((HO OR delayed fusion OR spontaneous fusion OR Heterotopic Ossification)). We included studies involving adult patients, who underwent CDA, documentation of HO, with >12 month follow up. The pooled results were obtained by calculating the effect size based on the logit event rate. Per annum rates were determined based on weighted averages according to average follow-up period.

Results: The initial database review resulted in 230 articles. After abstracts were reviewed, 19 articles that met inclusion criteria were identified: 8 IDE studies and 11 independent studies. Redundant studies (IDE 2-, 5-, 7-year etc) were excluded and only the most recent, longest follow-up studies were included. Mean age of patients included was 43.2. The mean follow up was 51.3 months. The overall rate of HO was 29.7%. The overall per annum rate of HO was 5.9% per year. The rate of HO reported by IDE studies was 17.7% while non-conflicted studies reported a rate of 68% ($p < 0.0001$).

Presentation #33 (cont.)

Conclusion: The findings of the pooled data show the incidence of HO following CDA to be 5.9% However, there is a significant difference in reported rates of HO between IDE and non-conflicted, independent data. This data suggests that HO may be underreported in the industry sponsored IDE studies when compared to independent non-conflicted studies.

Presentation #34

Comparing Range of Motion in Follow Up of Anterior Cervical Discectomy with or without Interbody Fusion and Arthroplasty

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Introduction: Many previous studies reported that in cervical discectomy with arthroplasty range of motion (ROM) was maintained. However, the vast majority of these studies focused on ROM at the index level. Only limited research was performed into ROM of the total cervical spine after anterior discectomy. In this study, we compared the ROM at both index level and of the total cervical spine (C2 to C7) of patients treated by anterior cervical discectomy with or without interbody fusion and arthroplasty for cervical radiculopathy.

Methods: 111 patients with one level disc herniation were randomly treated by anterior cervical discectomy with arthroplasty (ACDA), anterior cervical discectomy with intervertebral cage (ACDF), or anterior cervical discectomy without intervertebral cage (ACD). Range of motion was measured independently using Cobb's method on both index level and total cervical spine from C2 to C7 preoperatively, 12 and 24 months.

Results: At 2 years follow-up, the overall radiological follow-up rate was 78.6%. The most common operated level was C5-C6 (53.2%), followed by C6-C7 (45.9%). There was no significant difference in ROM at index level and total cervical spine between groups at baseline. For index level, at 1 year follow up, ACDA patients had a significantly higher ROM than patients with ACDF (P=0.031), and at 2 years follow-up, ACDA patients had a significantly higher ROM than both ACD and ACDF patients (P=0.017 and P=0.015). ROM of the total cervical spine, was comparable for the 3 patient groups, neither at 1 year nor two years follow-up (P=0.532 and P=0.562).

Conclusions: Cervical discectomy with arthroplasty segmental range of motion at index level is persisting. However, loss of ROM in anterior discectomy with fusion is compensated since ROM of the whole cervical spine (C2-C7) is comparable to ACDA C2-C7 ROM. For patients with single-level cervical discectomy, the advantage of arthroplasty for maintaining range of motion of the whole cervical spine is not confirmed.

Presentation #35

Timing of Tracheostomy After Anterior Cervical Discectomy and Fusion

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Introduction: Spinal cord injury (SCI) is a devastating, life-altering event with significant associated morbidity and mortality. Approximately 17,000 new spinal cord injuries occur annually in the US, with more than half involving the cervical cord. In addition to paralysis, high cervical cord injuries are often associated with respiratory failure due to phrenic and intercostal nerve deficits, requiring tracheostomy and long term ventilation. High SCIs often require operative stabilization with anterior cervical discectomy and fusion (ACDF). Current practice often delays tracheostomy following ACDF for 5-7 days out of concern for increased risk of an infection.Although ACDF has a low baseline rate of surgical site infection (SSI), the concern is that infection from the tracheostomy will seed the fusion hardware and require a morbid reoperation. The method of tracheostomy has further clouded the discussion, as percutaneous and open tracheostomies have different rates of documented SSI. We hypothesized that there would be no association between infection and timing between tracheostomy and ACDF, and that this common delay in therapy is unnecessary.

Materials/Methods: We performed a 5-year retrospective study at our Level 1 trauma center and identified patients admitted with cervical SCI who underwent both ACDF and tracheostomy. Demographics and injury specifics are provided in **Table 1**. Data extracted from medical records included dates of operations, need for reoperation, and the occurrence of infection. Patients were categorized into groups based on the length of time between procedures (0-3, 4-6, 7-14, and >14 days). The types of tracheostomies performed were also recorded to compare open versus percutaneous approaches.

Results: During the 5-year study period, 23,410 adult trauma patients were admitted, and 961 had spinal cord injuries (4.1%). The cervical cord was injured in 69% (664), and 23% (150) of them required tracheostomy. After chart review, we identified 69 patients that underwent both ACDF and tracheostomy. Subgroup analyses identified 12 patients whose procedures were separated by 0-3 days, 16 separated by 4-6 days, 36 separated by 7-14 days, and 5 separated by >14 days separation. Open tracheostomy was performed in 77% (53 patients) and the percutaneous approach was used in the remaining 23%. There were no surgical site infections in any of the patients, regardless of timing or tracheostomy technique (**Table 2**).

Conclusion: There were no observed changes in the numbers of surgical site infections according to the timing of cervical ACDF and tracheostomy irrespective of technique.

Presentation #35 (cont.)

Table 1. Demographics of patients included in study

Time Period	1-3 Days	4-6 Days	7-14 days	>14 days	Total
n	7	17	39	6	69
Age, y	60.6 ± 12.9	54.1 ± 17.5	44.2 ± 15.8	35.5 ± 14.2	47.5 ± 17
Length of stay, days	20.3 ± 14	27 ± 15.9	29.5 ± 18.4	41.5 ± 16.8	29 ± 17.6
Caucasian (%)	28.6	58.8	53.8	50	52.2
Men (%)	85.7	88.2	71.8	83.3	78.2
Mechanism					
Motor vehicle accident	2	8	27	6	43
Motor cycle accident	1	3	2	0	6
Fall from standing	2	3	2	0	7
Fall from height	0	1	2	0	3
Fall down stairs	0	1	2	0	3
Other	2	1	3	0	6
ISS	28.9 ± 22.7	25.5 ± 6.6	32.3 ± 13.1	37.5 ± 18.4	30.73 ± 13.5

Table 2. Summary of Data Involving Timing of Tracheostomy Relative to ACDF.

Time Period	1-3 days	4-6 days	7-14 days	>14 days
Number of patients	7	17	39	6
Average days between ACDF and tracheostomy	2.7	4.9	9.5	22.5
Open Tracheostomies	6	15	32	3
Percutaneous Tracheostomies	1	2	7	3
Tracheostomy Infections	1	0	0	0
ACDF Surgical Site Infections	0	0	0	0

Presentation #36

Clinical Adjacent Segment Pathology Risk is Less Following Cervical Disc Arthroplasty Compared to Anterior Cervical Discectomy and Fusion at 7 Years Postop

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Introduction: One of the primary motivations for the development of cervical disc arthroplasty (CDA) technologies has been a perceived protection against adjacent segment pathology (ASP) through motion preservation. Though much has been reported regarding radiographic ASP (rASP) between CDA and ACDF, there continues to be a paucity of literature comparing the effects of these treatments on clinical ASP (cASP). While there are multiple clinical indicators of ASP, adjacent level surgeries are finite and therefore the focus of this analysis

Materials/Methods: We performed post- hoc analyses of factors associated with ASP collected through 7 years in a prospective, randomized, controlled clinical trial comparing CDA to ACDF at one or two contiguous levels. The patient population consisted of 575 randomized patients: 164 one-level CDA and 81 one-level ACDF; 225 two-level CDA and 105 two-level ACDF. Kaplan-Meier survival curves for adjacent level surgery were compared using the log-rank test. Cox regression was used to assess the impact of treatment on the relative risk of adjacent level surgery.

Results: Overall follow-up rate was 74.6%.
Patients undergoing a secondary surgery at one or both adjacent levels was almost 3.5 times higher in 1-level ACDF (14.8%) compared to 1-level CDA (4.3%) and more than 2.5 times higher for 2-level ACDF (12.4%) compared to two-level CDA (4.9%). Kaplan-Meier survival estimates of the probability of adjacent level surgery were significantly higher for ACDF over CDA ($p < 0.0001$). The estimated rate of adjacent level surgery per 100 persons per year was 2.5 for ACDF and 0.7 for CDA ($p < 0.0001$), a more than 3.5 fold difference.

In the Cox model, treatment was a significant baseline predictor of adjacent level surgery, with a patient treated with ACDF being 3.9 times more likely to undergo adjacent level surgery than one treated with CDA ($p = 0.0001$).

Conclusion: At 7 years followup, risk of requiring an adjacent segment surgery is 2.5 and 3.5 times greater for one and two level disease, respectively, when treated with ACDF vs CDA as the index procedure. This is the first analysis of a randomized controlled clinical trial to demonstrate a clear advantage of CDA compared to ACDF in the rate of cASP following both one and two level surgeries. These data should compel surgeons to consider CDA as not only a viable option but as a preferred treatment in patients consistent with this study population.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #37

Analysis of Re-Operations After Cervical Total Disc Replacement in a Consecutive Series of 504 Patients Receiving the Same Device Type

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Introduction: One important factor in evaluating the safety of an implant is the rate of subsequent surgery and the reasons for surgery, particularly those that are related to possible problems with the implant. The purpose of this study was to determine the re-operation rate for a series of cervical total disc replacement (TDR) patients.

Methods: Cervical TDR cases involving one implant type were identified, beginning with the first case performed in 2003 at a multisite spine specialty center. Only patients who were at least 2 years post-operative were included, producing a consecutive of 504 patients. The number of levels operated was: 1 level in 463 patients, 2 levels in 39 patients, and 3 levels in 2 patients. There were 112 hybrids in the series (TDR at one level and fusion at an adjacent segment). Study records and a surgery log through 12-31-17 was searched to identify re-operations that occurred in this patient population. For each re-operation, the reason, duration from index surgery, and procedure were recorded. The mean duration form the index surgery to the search for re-operations was 69.4 months, range 24 to 169 months.

Results: Re-operation occurred in 28 patients (5.5%). These included: 3 TDR removals and ACF performed (1 for migration, 1 subsidence, and 1 spondylosis), 1 TDR repositioning, 20 adjacent segment degeneration (5 of which were hybrid procedures or fusion prior to TDR) , 1 wound infection, 1 hematoma and 2 received stimulators for pain control. There were no re-operations for device failure. The mean duration between the index surgery and re-operation at an adjacent segment was 44.8 months.

Conclusion: The re-operation rate was relatively low at 5.5%, none of which were performed for device failure. These results support the safety of the device.

Presentation #38

Are Outcomes of ACDF Influenced by Presurgical Depressive Symptoms on the Mental Component Score of the Short Form 12 Survey?

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Introduction: The relationship between the mental component score (MCS) of the SF-12 and disability after an ACDF is uncertain. The purpose of this study was to investigate whether presurgical depressive symptoms measured by the MCS influenced disability following an ACDF.

Methods: A cohort study was performed comparing people with and without depressive symptoms on the MCS who underwent an ACDF for a degenerative cause. Patients with trauma, tumor infection, previous cervical spine surgery, or those with less than one year of clinical follow up were excluded. Outcomes including NDI, SF-12 PCS, VAS arm pain, VAS neck pain were evaluated. An MCS < 45.6 was used as a diagnostic criteria of depressive symptoms. Outcomes were compared among the depressive and non-depressive group using linear mixed effect models, controlling for age, sex, and BMI. Results were reported with 95% confidence interval.

Results: Two hundred and sixty four patients were included with a mean follow up was 19.8 (range 12-46.6) months. The mean age was 53.1 (range 18-84) years old, and the mean BMI was 29.6 (range 18.7-54.9). There were 135 patients with an SF-12 MCS < 45.6, and 129 with an SF-12 MCS > 45.6. The mean improvement in NDI was 16.8 points (95%CI: -19.93,-13.72, p<0.001). Compared to the patients with an MCS > 45.6, patients with an MCS< 45.6 had higher NDI both preoperatively, 48.86 (95%CI: 45.80, 51.92) versus 35.73 (95%CI: 32.45, 39.00) (p<0.0001) and post-operatively, 29.05 (95%CI: 25.04, 33.07) versus 22.01 (95%CI: 18.44, 25.58) (p=0.01), but both groups demonstrated a significant improvement from baseline (p<0.0001). While the patients with an MCS < 45.6 of had more disability postoperatively, these patients demonstrated even greater benefit from surgery, as the improvement of the NDI was actually greater than patients with a higher MCS, -19.8 versus -13.7 (p=0.011).

Mean improvement of PCS after ACDF was 7.78 (95%CI: 6.27, 7.30, p<0.001). No significant difference in baseline PCS was found between patients with an MCS < 45.6 (32.87(95%CI:

Presentation #38 (cont.)

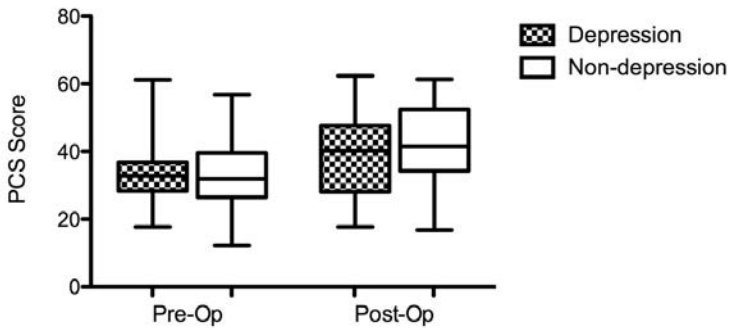
31.69, 34.06)) and those with an MCS > 45.6 (33.54(95%CI: 31.92,35.16)). Both groups demonstrated statistically significant improvement from baseline, with the final PCS scores of 39.06 (95%CI: 37.13, 40.99) in patients with an MCS < 45.6, and 42.10 (95%CI: 40.22, 43.97) in patients with an MCS > 45.6 PCS (p = 0.043). Importantly, while the final PCS score was lower in patients with an MCS < 45.6 they reported more improvement (p=0.04) compared to patients with an MCS > 45.6 (Figure 1).

Similarly, when evaluating both VAS neck and VAS arm, the results were similar (Figure 2); patients with a low MCS had higher level of preoperative neck pain (p<0.001), and arm pain (p<0.0001). However, while their pain was still higher postoperatively (p=0.0011) than patients with an MCS > 45.6, the patients with low MCS reported more pain improvement(p<0.01) than those with an MCS > 45.6.

Conclusion: Patients who presented with presurgical depressive symptoms identified on MCS reported more severe symptoms preoperatively and postoperatively, however in spite of residual symptoms these patients actually benefited more from surgery than those without depressive symptoms.

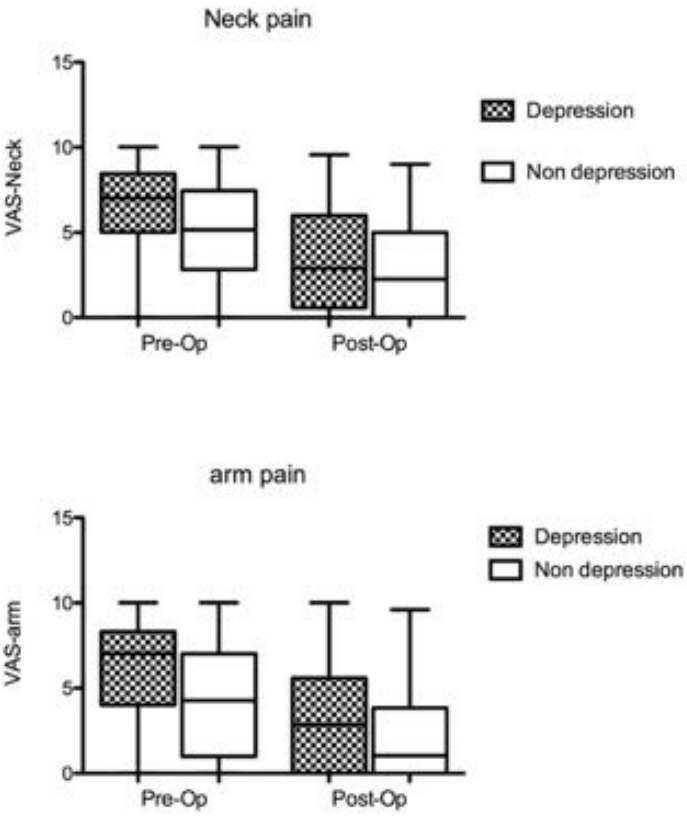
Figure 1

Comparison of PCS score between depressive and non-depressive patients



Presentation #38 (cont.)

Figure 2



Presentation #39

Crossing the Cervicothoracic Junction in Cervical Spine Fusion Surgery Involves Higher Operative Risks, but Superior Long-Term Outcomes

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Background Context: Whether the cervicothoracic (CT) junction should be crossed in cervical spine fusion surgery remains up for debate. Keeping C7 as the distal end of the fusion risks adjacent segment disease (ASD) and can result in myelopathy or radiculopathy. Longer fusions are thought to increase operative risk and complexity, but result in lower rates of ASD. This study evaluates the risks and benefits of crossing the CT junction in cervical spine fusion surgery.

Methods: We completed a retrospective review of patients undergoing cervical spine fusion surgery from 2005 to 2016 at a single tertiary care center. Only patients with fusions ending at C7 or T1 and ≥2-year follow-up were included. To evaluate operative risk, estimated blood loss (EBL), operative time and length of hospital stay were collected. Revision surgery data was also obtained. To evaluate patient-reported outcomes (PROs), Neck Disability Index (NDI) and SF-12 questionnaires (PCS12 and MCS12) were obtained both preoperatively and at follow-up. Changes in PRO scores (D) were analyzed. In terms of PROs, available data was limited.

Results: 177 patients were included (mean age 57.4 years) and divided into a C7 end-of-fusion cohort (N_{C7}=61) and a T1 end-of fusion cohort (N_{T1}=116, CT-crossing). Multivariate regression analysis adjusting for age, gender and race showed that EBL (262 vs. 456 mL, p=0.02) and operative time (254 vs. 317 min, p=0.03) are significantly increased in the T1 end-of-fusion cohort. Length of hospital stay was not significantly different (4.0 vs. 5.7 days, p=0.41) (Figure 1). Mann-Whitney analysis of PROs showed no significant difference in ΔNDI (-6.4 vs. -4.3 pts, p=1), ΔPCS12 (-1.6 vs. 0.1 pts, p=0.16) or ΔMCS12 (3.2 vs. -0.5 pts, p=0.25) between cohorts (Figure 2). Fisher analysis showed significantly higher revision rates in the C7 end-of-fusion cohort (6/61 for C7 vs. 2/116 for T1, OR=5.6, CI=[1.0, 58.8], p=0.03).

Conclusion: Crossing the CT junction in cervical spine fusion surgery increases blood loss and operative time, thus resulting in a longer, riskier operation that may not be suitable for fragile patients. However, crossing the CT junction also leads to lower revision rates, likely due to the avoidance of ASD, and comparable PROs. Thus, the higher short-term risks of crossing the CT junction may be justified given it can help prevent complications without negatively affecting long-term PROs.

Presentation #39 (cont.)

Figure 1. Estimated Blood Loss and Operative Time are significantly increased in the T1 end-of-fusion cohort. There was no significant difference in Length of Hospital Stay.

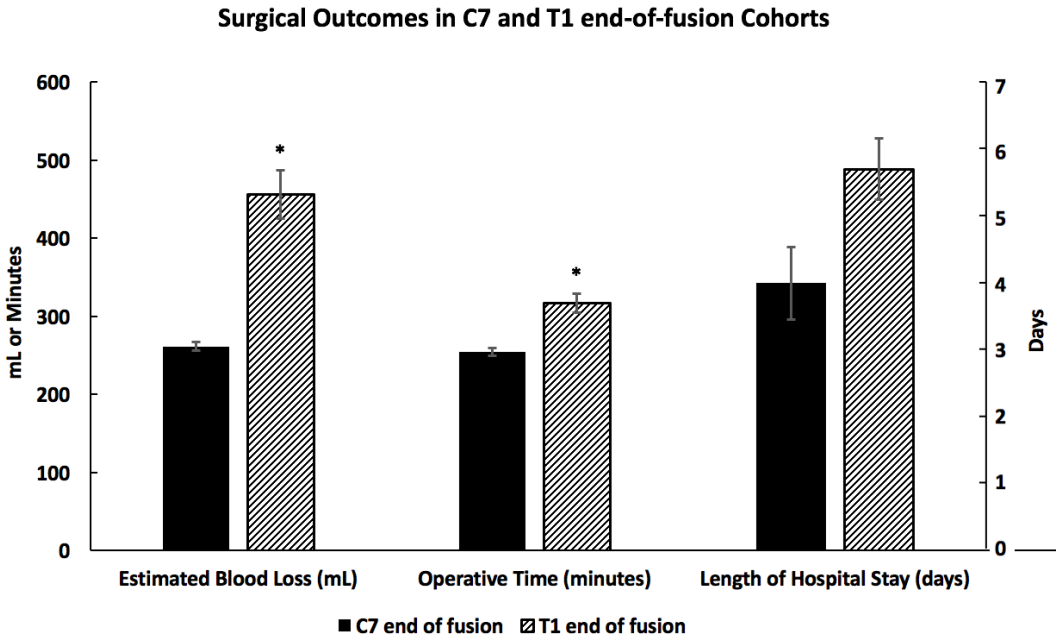
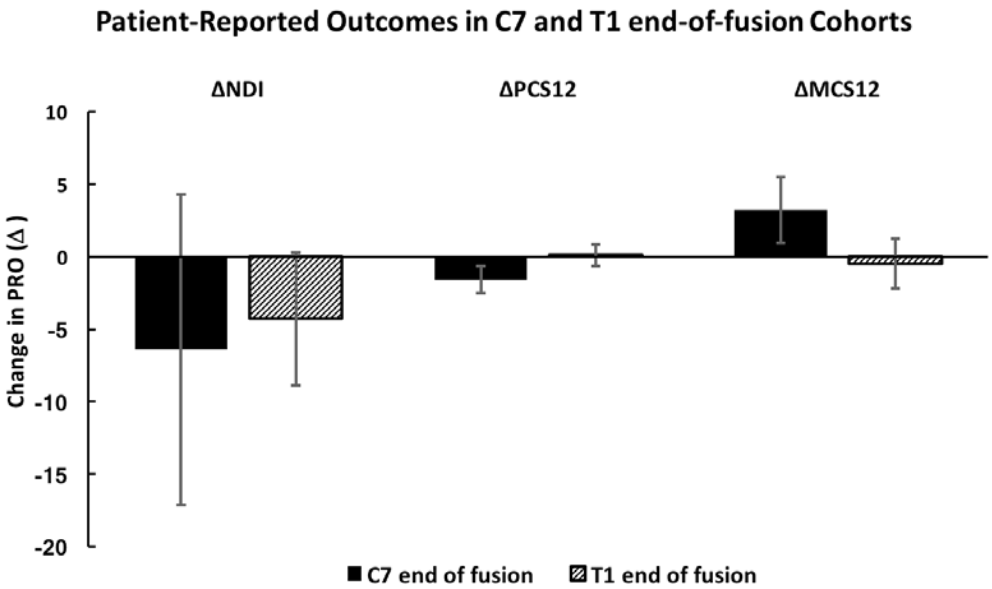


Figure 2. There was no significant difference in patient-reported outcomes (ΔNDI, ΔPCS12 and ΔMCS12) between the C7 end-of-fusion cohort and the CT-crossing cohort.



Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #40

Metabolic Syndrome and 30-Day Outcomes Following Elective Anterior Cervical Discectomy and Fusion (ACDF)

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Introduction: Metabolic Syndrome(MetS) is defined as the presence of a combination of hypertension, diabetes mellitus and obesity. Past literature has reported MetS to complicate post-operative care in patients undergoing various surgical procedures. With an increasing number of MetS patients undergoing spine surgical procedures and current evidence with regards to anterior cervical discectomy and fusion(ACDF) to be limited, we sought to analyze the impact of MetS on 30-day outcomes following elective ACDF.

Materials & Methods: The 2015-2016 American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) database was queried using Current Procedural Terminology (CPT) codes 22551 (single-level)) and 22552 (additional level). Patients undergoing disc arthroplasty, multi-level (>2) fusion, posterior cervical spine surgery, and patients with fracture, tumour, infection were excluded. MetS was defined using a pre-set criteria used by other NSQIP studies as the presence of - 1) diabetes mellitus AND 2) hypertension requiring medication AND 3)BMI≥30kg/m^2. Uni-variate analysis was performed using Pearson-Chi square tests to assess for significant unadjusted associations between MetS and 30-day outcomes. Multi-variate regression analysis using a backward-elimination approach was then used to analyze the impact of Metabolic syndrome on 30-day outcomes while controlling for all baseline demographics, pre-operative and operative clinical characteristics.

Results: A total of 1,384 (8.8%) patients with MetS underwent a cervical fusion. Unadjusted uni-variate analysis showed that presence of MetS was significantly associated with higher odds of prolonged length of stay, respiratory complications, cardiac complications, renal complications, bleeding requiring transfusions, sepsis/septic shock, 30-day reoperations, 30-day readmissions and non-home discharge **(Figure 1)**. Following adjusted analysis, results showed that presence of MetS was only associated with higher odds of a prolonged length of stay≥3 days (OR 1.32 [95% CI 1.12-1.56]; p=0.001)**.** No significant association was found between MetS and 30-day reoperations, 30-day complications, 30-day re-admissions, a non-home discharge and death **(Figure 2)**.

Conclusion: While MetS was associated with a prolonged length of stay, it's presence does not have a large impact on 30-day outcomes following elective ACDF. Providers can utilize this data to disseminate knowledge regarding the minimal impact of MetS on 30-day outcomes among patients and hospital staff to address concerns of peri-operative care, expedite discharge and thus curb excess healthcare costs.

Presentation #40 (cont.)

Figure 1: Uni-variate analysis for significant complications associated with prior existence of MetS.

30-day Outcomes			
Variable	**With Metabolic Syndrome**	**Without Metabolic Syndrome**	**P-value**
Length of stay (days)			**<0.001**
0-2 days	1159(83.7%)	12988(90.5%)	
≥3 days	225(16.3%)	1363(9.5%)	
Surgical Site Infections (Superficial/Deep/Organ-Space)	11(0.8%)	68(0.5%)	0.107
Respiratory complications	26(1.9%)	102(0.7%)	**<0.001**
Cardiac complications	7(0.5%)	32(0.2%)	**0.043**
Thrombo-embolic complications	5(0.4%)	45(0.3%)	0.763
Renal complications	4(0.3%)	8(0.1%)	**0.003**
Urinary tract infection(UTI)	6(0.4%)	72(0.5%)	0.730
Bleeding Transfusions	3(0.2%)	9(0.1%)	**0.047**
Stroke	0(0%)	12(0.1%)	0.282
Sepsis/Septic Shock	4(0.3%)	24(0.2%)	0.284
30-day reoperations	27(2.0%)	181(1.3%)	**0.032**
30-day readmissions	66(4.8%)	403(2.8%)	**<0.001**
Death	2(0.1%)	18(0.1%)	0.849
Discharge destination			**<0.001**
Home	1305(94.3%)	13860(96.6%)	
Non-Home	79(5.7%)	491(3.4%)	

Figure 2: Adjusted analysis showing the impact of metabolic syndrome on significant post-operative outcomes in patients undergoing 1-to-3 level ACDF. Each post-operative complication category with p<0.05 from univariate analysis was entered into a backward elimination model which adjusting for all baseline demographic and clinical characteristics.

Outcome Variable	Odds Ratio [95% CI]	P-Value	AUC [95% CI]
Length of stay(days) ≥3 days	1.32 [1.12-1.56]	**0.001**	**0.76 [0.74-0.77]**
Respiratory Complications	1.50 [0.95-2.38]	0.081	**0.79 [0.76-0.83]**
Cardiac Complications	1.28 [0.54-3.06]	0.579	**0.79 [0.72-0.87]**
Renal Complications	2.43 [0.64-9.32]	0.195	**0.92 [0.80-1.00]**
Bleeding Transfusions	2.90 [0.71-11.77]	0.137	**0.87 [0.79-0.95]**
30-day reoperations	1.14 [0.74-1.74]	0.554	**0.68 [0.64-0.71]**
30-day readmissions	1.20 [0.91-1.59]	0.193	**0.66 [0.64-0.69]**
Non-Home Discharge	1.02 [0.79-1.33]	0.867	**0.77 [0.75-0.79]**

Adjusted for age, gender, smoking, dyspnea, functional health status, ventilator dependence, severe COPD, ascites, CHF, pre-op ARF, currently on dialysis, disseminated cancer, steroid use, >10% body weight loss in last 6 months, bleeding disorders, transfusion≥1 unit packed RBCs 72 hours before surgery, presence of prior sepsis, ASA grade, admission status, total operative time, type of anesthesia, and number of levels fused.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #41

Role of the Sodium/Glutamate Blocker Riluzole in Enhancing Functional Outcomes in Patient Undergoing Surgery for Degenerative Cervical Myelopathy: Results of the Prospective, Multicentre Double Blind Controlled CSM-Protect Randomized Trial

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Introduction: Degenerative cervical myelopathy (DCM), which encompasses cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament, is the most common cause of spinal cord impairment. Decompressive surgery is the most effective treatment, however, most patients are left with residual neurological impairment and some experience neurological decline. Based on strong preclinical basic science evidence and collateral evidence from trials in human spinal cord injury and amyotrophic lateral sclerosis, we sought to explore if the sodium-glutamate antagonist riluzole would enhance neurological recovery and reduce perioperative neurological decline.

Methods: This is a phase III multi-center, double-blind, placebo-controlled, randomized controlled trial. Between March 2012 and June 2017, 300 surgically naive patients with moderate to severe DCM were enrolled at 16 sites. Subjects were randomized 1:1 to either the 50 mg riluzole bid or placebo-controlled group, beginning the medications at 14 days pre-surgery and ending at 28 days post-operative. Follow-up was at 6- and 12-months to determine the primary endpoint, change in mJOA scores; and the secondary endpoints, change in SF-36v2, Neck Disability Index (NDI), Nurick grade, EQ-5D, ASIA motor and sensory scores, Bazaz scale, Visual Analog Scale (VAS) for Pain, grip strength and neurological compilations.

Results: The average age was 57.9 years (SD 10.2); 55.7% males; 80.1% white; 9.7% black. Baseline mJOA score was 11.84 (SD 1.5, range 8 to 14); Nurick grade was 3.3 (SD

Presentation #41 (cont.)

0.8); NDI 42.9 (SD 13.5); VAS arm/shoulder 4.7 (SD 2.9); VAS neck 4.9 (SD 3.0). The study will complete in December 2017 with a projected follow-up rate exceeding 90%. Efficacy results will be available and presented at the conference.

Conclusions: This study contributes Level I evidence concerning efficacy and safety of riluzole as an adjunct therapy to decompressive surgery for patients with DCM.

Key Words: Riluzole, cervical spondylotic myelopathy, ossification of the posterior longitudinal ligament (OPLL), degenerative cervical myelopathy, efficacy, surgical treatment, pharmaceutical treatment, randomize controlled trial

Presentation #42

Use of Recombinant Human Bone Morphogenetic Protein-2 at the C1-2 Lateral Articulation in Posterior Atlantoaxial Fusion in Adult Patients with or without Conventional Structural Bone Graft

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Introduction: Posterior atlantoaxial fusion is an important armamentarium for neurosurgeons to treat several pathologies involving the craniovertebral junction as well as the upper cervical region, including degenerative diseases, trauma, and basilar invagination. In terms of bone graft options surrounding this region, various methods have been documented in the literature, such as structural autograft/allograft, morselized autograft/allograft, and recombinant human bone morphogenetic protein-2 (rhBMP-2). Although the potential advantages of rhBMP-2 over autograft and/or allograft alone are well-documented in the lumbar spine, its indication in posterior atlantoaxial fusion has not been well-characterized. In our institution, for selected adult cases of posterior atlantoaxial fusion where risk of pseudoarthrosis is deemed high such as revision surgeries, the elderly, and/or patients with poor bone quality, we apply rhBMP-2 to the C1-2 joint, either (A) alone or with hydroxyapatite and/or locally harvested autograft chips, or (B) with conventional structural autogenic/allogenic bone graft (SAABG). Here, we will compare clinical outcomes of the two groups with special attention to their fusion rates to elucidate feasibility of the techniques.

Methods: Single-center, retrospective data review from 2008 to 2014 identified 58 patients who underwent posterior atlantoaxial fusion with rhBMP-2. They were further classified into (A) 34 patients without SAABG (11 patients with rhBMP-2 only, 11 patients with rhBMP-2 plus hydroxyapatite, and 12 patients with rhBMP-2 plus morselized autograft) and (B) 24 patients with SAABG. In terms of surgical techniques, after posterior decompression had been achieved, both C1 and C2 were decorticated bilaterally at the C1-2 lateral articulation and collagen sponge strips with rhBMP-2 were inserted into the joints. Clinical records of these 58 patients were collected and statistically analyzed. P values <.05 were regarded as statistically significant.

Presentation #42 (cont.)

Results: Baseline characteristics such as age, sex, BMI, and smoking status, no statistically significant differences were identified. The overall fusion rate was 94.8% (55/58), which was comparable to other conventional techniques documented in the literature. The (A) group had significantly shorter operative time (p=0.03) and less estimated blood loss than the (B) group (p=0.003). Long-term complication rates were similar between the two groups: one-year C1-2 instability/pseudoarthrosis rate, (A)5.8% versus (B)4.2%, p=1; one-year instrumentation failure rate, (A)8.8% versus (B)12.5%, p=0.68; one-year revision surgery rate, (A)8.8% versus (B)16.7%. p=0.43. No surgical site infections, ectopic ossifications, soft-tissue edema at the surgical site, or donor-site morbidities (group (B) only) were noted in both groups. Representative images from the group (A) were shown in Figure 1. Time-to-fusion analysis revealed no statistically significant difference between the two groups (p = 0.47, Figure 2).

Conclusions: Albeit retrospective, single-center nature of the study, it was demonstrated that the use of rhBMP-2 at the C1-2 joint without conventional SAABG was a safe, reasonable alternative with the long-term outcomes comparable to rhBMP-2 with SAABG or historical controls in the literature. Future prospective, multi-center studies will be necessary to further scrutinize efficacy and safety profile of this surgical strategy.

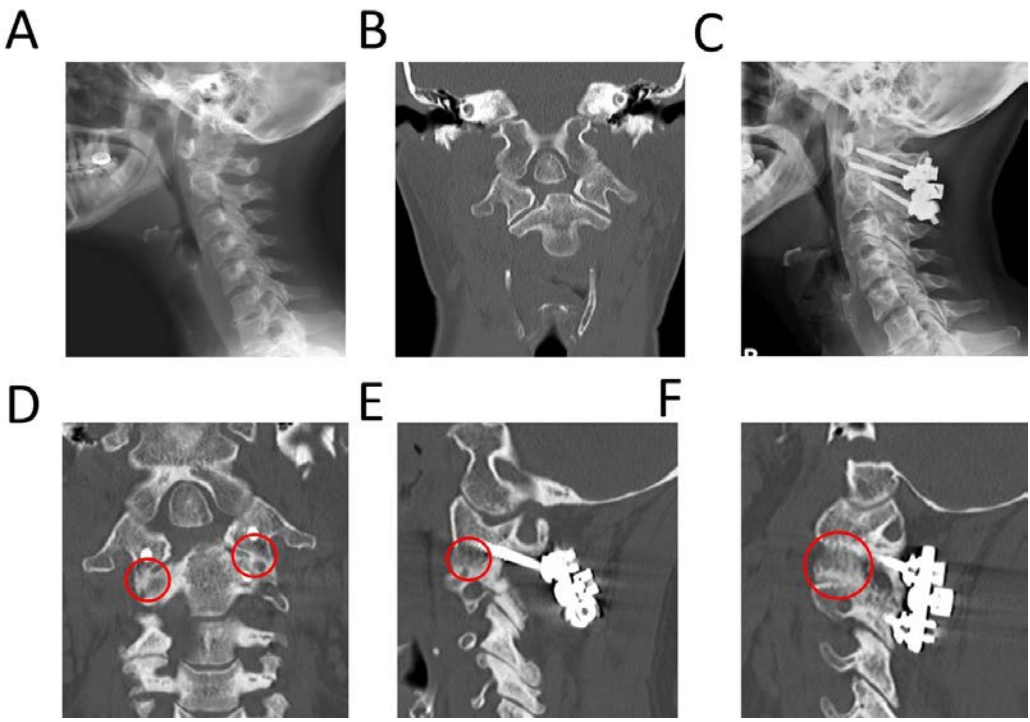

Figure 1
A 52-year-old female with osteoporosis presented with hand clumsiness. Preoperative lateral X-ray (A) and reconstructed CT scans (B) at the time revealed instability at the C1-2

Presentation #42 (cont.)

joint caused by os odontoideum. She underwent posterior instrumented arthrodesis from C1-C2 with bilateral C1 lateral mass screws, C2 right translaminar screw, and C2 left pedicle screw alongside rhBMP-2 at the C1-2 lateral articulation. One year postoperatively, lateral X-ray (C) and reconstructed CT images (D, E, and F) demonstrated the instrumentations in adequate positions and the solid bony fusion at the C1-2 joint.

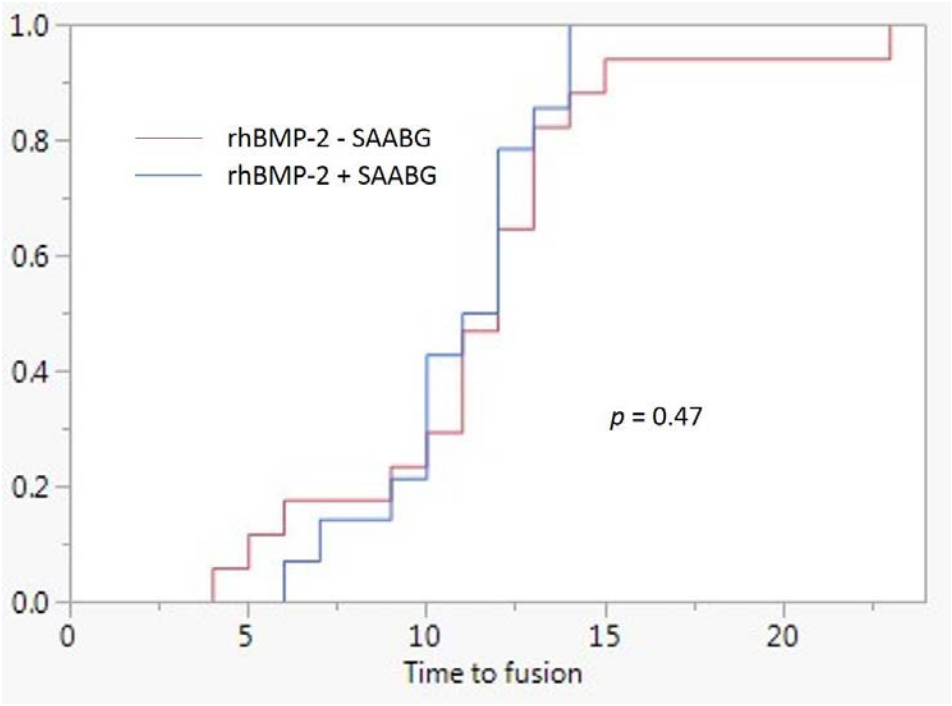

Figure 2
Time-to-fusion analysis using Kaplan-Meier curves. No statistically significant difference was identified between the rhBMP-2 without SAABG group and the rhBMP-2 with SAABG (p = 0.47).

Presentation #43

Functional Integration of a Tissue Engineered Intervertebral Disc and Translation to a Large Animal Cervical Spine Model

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Introduction: We recently developed tissue engineered endplate-modified disc-like angle-ply structures (eDAPS) as an alternative to fusion surgery for the treatment of intervertebral disc pathology. eDAPS are composed of a nucleus pulposus (NP) cell seeded hydrogel surrounded by concentric, aligned layers of poly (e-caprolactone) (PCL) seeded with annulus fibrosus (AF) cells, and PCL foams as endplate analogs.[1] The aim of this study was to assess the mechanical function and integration of eDAPS after long-term *in vivo* implantation, and to scale up constructs for application in a large animal model.

Materials/Methods: eDAPS were fabricated and matured *in vitro* for 5 weeks prior to implantation in the rat caudal disc space with external fixation for 10 (n=5) or 20 (n=9) weeks.[1,2] eDAPS composition was assessed via MRI T2 mapping, biochemical assays (GAG, collagen), and histology. Mechanical function and integration of eDAPS implanted motion segments were assessed via both compression and tension to failure testing. Large scale eDAPS were matured *in vitro* for 13 weeks, implanted into the goat cervical spine (n=6), and evaluated histologically at four weeks (n=3) and at 8 weeks (n=3).

Results: eDAPS NP T2 values were maintained at native levels for up to 20 weeks *in* vivo in the rat tail (Figure 1A). Histology and biochemical assays demonstrated physiologic proteoglycan content in the NP region, and increased deposition of collagen within the AF and endplate regions (Figure 1B). Compressive mechanical properties matured over time to reach near native levels (Figure 1C), and tensile properties achieved ~50% of native failure stress and strain at 20 weeks (Figure 1D). A pilot series of eDAPS implantations in the goat cervical spine (Figure 2A-B) illustrated initial integration of the eDAPS with the adjacent bone after 4 weeks with organized collagen deposition within the PCL endplates (Figure 2 D-F) and maintenance of pre-implantation composition (Figure 2C).

Conclusion: In the rat tail, eDAPS composition and compressive mechanical properties reached near native levels after 20 weeks *in vivo*, and were functionally integrated with the adjacent vertebral bodies. Our preliminary results in the goat cervical spine demonstrate the feasibility of eDAPS implantation in a large animal model at a clinically relevant size scale.

References: [1] Martin+ *Sci Rep,* 2017 [2] Martin+ *Acta Biomat,* 2014

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Presentation #43 (cont.)

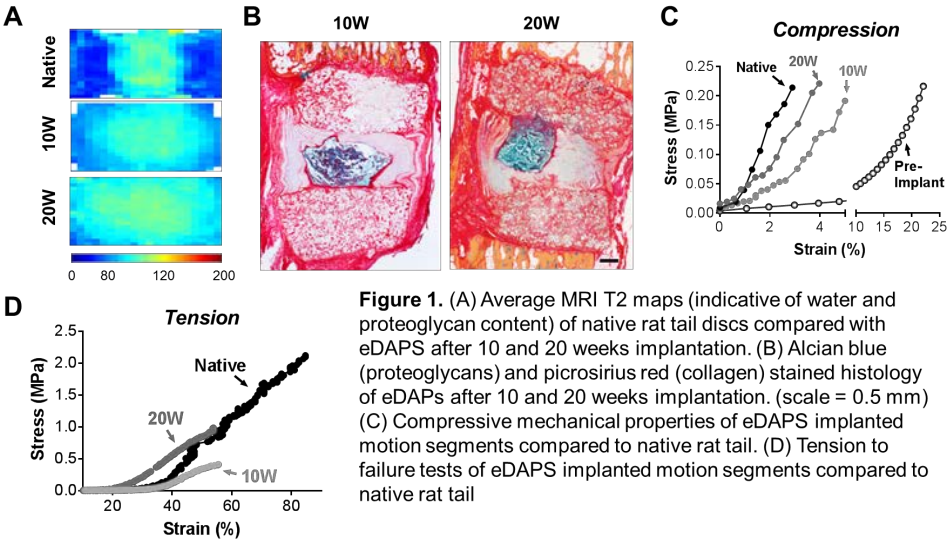

Figure 1. (A) Average MRI T2 maps (indicative of water and proteoglycan content) of native rat tail discs compared with eDAPS after 10 and 20 weeks implantation. (B) Alcian blue (proteoglycans) and picrosirius red (collagen) stained histology of eDAPs after 10 and 20 weeks implantation. (scale = 0.5 mm) (C) Compressive mechanical properties of eDAPS implanted motion segments compared to native rat tail. (D) Tension to failure tests of eDAPS implanted motion segments compared to native rat tail

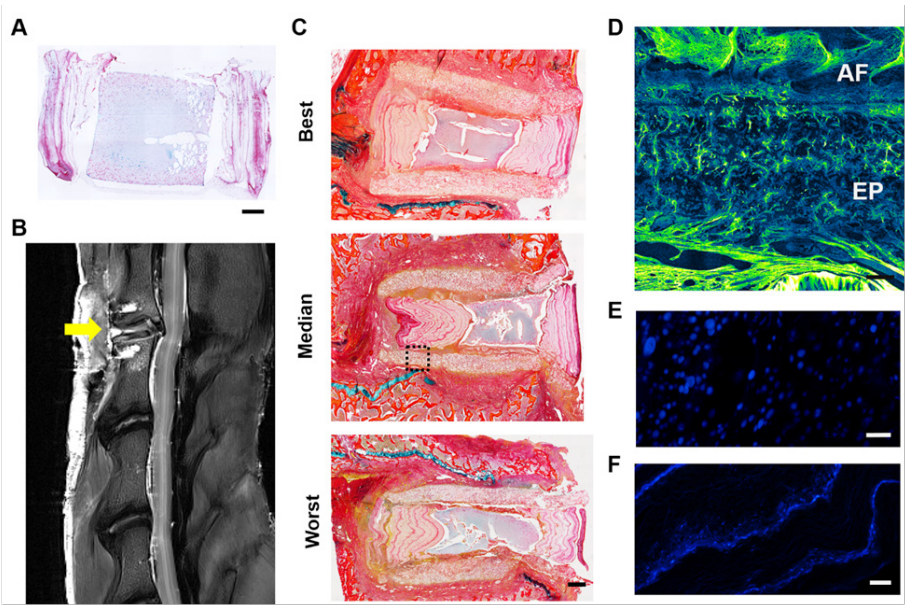

Figure 2. ***In vivo*** **performance of eDAPS in a goat cervical disc replacement model.** (A) Alcian blue (proteoglycans) and picrosirius red (collagen) stained sections of the eDAPS prior to implantation (13 weeks of pre-culture). (B) T2 weighted MRI showed bright signal intensity within the implant (yellow arrow). (C) Alcian blue and picrosirius red stained sagittal histology sections 4 weeks following implantation. Scale = 1 mm. (D) SHG imaging illustrates organized collagen deposition within the PCL endplates and integration with the native goat vertebral body. Scale = 200 µm. Cells were present within the eDAPS implants at 4 weeks as evidenced by DAPI staining of the (E) NP and (F) AF regions. Scale = 50 µm.

Presentation #44

Correlating Radiologic Signs of Disc Degeneration with Changes in Cervical Spine Biomechanics

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Introduction: Radiologic grading of cervical spine has long been used to identify and assess disc degeneration (Kellgren et al 1957). Commonly, biomechanical studies evaluate degree of disc degeneration using this method, and separate specimens. However the link between radiologic signs of disc degeneration and degenerated biomechanics is uncertain. The goal of this study was to identify how cervical spine biomechanics are affected by disc degeneration as perceived from radiologic images. We hypothesized that discs with greater radiologic disc degeneration would exhibit less maximal range of motion at every level and in every mode than discs with less or no radiologic disc degeneration.

Methods: 18 human cadaveric cervical spine specimens (C3-T1) were tested (7 females, 11 males, mean age: 59.1 ± 11.1 years). Residual musculature and adipose tissues were removed, preserving ligamentous structures. The terminal ends of each specimen were potted using high strength resin. The specimens were mounted within a 6 degree-of-freedom kinematic testing machine at the C3 and T1 pots, and tested by applying non-destructive pure moment loading. The specimens were loaded to a maximum moment of ±2.0 Nm in three sequential cycles of flexion-extension, lateral bending, and axial rotation. Motion of each vertebral body was tracked and recorded in each mode using an optoelectronic motion measurement system. Using this system, the motion of each level could be measured relative to its adjacent level.

Prior to testing, lateral fluoroscopic images were taken. The degree of disc degeneration was assessed by a board certified orthopedic surgeon using a four point scale, with 0 representing healthy and 4 representing facet arthrosis and disc fusion (Cusick et al 1996). Each segment of each spine was graded, and separated into healthy (<=1) and degenerated (>1) groups. The maximum range of motion of each mode during the final cycle was collected. ANOVA and student's t-score were used to determine if significant differences existed between the healthy and degenerated groups in terms of disc grade, and maximum flexion-extension, left-right axial rotation, and left-right lateral bending for each motion segment.

Results: For each motion segment, healthy discs graded significantly lower than degenerated discs ($p<.05$); no difference was found in grades between levels for both the healthy and degenerated group ($p>.05$). In maximum flexion range of motion, no difference was found at all levels between healthy and degenerated discs ($p>.1$) (Figure 1). No difference was found between maximum extension for all levels except C5-C6 ($p<.01$). Significant differences were found for RAR at C4-C5 ($p<.05$) and C5-C6 ($p<.05$), LAR at C4-C5 ($p<.05$), RLB at C5-C6 ($p<.01$), and LLB at C5-C6 ($p<.001$).

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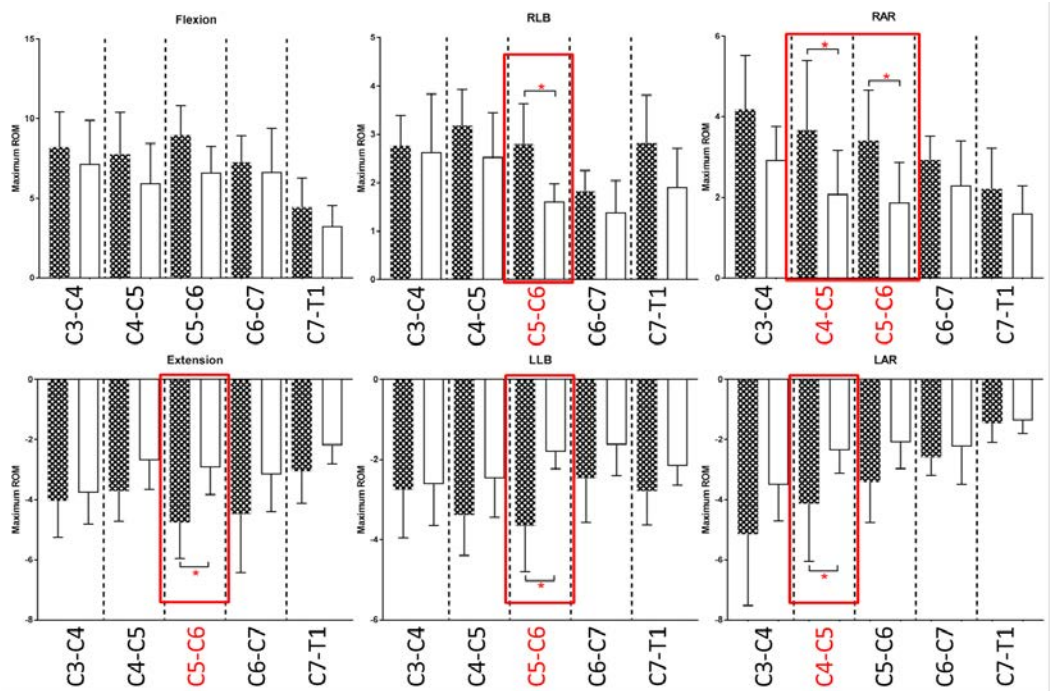

Figure 1: *Maximum range of motion exhibited in each of the modes of motions for each motion segment, with comparisons between healthy and degenerated specimens. Levels highlighted in red indicate significant differences between healthy and degenerated.*

Conclusion: Radiologic indications of disc degeneration do not correlate well with changes in maximum flexion ROM. In general, C5-C6 was the only level in which radiologic signs of disc degeneration correlated with decreased maximum range of motion.

References: Kellgren, J. H., & Lawrence, J. S. (1957). Radiological Assessment of Osteo-Arthrosis. *Annals of the Rheumatic Diseases*, *16*(4), 494–502.
Cusick, J.F., Yoganandan, N., Pintar, F.A., Gardon, M., (1996). Cervical spine injuries from high-velocity forces: pathoanatomic and radiologic study. *Journal of Spinal Disorders, 9(1)*, 1–7.

Presentation #45

Cost-Utility of Revisions for Cervical Deformity Correction Warrants Minimization of Reoperations

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Introduction: Cervical deformity (CD) surgery has become increasingly more common and complex, which has also led to reoperations for complications such as distal junctional kyphosis (DJK). Cost-utility analysis has yet to be used to analyze CD revision surgery in relation to the cost-utility of primary CD surgeries. The aim of this study was to determine the cost-utility of revision surgery for CD correction.

Methods: Retrospective review of a multicenter prospective CD database. CD was defined as at least one of the following: C2-C7 Cobb>10°, CL>10°, cSVA>4cm, CBVA>25°. QALY were calculated by EQ5D and NDI mapped to SF6D index and utilized a 3% discount rate to account for residual decline to life expectancy (men: 76.9 years, women: 81.6 years). Medicare reimbursement at 30-days assigned costs for index procedures (9+ level posterior fusion, 4-8 level posterior fusion with anterior fusion, 2-3 level posterior fusion with anterior fusion, 4-8 level anterior fusion) and revision fusions (2-3 level, 4-8 level, or 9+ level posterior refusion). Cost per quality adjusted life years (QALY) gained was calculated.

Results: 89 CD patients were included (61.6 years, 65.2% female). CD correction for these patients involved a mean 7.7±3.7 levels fused, with 34% combined approach surgeries, 49% posterior-only and 17% anterior-only, 19.1% three column osteotomy. Costs for index surgeries ranged from $20,001-$55,205, with the average cost for this cohort of $44,318 and cost per QALY of $27,267. 11 revision surgeries (mean levels fused 10.3) occurred up to 1-year, with an average cost of $41,510. Indications for revisions were DJK (5/11), neurologic impairment (4), infection (1), prominent/painful instrumentation (1). Average QALYs gained was 1.62 per revision patient. Cost was $28,138 per QALY for reoperations.

Conclusions: Cervical deformity revisions had a cost of $28,138 per QALY, in addition to the $27,267 per QALY for primary CD surgeries. For primary CD patients, CD surgery has the potential to be cost effective, with the caveats that a patient livelihood extends long

Presentation #45 (cont.)

enough to have the benefits and durability of the surgery is maintained. Efforts in research and surgical technique development should emphasize minimization of reoperation causes just as DJK that significantly affect cost utility of these surgeries to bring cost-utility to an acceptable range.

Presentation #46

Economic Impact of Older Age on the Initial Spine Care of Individuals with Acute Spine Trauma

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Introduction: Aging of the population has prompted an escalation of service utilization and costs in many jurisdictions including North America. Yet, the economic impact of the caring for the elderly with spine trauma remains incompletely understood. This study was undertaken to examine the potential effects of age on the service utilization and costs of the management of patients with acute spine trauma (AST).

Design/Method: This retrospective cohort study included consecutive patients with AST admitted to an acute spine care unit of a quaternary university hospital between February/2002 and September/2007. The study population was grouped into elderly (age of 65 years or older at the time of trauma) and younger individuals. All costing data were converted and updated to US dollars.

Results: There were 55 women and 91 men with AST (age range from 16 to 92 years, mean age of 49.9 years) of whom 37 were elderly. Elderly individuals with AST had a significantly longer stay in the acute spine trauma center (10.5±1.3 days vs. 22.1±6.2 days, $p<0.01$) and greater total hospital costs than younger individuals with AST (USD$ 19,338±$4,892 vs. USD$13,775 **±$1,344; p=0.04). However, elderly people with AST had significantly lower** *per diem* total costs, lower *per diem* fixed costs, lower *per diem* direct costs, and lower *per diem* indirect costs than younger individuals with AST (Fig. 1). While elderly people with AST had significantly lower *per diem* fixed costs than younger individuals with AST ($p<0.01$), there were no significant differences between the groups regarding their *per diem* variable costs ($p=0.28$).

Using multivariate regression analysis, higher total hospital costs were significantly correlated to longer stay in the acute spine trauma center, complete traumatic SCI, and need for mechanical ventilation ($p<0.05$). Further multivariate regression analysis revealed a significant interaction between longer hospital stay and need for mechanical ventilation ($p<0.01$); there was no significant interaction between length of hospital stay and severity of AST ($p>0.14$).

In another multivariate regression analysis, higher per diem total costs were significantly associated with shorter stay in the acute spine trauma center and lumbosacral AST ($p<0.05$). Further multivariate regression analysis revealed that there was no significant interaction between length of stay and level of AST ($p>0.39$).

Finally, elderly people with AST were statistically comparable to their younger counterparts regarding their proportions of the hospital services utilized during admission for management of AST ($p=1.00$). The top 10 most costly services utilized during admission were, in the decreasing order, intensive care unit, ward, operating room, pharmacy, respiratory therapy, imaging, laboratory, occupational therapy, emergency department, and social work.

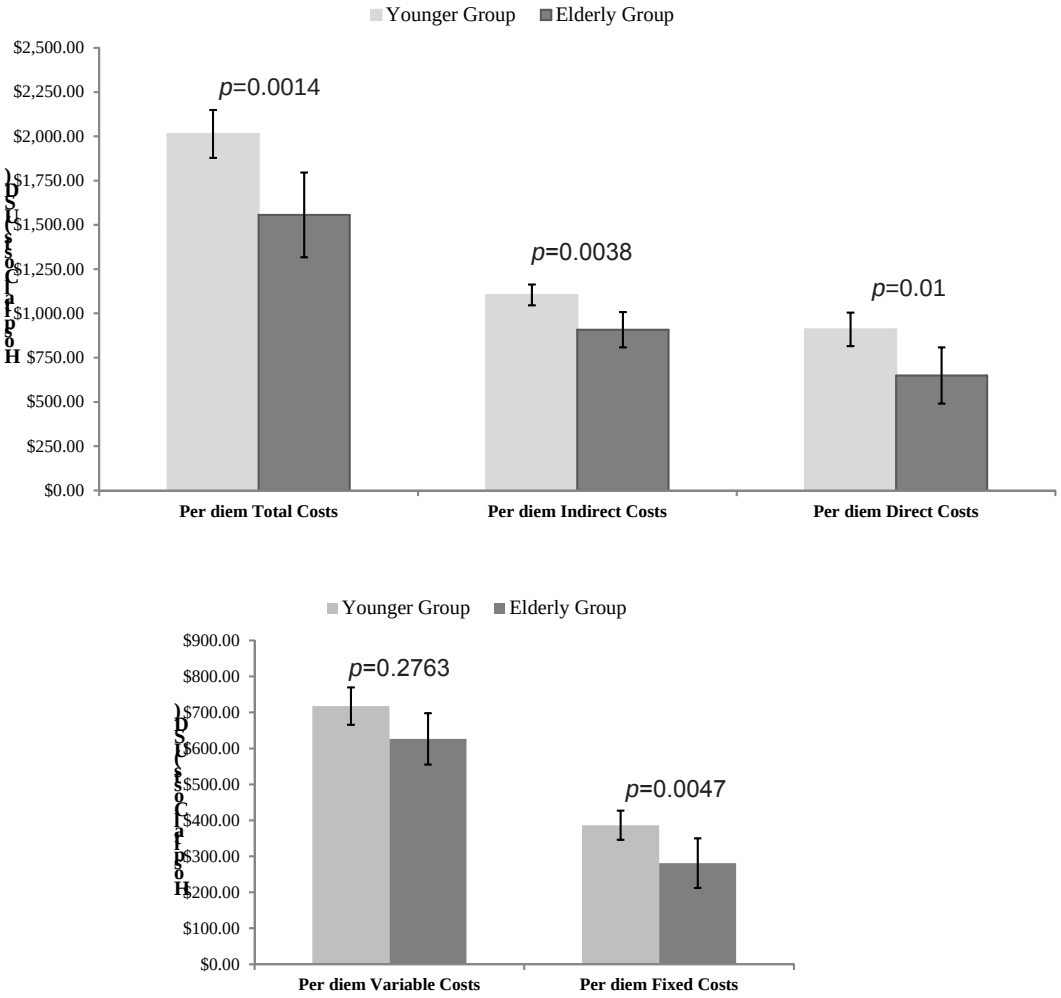
Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #46 (cont.)

Conclusion: Given the escalating demand for surgical and nonsurgical spine treatment in the age of aging population, the results of this study timely underline key aspects the economic impact of the spine care of the elderly. Further investigations are needed to fulfill significant knowledge gaps on the economics of caring for elderly with AST.

Support: Dr. Furlan receives salary support from the Wings for Life Spinal Cord Research Foundation

Figure 1. Comparisons between elderly and younger individuals with acute spine trauma with regards to their *per diem* total, fixed, variable, direct, and indirect costs.



Presentation #47 – 2nd Place Resident/Fellow Research Award Winner

30-day Preoperative Opioid Dosage Predicts 12-month Satisfaction in Cervical Spine Surgery

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Introduction: Preoperative opioid use is widespread and a known detriment to patient outcomes after spine surgery. However, clear guidelines and targets are not well established. Prescription Drug Monitoring Programs (PDMP) now exist in 49 of 50 states and provide instant reports on patient's opioid intake to healthcare providers. The purpose of this study was to develop a predictive model for satisfaction using a clinical spine registry and opioid reports from the state's PDMP. We aimed to establish a preoperative opioid dosage and duration impacting 12-month satisfaction with surgery.

Methods: Patients undergoing elective cervical spine surgery were enrolled in a prospective registry tracking patient and surgery-specific characteristics, and satisfaction at 1 year. Patients undergoing surgery after January 1, 2011, with 1-year follow-up, and with accessible state PDMP reports were identified through the registry. Opioid prescription reports were generated though the states PDMP and all prescription dates, dosages and duration, spanning 1 year preoperatively to 1 year postoperatively were recorded. Prescription data was used to calculate 30-day and 90-day preoperative average morphine equivalent dose (MED) (Figure 1). Correlations were conducted between preoperative and postoperative opioid intake. Receiver operating characteristic (ROC) analysis determined the optimal cutoff point for average daily MED predicting 12-month satisfaction. A logistic regression model identified the impact of preoperative opioid dose on 12-month satisfaction, controlling for other factors.

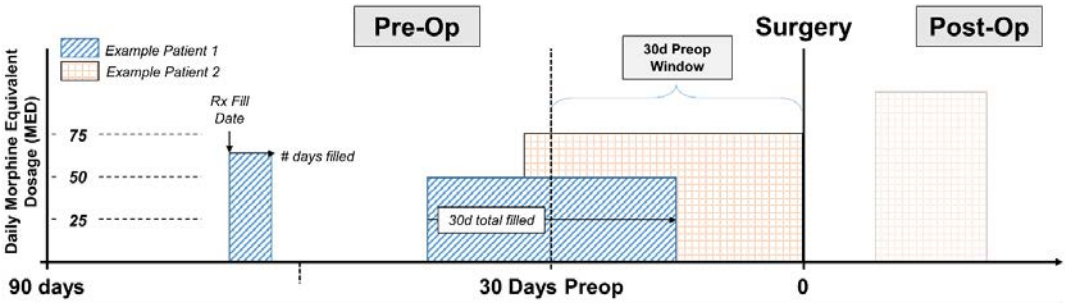
Results: Of the 737 patients meeting inclusion criteria, 48% (n = 357) had an active prescription within 30 days prior to surgery and 61% (n = 451) within 90 days. The 30-day and 90-day preoperative average MED strongly correlated with one-year postoperative average MED (Spearman's rho = 0.61, $p < .001$ and 0.67, $p < .001$, respectively). Overall, 81% (n = 543) of patients were satisfied with surgery at 12 months. ROC analysis for patients with 30-day preoperative opioid intake (n = 357) found a 30-day preoperative average MED optimal cutoff point of 30 (Youden index criterion) when predicting 12-month satisfaction. A logistic regression predicting 12-month satisfaction from 30-day preoperative average MED (<30 vs. ≥30), controlling for patient and surgical characteristics, was significant ($\chi^2 = 25.60$, $p = .001$, Nagelkerke $R^2 = .14$, C'= 81.6%). Odds of satisfaction at 12-months after surgery was 3.0 times higher for patients with a 30-day preoperative average MED of less than 30 compared to patients taking more (95% CI 1.6-5.6, $p = .001$). Lower depression scores were also significantly associated with greater odds of satisfaction (OR = .92, 95% CI .87-.98, $p = .005$) (Figure 2).

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #47 (cont.)

Conclusion: Our predictive model for 12-month satisfaction after cervical spine surgery found patients with a 30-day preoperative average MED of less than 30 are 3 times more likely to be satisfied with surgery at 12-months compared to patients taking more. Preoperative opioid consumption is a modifiable risk factor that negatively affects the value of spine surgery. We provide a target dose and duration for preoperative opioid intake, based on prescription data instantly accessible through a state's PDMP, to be used in the shared-decision making process for cervical spine patients.

Figure 1. Calculation of Preoperative Opioid Average Morphine Equivalent Dosages (MED)



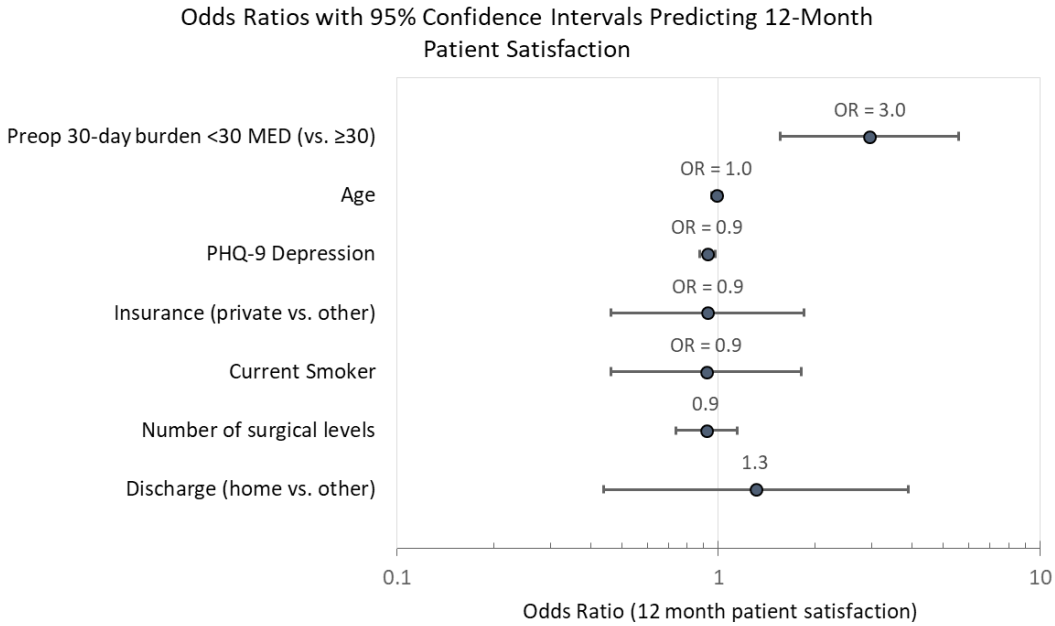
Calculated Variable		Definition/Calculation
30-day Pre-op Average MED	=	(Number of Days of Rx that are active within 30-day Preop Window × MED of Rx)/30
90-day Pre-op Average MED	=	(Number of Days of Rx that are active within 90-day Preop Window × MED of Rx)/90

Example Patients		Average 30-day MED
Example Patient 1	[(15 days of Rx active within 30d Preop Window) × (50 daily MED)]/30 =	**25**
Example Patient 2	[(30 days of Rx active within 30d Preop Window) × (75 daily MED)]/30 =	**75**

Note: While this chart focuses on prescriptions in the 90 days preoperative period, the date, duration and MED of all opioid prescriptions filled 1 year preoperatively to 1 year postoperatively were captured for additional analysis.

Presentation #47 (cont.)

Figure 2. Odds ratios with 95% Confidence Intervals for Achieving 12-Month Satisfaction after Cervical Spine Surgery



Presentation #48

Impact of Neck Disability Index on 12-Months Satisfaction After Elective Surgery for Cervical Radiculopathy

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Introduction: Modern healthcare reforms focus on identifying and measuring the quality and value of care. Patient satisfaction is particularly important in the management of degenerative cervical radiculopathy (DCR) since it leads to significant neck pain and disability primarily affecting the patients' quality of life. In this study, we set out to determine the impact of baseline and 12-month NDI on patient satisfaction after elective surgery for DCR.

Methods: The QOD (Quality and Outcomes Database) cervical module was queried for patients who underwent elective surgery for DCR. A multivariable proportional odds regression model was fitted with 12-month satisfaction as the outcome. The covariates for this model included, age, gender, body mass index (BMI), race, education level, occupation, history of prior surgery, smoking status, co-morbid conditions, ASA grade, symptom duration, indication for surgery, workers' compensation, liability claim, anterior vs. posterior approach, baseline and 12-month patient reported outcomes (PROs). Wald statistics were calculated to determine the relative importance of each independent variable for 12-months patient satisfaction.

Results: The analysis included 2206 total patients who underwent elective surgery for DCR and had complete 12-months follow-up. Among all, 1481 (67%) of the patients reported satisfaction at NASS level 1 (Surgery met my expectations) and 449 (20%) reported satisfaction at NASS level 2 (I did not improve as much as I had hoped but I would undergo the same operation for the same results), while a total of 278 (13%) reported lower level of satisfaction or dissatisfaction at 12-months follow-up. In multivariable analysis, after adjusting for baseline and surgery specific variables, the 12-month neck disability index (NDI) score showed the highest impact on 12-months satisfaction (Wald $\chi 2=101.17$, 17.29% of the total $\chi 2$) (Figure 1). The level of satisfaction increases with decrease in 12-month NDI score regardless of the baseline NDI score (Figure 2).

Conclusion: Our study identifies 12-months NDI score as a very influential driver of 12-month patient satisfaction after surgery for DCR. In addition, there are lesser contributions from other 12-months PROs, baseline numeric rating scale-arm pain (NRS-AP) and ASA grade. We also demonstrate that higher baseline disability requires greater improvement post-surgery in order to achieve patient satisfaction. Baseline NDI should therefore be accounted for, in addition to patient satisfaction, when assessing the success of surgeries for DCR.

Presentation #48 (cont.)

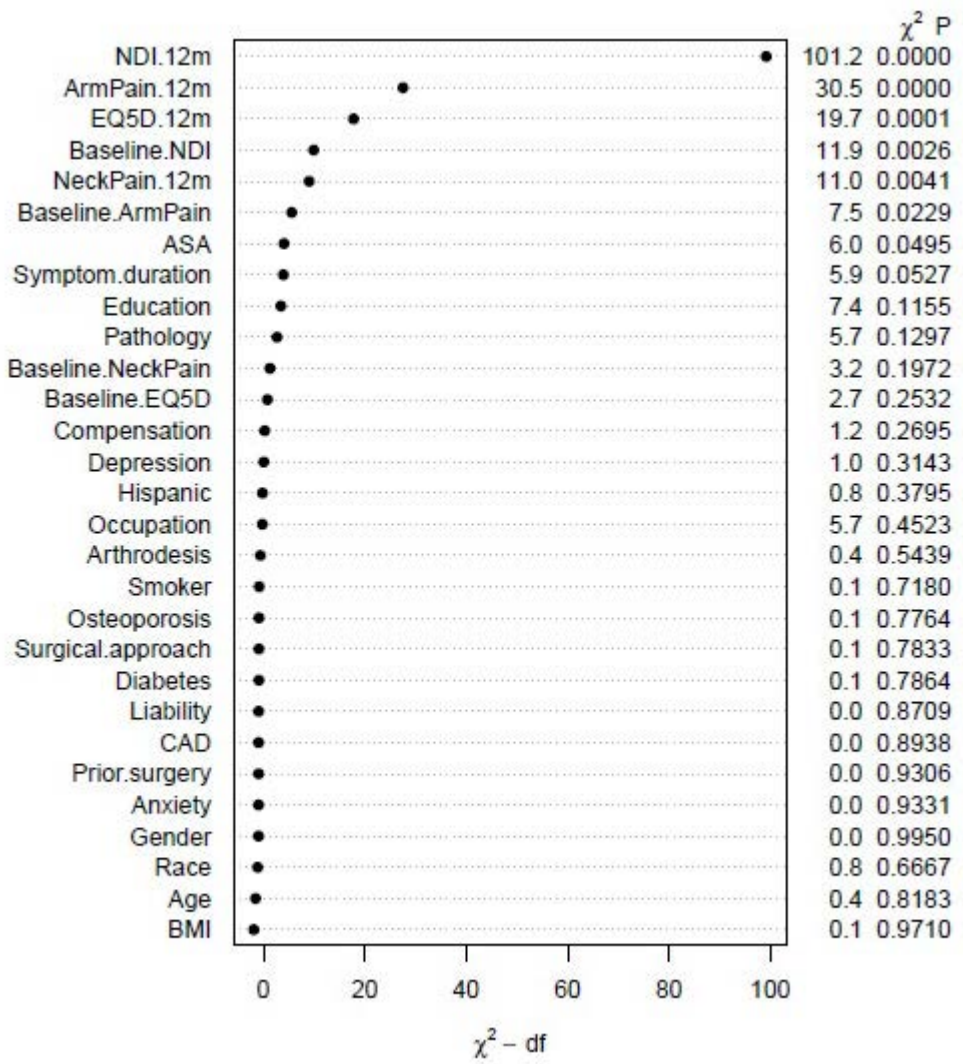

Figure 1 - displays importance of each independent variable for satisfaction as measured by Wald chi-square value minus the degree of freedom of the predictor, based on multi-variable model.

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Presentation #48 (cont.)

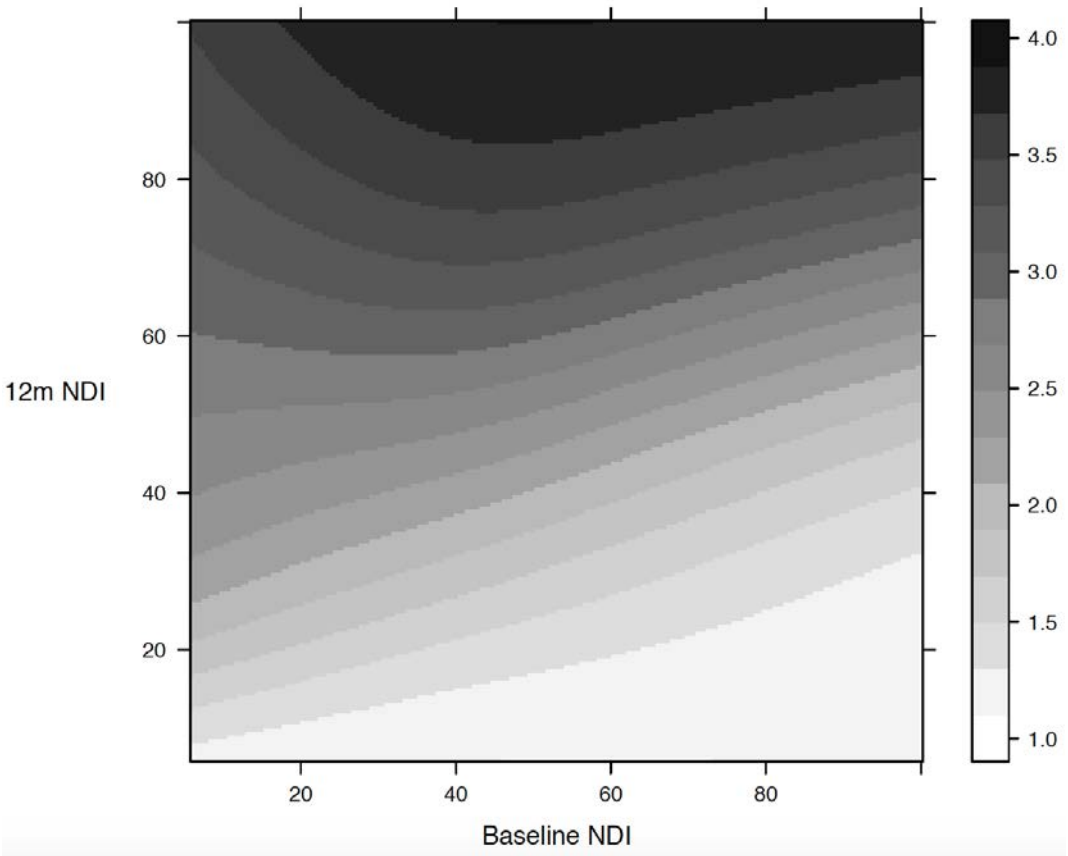

Figure 2 - demonstrate the 3-dimensional relationship (heat map) for prediction of satisfaction with outcomes as a function of baseline NDI score and 12-month NDI scores. The legend bar on the right shows the correspondence between the predicted mean satisfaction index (NASS satisfaction index 1-4) and the color in the heat map. White color represents highest level of satisfaction (NASS satisfaction index=1) and black represents least satisfaction (NASS satisfaction index=4). One can see that baseline NDI Score is barely relevant to predicting 12m satisfaction whereas 12m NDI score is a major explanatory variable.

Presentation #49

Thirty-day Readmission Risk Following Cervical Spine Surgery: Derivation and Validation of a Predictive Model

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Introduction: Recent healthcare reforms levies financial penalties on hospitals based on their performances that includes assessment of readmission rates. To optimize outcomes and enhance quality of care delivered to spine patients, it is critical to identify inherent risks associated with readmissions to implement appropriate preventive measures for modifiable risk-factors. The purpose of this study is to develop and validate a predictive model of 30-day readmission risk after cervical spine surgery.

Materials/Methods: The National Readmission Database 2013-2014 was queried for adult patients undergoing elective cervical spine surgery using ICD-9 codes. A split-sample 1:1 randomization was performed to create a derivation (model) and validation (training) cohort.

A multivariable log-binomial regression fitted with generalized estimating equations to control clustering of outcomes by hospitals was utilized to derive a parsimonious model predicting the risk of 30-day readmission following cervical spine surgery. The parsimonious model was internally validated in the training cohort. The predictive value or model accuracy was explored by assessing the c-statistics or area under the receiver-operating characteristics curves (AUROC).

Results: Overall, 22798 patients (median age:56 years; 42% female; derivation cohort: 11343; 49.8%) underwent cervical spine surgery (primary surgery: 96.7%; revision: 3.3%). Of these, 1671 (7.3%) were readmitted within 30-days. Most common primary causes for readmissions included septicemia (7.9%), wound infections and complications (7.7%), pneumonia (3.0%), pulmonary embolism (2.6%) and hardware-related mechanical complications (2.2%).

Factors associated with increased odds of 30-day readmission risks include advancing age at surgery (OR:1.01), weekend admissions (OR:1.2), increased total procedures (OR:1.05) and longer hospital stay (OR:1.01). Major comorbidities impacting readmission risks are metastatic cancer (OR:2.47), liver disease (OR:1.52), coagulopathy (OR:1.4), chronic renal failure (OR:1.41) and chronic lung disease (1.30). Postoperative complications (wound and acute renal failure), and those incurring discharge to skilled nursing facility and home healthcare compared to routine discharge to home are at higher risks for readmissions [Fig. 1]. The parsimonious model demonstrated good discriminatory ability as estimated using AUROC at 0.72 and model training noted less than 5% difference in the AUROC's following validation. Model risk-predictive ability was explored by plotting the most significant variables against patient's age [Fig. 2]. The model findings were integrated into a web-based and offline-based (Microsoft excel) app.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #49 (cont.)

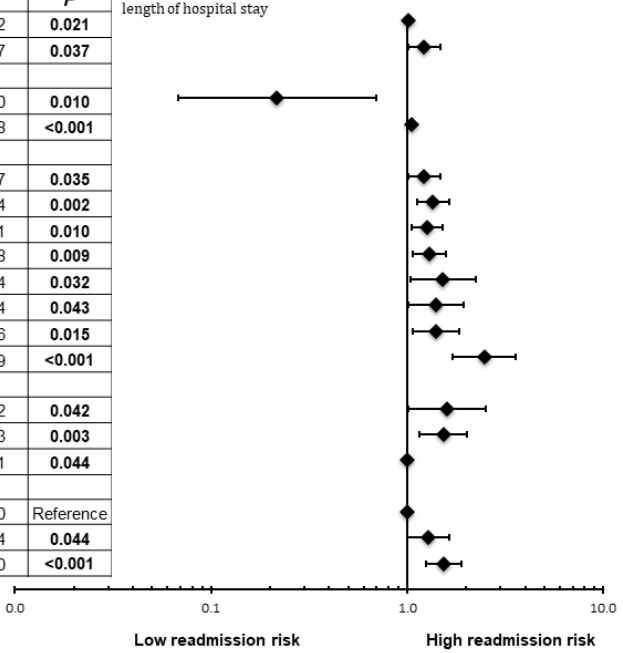
Conclusion: The study quantifies risk estimates associated with the risk of 30-day readmission in patients undergoing cervical surgery. The proposed model is integrated into a validated web-based tool (app) that could potentially be utilized by patients, providers, stakeholders and policy makers to assess individualized risks, shared decision making and guiding the process of patient counselling and informed consent.

Figure 1: A multivariable (GEE) model demonstrating the association of patient demographics, baseline clinical comorbidities and post-operative complications on the risk of 30-day readmission after cervical spine surgery

Factors predictive of a 30-day readmission risk in patients undergoing cervical surgeries

	OR	95% CI		*P*
Age	1.01	1.00	1.02	**0.021**
Weekend admission	1.22	1.01	1.47	**0.037**
Metropolitan non-teaching				
Non-metropolitan	0.22	0.07	0.70	**0.010**
Total procedures	1.05	1.02	1.08	**<0.001**
Comorbidities				
Fluid/electrolyte disorders	1.22	1.01	1.47	**0.035**
DM	1.36	1.12	1.64	**0.002**
Hypertension	1.26	1.06	1.51	**0.010**
Chronic lung disease	1.30	1.07	1.58	**0.009**
Liver disease	1.52	1.04	2.24	**0.032**
Coagulopathy	1.40	1.01	1.94	**0.043**
Chronic renal failure	1.41	1.07	1.86	**0.015**
Metastatic cancer	2.47	1.70	3.59	**<0.001**
Complications				
Wound complications	1.60	1.02	2.52	**0.042**
Acute renal failure	1.53	1.16	2.03	**0.003**
Length of hospital stay	1.01	1.00	1.01	**0.044**
Discharge disposition				
Home (routine discharge)	1.00	1.00	1.00	Reference
Home healthcare	1.29	1.01	1.64	**0.044**
Rehab (SNF/ICF/others)	1.54	1.25	1.90	**<0.001**

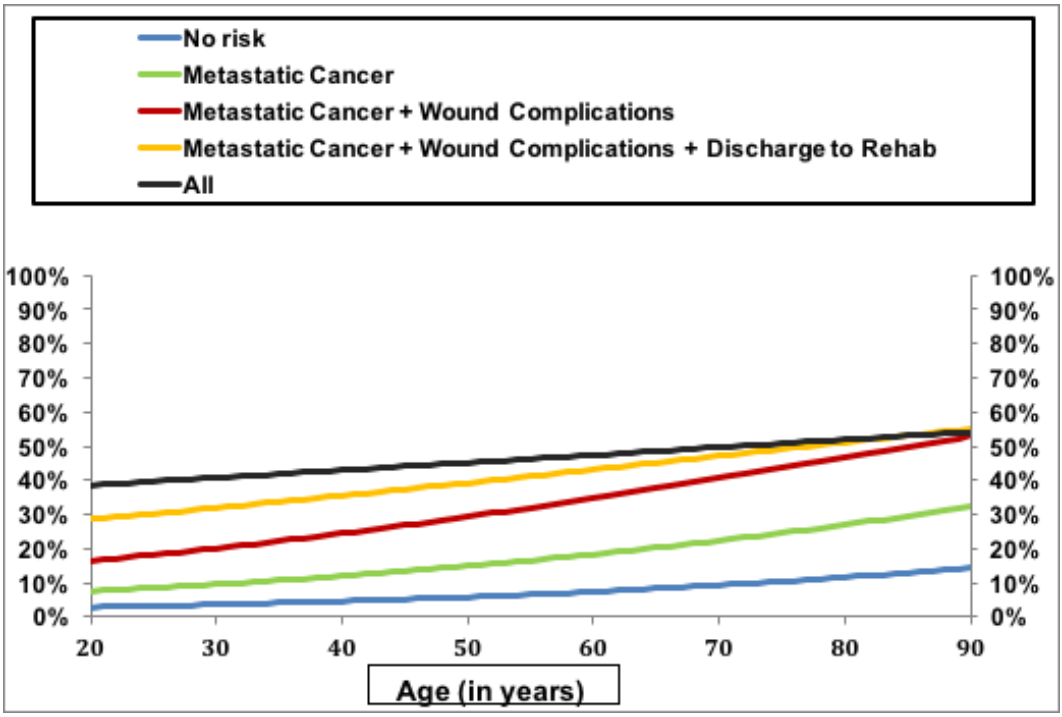
*Model was adjusted for patient demographics (age, gender, payer, income); Hospital characteristics (bedsize, teaching status, ownership); weekend admission; smoking status, alcohol abuse, drug abuse; total number of inpatient procedures; type of lumbar surgery (revision vs primary); 21 comorbidities; 8 post-operative complications, discharge disposition, and length of hospital stay



Significant predictors associated with the risk of 30-day readmission derived at alpha set at 5% are depicted on the forest plot (right side of table)

Presentation #49 (cont.)

Figure 2: Line graph demonstrating the age-dependent probability for 30-day readmission risk following cervical spine surgery. Statistically significant variables (with three highest odds ratios) in regression model as well as their combination are plotted against patients' age (x-axis). The y-axis depicts the absolute probability of readmission for individual risk-factors or their combination



Presentation #50

Using a Machine Learning Approach to Predict Outcome After Surgery for Degenerative Cervical Myelopathy

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Introduction: Degenerative cervical myelopathy (DCM) is a spinal cord condition that results in progressive non-traumatic compression of the cervical spinal cord[1]. Spine surgeons must consider a large quantity of information relating to disease presentation, imaging features, and patient characteristics to determine if a patient will benefit from surgery for DCM[2]. In recent years a number of studies have applied machine learning techniques to clinical databases to predict disease and treatment outcomes for conditions[3,4]. In this abstract we applied a supervised machine learning approach to develop a classification model to predict individual patient outcome after surgery for DCM.

Materials/Methods: Patients undergoing surgery for DCM as a part of the AOSpine CSM-NA or CSM-I trials were included in the study[5]. Predictor variables reflected information about pre-operative disease severity, disease presentation, patient demographics, and comorbidities. The outcome was improvement in the SF-6D quality of life indicator or modified Japanese Orthopedic Association (mJOA) score by the minimum clinically important difference (MCID)[6]. Feature engineering and data pre-processing was conducted and a decision tree, logistic regression, support vector machine, and random forest model were trained. The best performing model was further optimized and evaluated against a separate testing patient cohort that was not used for model development. Models were developed using R Studio v3.3.0.

Results: Out of 757 patients 605, 583, and 539 patients had complete follow-up information at 6, 12, and 24 months respectively and were included in the analysis. Following data pre-processing 48, 108, and 101 features were chosen for model training at 6, 12, and 24 months respectively. The best performing predictive model used a random forest structure and had an average area under the curve (AUC) of 0.70 (95% CI, 0.68-0.72), classification accuracy of 77%, and sensitivity of 78% when evaluated on an independent testing cohort that was not used for model training (Figure 1). Worse pre-operative disease severity, longer duration of DCM symptoms, older age, higher body weight, and current smoking status were associated with worse surgical outcomes.

Conclusions: We developed a model that predicted positive surgical outcome for DCM with good accuracy at the individual patient level on an independent testing cohort. To our knowledge our model, using a machine learning approach, achieved a higher accuracy than previously published models. This predictive model may be able to support clinical decision-making and optimize patient care.

Presentation #50 (cont.)

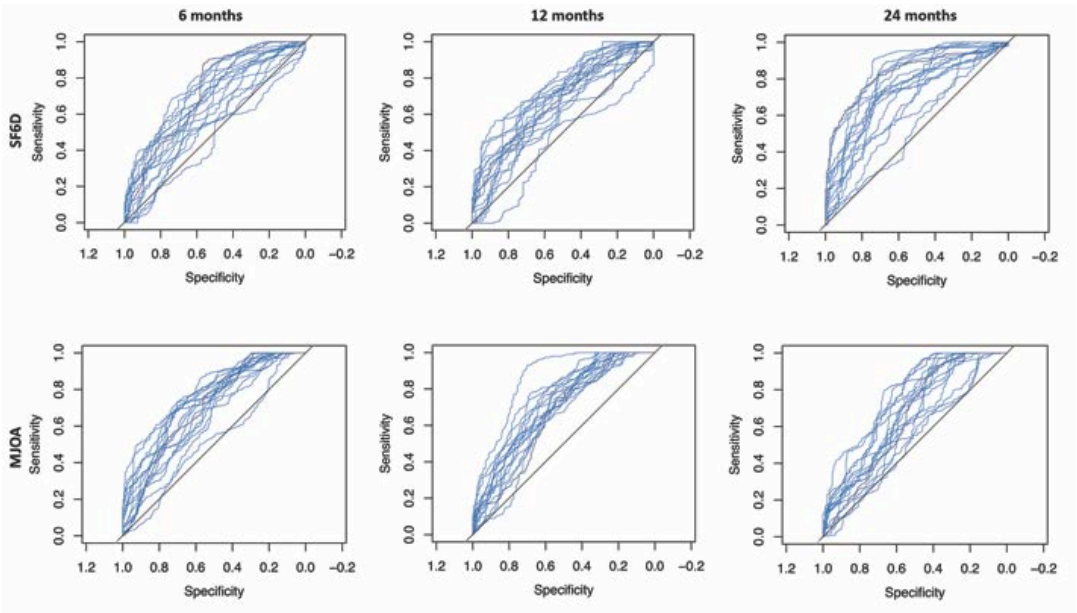

Figure 1 – Receiver operating characteristic curves for the random forest model at all follow-up points on the training/validation dataset. The blue lines represent each cross validation fold, while the average ROC curve is depicted by a red line.

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Presentation #51

Model for 90-Day and 1-Year Outcome Prediction After Cervical Spine Arthrodesis: A Web-Based Clinical Utility Tool

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Introduction: Recent seismic reforms focus on improving value in healthcare delivery and cost-containment. As a result, regulatory agencies are implementing standardized quality metrics upon which surgical outcomes will be gauged. As financial bundles in cervical spine surgery evolves with inclusion of several unfavorable outcomes penalizing reimbursement criteria, it is critical to identify factors associated with adverse outcomes. The purpose of this study is to create a model predicting longitudinal postoperative complications tailored upon patient characteristics and comorbid status following cervical spine fusion surgery.

Materials/Methods: The Humana Inc. claims dataset was queried from 2007-2015 for patients undergoing primary cervical spine arthrodesis using ICD-9 coding definitions [81.01-81.03]. Multivariable regression techniques were employed to develop a model for 90-day and 1-year post-operative outcome prediction based upon individual patient characteristics. Outcomes included reoperations including adjacent segment disease, emergency department (ED) visits, epidural steroid and facet-joint injections, postoperative opioid use, and adverse events (constipation, "never-events" including acute renal failure, venous thromboembolism, post-operative wound, neurologic, respiratory or cardiac complications, and infections). Prior to integrating model findings into a web-based utility tool, regression diagnostics including assessment of model calibration (goodness of fit tests) was performed.

Results: A total of 20730 patients [48.7% male] underwent primary cervical spine arthrodesis. Rates of 90-day and 1-year reoperations were 5.24% and 6.78% respectively. Approximately 20% and 41% patients will incur ED visits within 90-days and at 1-year respectively [Table a]. Generalized linear models identified risk-factors associated with respective outcomes at 1-year and 90-days. For instance, preoperative chronic opioid therapy [COT] (OR: 1.17; p=0.042), smoking (OR:1.17; p=0.05), osteoporosis (OR:1.32;p=0.009), seizure disorders (OR:1.59; p=0.008) and male gender (OR:1.19; p=0.029) were associated with risk of 1-year reoperation. Likewise, preoperative COT (OR:1.31; p<0.001), smoking (OR:1.27; p<0.001), diabetes (OR:1.22; p<0.001), obesity (OR:1.10; p=0.019), hypertension (OR:1.15; p<0.001), congestive heart failure (OR:1.35; p<0.001), chronic renal failure (OR:1.20; p<0.001), hypercholesterolemia (OR:0.84; p<0.001), psychiatric disorder (OR:1.25; p<0.001), anemia (OR:1.22; p<0.001), history of ischemic stroke (OR:1.27; p<0.001), seizure disorders (OR:1.46; p<0.001), coronary artery disease (OR:1.33; p<0.001), chronic lung disease (OR:1.32; p<0.001), drug abuse (OR:1.48; p<0.001), degenerative cervical conditions (OR:0.73; p<0.001), young age (OR:1.16; p=0.002) and male gender (OR:0.88; p<0.001) were associated with ED visits at 1-year. All models demonstrated good calibration as assessed by Hosmer Lemeshow goodness-of-fit tests (p>0.10). A web-based tool was developed and can be accessed at https://neuro-risk.com/spine-surgery/cervical

Presentation #51 (cont.)

Conclusion: The derived models provide individualized estimates of the risk of longitudinal complications after cervical fusion surgery. These findings can assist in preoperative planning, shared decision-making, patient counseling and consenting, creation of data-driven policies including reimbursement criteria based upon patient comorbid status.

Table A: Outcomes After Cervical Arthrodesis at 90-days and at 1-year

Postoperative Outcomes	At 90-day		At 1-year	
	N	%	N	%
Reoperations	1,087	5.24%	1,406	6.78%
ED visits	4,117	19.86%	8,403	40.54%
Epidural steroid injections	109	0.53%	734	3.54%
Facet-joint injections	28	0.14%	388	1.87%
Postoperative opioid use	15,614	75.32%	6,167	29.75%
Constipation	1,010	4.87%	2,145	10.35%
Acute renal failure	445	2.15%	923	4.45%
Venous thromboembolism	408	1.97%	1,025	4.94%
Wound complications	460	2.22%	718	3.46%
Infections	126	0.61%	244	1.18%
Neurological complications	90	0.43%	239	1.15%
Cardiac events	12	0.06%	31	0.15%
Respiratory complications	41	0.20%	61	0.29%
GIT	41	0.20%	108	0.52%

Presentation #52

The Predictor of Patients Who Failed to Achieve the Minimum Clinical Important Differences Following Laminoplasty for Cervical Spondylotic Myelopathy

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Introduction: Surgical treatment such as laminoplasty is recommended as the treatment strategy for severe cervical spondylotic myelopathy (CSM). However, in some patients, the postoperative outcomes are undesirable. Therefore, the aim of this study is to investigate the characteristics of patients who failed achieving the minimum clinically important difference (MCID) of Japanese Orthopedic Association (JOA) score after laminoplasty and identify the factor to predict such patients preoperatively.

Materials/Methods: This study is the retrospective cohort study with consecutive 101 patients who underwent laminoplasty for CSM and followed >2 years after surgery. Laminoplasty was indicated to all patients with CSM except for severe kyphosis. Overall patients were divided into two groups based on the difference between preoperative and two years postoperative JOA score: poor recovery group (JOA score improved ≤2.0 points, n=34) and control group (>2.0 points, n=67). 2.0 points was set as previously reported MCID of the cervical JOA score. Subsequently, to dismiss the differences of patient's demographics between the two groups, matched poor recovery group (n=22) and matched control group (n=22) were created according to propensity score calculated in a logistic regression model adjusted for age, gender and preoperative JOA score. Preoperative clinical score (Detailed component of JOA score and, JOA Cervical Myelopathy Evaluation Questionnaire (CMEQ)) and radiographic parameters (C7 slope, C2-C7 lordotic anglae, C2-C7 sagittal vertical axis) were compared between two matched groups using Mann-Whitney U test. In addition, the change of each score after operation were compared using two-way analysis of variance. Finally, the receiver operating characteristic (ROC) curve analysis were calculated. A p value of <0.05 was considered statistically significant.

Results: In the comparison of unmatched groups, the age and preoperative JOA score were significantly high in poor recovery group (age: p=0.027, preop JOA score: p<0.001). In the comparison of matched groups, although the all detailed segments of preoperative JOA score showed no significant differences between two matched groups, the postoperative improvements of lower extremity function of JOA score were significantly lower in the matched poor recovery group (p<0.001). The change of other segments of JOA score showed no significant differences between two matched groups. In the comparison of the preoperative JOACMEQ, only the domain of lower extremity function showed significantly differences; matched poor recovery group showed significantly lower score than matched

Presentation #52 (cont.)

control group (34.5 vs 59.0, p=0.039). ROC analysis demonstrated that the preoperative score of the JOACMEQ lower extremity function could predict the poor surgical outcome patients significantly (area under curve=0.771, p=0.024,) with 34.0 as cutoff value (sensitivity 82.5%, specificity 66.7%). Preoperative radiological parameters showed no significant differences between the matched groups.

Conclusion: Patients who failed achieving the MCID of JOA score after laminoplasty showed the lesser improvements of lower extremity function. In addition, although adjusting preoperative JOA score as same, preoperative lower extremity function assessed by patient oriented score showed significantly lower in poor recovery group. Current result can indicate that the preoperative score of JOACMEC lower extremity function with cutoff value of 34.0 can predict of the poor recovery after laminoplasty for CSM patients.

Presentation #53

Selective Surgical Treatment Strategies for Severe Cervical Kyphosis

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Introduction: Severe cervical kyphosis refers to cervical kyphosis greater than 40 degrees. Such patients often suffer from severe clinical symptoms. Surgical treatment usually difficult, risky and has more complications. And there is still no widely accepted surgical strategy for the treatment of severe cervical kyphosis. The aim of the present study was to investigate the clinical efficacy of the selective surgical treatment strategies for severe cervical kyphosis.

Methods: 146 patients with evere cervical kyphosis treated surgically in our hospital from 2000 to 2016 were reviewed. There were 81 males (55.5%), with an average age of 57.3±12.2 years, and 65 cases (44.5%) of females, with an average age of 61.5 ± 15.7 years. 49 Cases with flexible deformity, 97 cases with fixed deformity. Patients with flexible deformity were treated by anterior discectomy or corpectomy with fusion. Patients with fixed deformity were treated by skull traction and anterior discectomy or corpectomy with fusion. Patients with fixed deformity at cervicothoracic junction were treated by anterior discectomy or corpectomy with posterior instrument or posterior osteotomy only. Patients with fixed deformity with ankylosing spondylitis or fixed deformity need revision Surgery were treated by circumferential decompression and fusion.

Results: All patients were operated successfully and finished follow up. The average follow-up time was 34.6 ± 14.2 months, the average operative time was 106.8 ± 27.4min, and the average bleeding volume was 138.3 ± 34.6ml. Neurological symptoms were significantly improved in all patients after surgery($P < 0.01$). The JOA score increased from 9.4 ± 2.8 before surgery to 14.7 ± 3.6 at last follow up. Cobb angle of cervical spine improved from -45 ± 11.5 degrees to 7.2 ± 5.1 degrees at last follow up ($P < 0.01$). The average correction rate of was 80.3%. No significant correlation exists between correction rate of cervical Cobb angle and the improvement rate of JOA score after operation($P=0.14$). There were 8 patients had axial pain, 4 patients had C5 nerve root palsy and 1 patients had cerebrospinal fluid leakage after operation. The average correction rate of cervical Cobb angle in patients with complications was significantly higher than that in patients without complications ($P < 0.01$).

Conclusion: Symptoms of severe cervical kyphosis are caused mainly by nerve compression. Surgical treatment should be focused on nerve decompression. Moderate cervical spine correction (80%) can satisfy the objective of decompression. More correction rate can increase the risk of surgery and increase the incidence of complications.

Presentation #53 (cont.)

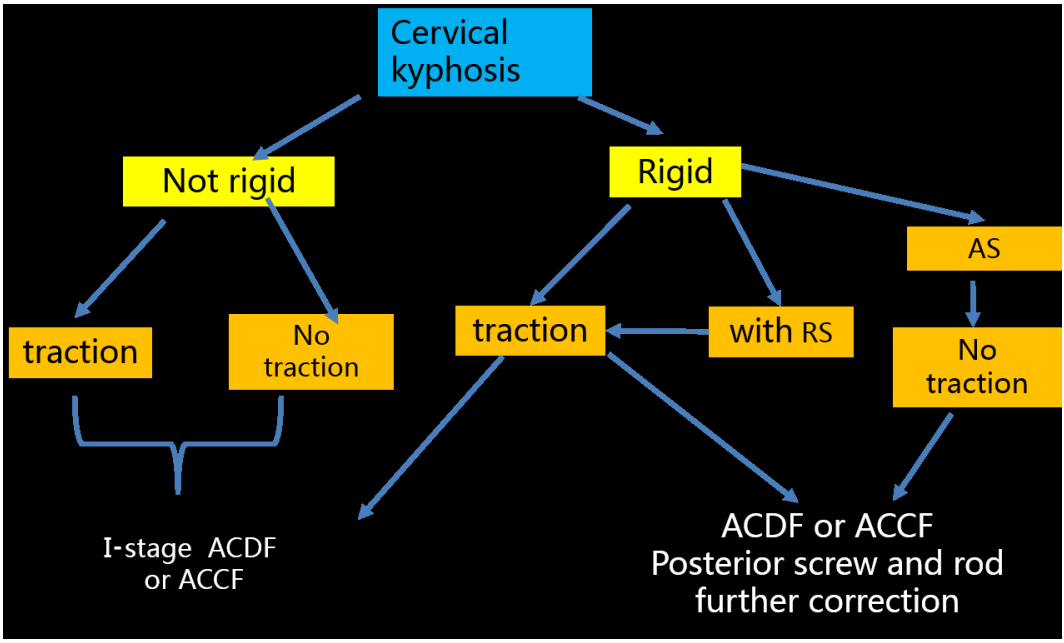

Figure 1. Selective Surgical Treatment of Cervical Kyphosis

Presentation #54

Successful Clinical Outcomes Following Surgery for Severe Cervical Deformity are Dependent Upon Achieving Sufficient Cervical Sagittal Alignment

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Introduction: Cervical malalignment is associated with disability. Surgical corrections of severe CD present considerable challenges. Demographic, surgical, and post-op factors associated with failed radiographic and clinical outcomes have not been well established. This study aims to identify patients at risk of failure to restore sagittal alignment in cervical deformity corrective surgery. Additionally, to analyze how failure to restore sagittal alignment post-operatively affects patient reported outcomes and to determine the clinical significance of failure to correct malalignment.

Methods: A prospective database of operative CD patients (Inclusion criteria: cervical kyphosis >10°, cervical scoliosis >10°, cSVA>4cm or CBVA>25°) was analyzed. Inclusion was restricted to severe baseline cervical deformities (cSVA>4cm or C2 Slope (C2S)>20°) and 1 year follow-up. Failed surgery was defined as cSVA>4cm at 1 year while successful surgery was defined as cSVA < 4cm at 1 year. Successful surgeries were compared to failed surgeries with health related outcome measures, including the MCID for NDI (improvement >7).

Results: 66 patients with severe CD met inclusion criteria, including 41 failed (62%) surgery and 25 successful. Failed surgery patients had worse sagittal alignment at baseline and 1 year by cSVA, C2S, T1S, TS-CL, and CTPA ($p < 0.05$). Failed surgery patients were more commonly in males (51.2 vs 12%, $p<0.01$) and had greater intraoperative blood loss (1.2 vs .44L, $p < 0.01$) than successful surgery. History of prior cervical fusion, age, frailty, fusion length, operative time, utilization of three column osteotomy, DJK rate, and revision surgery were not associated with failed surgery. Patients with failed surgery had less improvement

Presentation #54 (cont.)

in clinical outcome by NDI at both 6 months (-8.6 vs -21.7, p<.05) and 1 year (-7.7 vs -17.6, p<.05). More patients with successful surgery attained MCID for NDI at 6 months (84.2% vs 51.7%, p = 0.021) but there was no significant difference at 1 year (76.0% vs 56.8%, p = 0.120).

Conclusions: Baseline cervical malalignment, male gender and intra-operative blood loss were associated with failed radiographic outcomes in patients with severe cervical deformity. Failed surgery patients also had less improvement in NDI at 6 months and 1 year than successful surgeries. More patients with successful surgeries attained MCID for NDI at 6 months. In correcting severe CD, surgeons need to obtain optimal radiographic alignment to attain better clinical outcomes.

Figure 1:

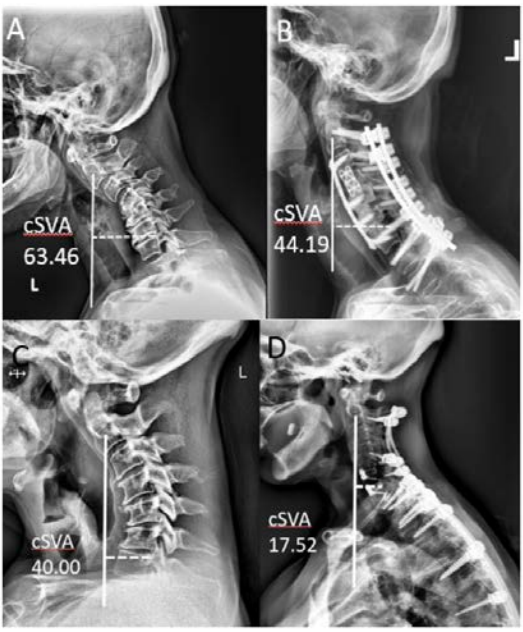

Figure 1 (A and B): Pre-operative and post-operative X-rays of a patient with severe cervical deformity and failed surgery due to persistent sagittal malalignment at 1 year post-op. (C and D): A patient with severe cervical deformity with successful correction of cSVA at 1-Year follow-up.

Failure to Correct cSVA at 1 Year in Patients with Severe CD			
Baseline Demographic Information	Failed Surgery (62.1%)	Successful Surgery (37.9%)	p-Value
Age	63.78	59.04	0.073
BMI	28.27	26.14	0.424
Gender (% Male)	51.2%	12.0%	0.001
CCI	0.86	0.82	0.901
Baseline Alignment			
T1 Slope	37.16	25.88	0.013
TS-CL	46.27	34.18	0.003
Cervical Lordosis	-9.11	-8.30	0.881
cSVA	61.38	37.70	<0.001
C2 Slope	48.16	33.20	0.001
TPA	15.00	11.62	0.267
CTPA	6.45	4.04	<0.001
Alignment at 1 Year			
T1 Slope	41.31	28.63	0.001
TS-CL	35.18	19.68	<0.001
Cervical Lordosis	6.14	8.95	0.520
cSVA	53.19	25.42	<0.001
C2 Slope	34.97	17.65	<0.001
TPA	16.82	11.11	0.045
CTPA	5.52	3.16	<0.001
Surgical Parameters			
Posterior Levels Fused	9.36	7.59	0.094
Three Column Osteotomy Use	34.1%	16.0%	0.108
Operative Time	453.37	499.20	0.613
EBL (mL)	1178.44	477.2	0.004
Revision Rate	14.6%	8.0%	0.423
Difference in HRQL at 6 mo.			
NDI	-8.61	-21.66	0.003
mJOA	0.75	0.81	0.933
EQ5D	0.04	0.06	0.425
MCID for NDI attained (%)	51.7%	84.2%	0.021
Difference in HRQL at 1 Year			
NDI	-7.74	-17.58	0.015
mJOA	0.39	0.26	0.861
EQ5D	0.04	0.07	0.231

Presentation #55

Effect of Correction Surgery for Cervical Kyphosis on Compensatory Mechanisms in Overall Spinopelvic Sagittal Alignment

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Introduction: Progression of kyphotic deformity at the middle/lower cervical spine can cause difficulty with horizontal gaze, so compensation at other spinopelvic parts may occur. However, the precise mechanism remains unclear. The present study investigated the effect of correction surgery for cervical kyphosis on the compensatory mechanisms in overall spinopelvic sagittal alignment.

Materials/Methods: Forty-one patients, 23 males and 18 females (mean age 67 years) underwent correction surgery for cervical kyphosis using the posterior screw-rod system. Spinopelvic lateral radiographs in the standing position were taken before and after surgery. C0-1 angle, C1-2 angle, clivo-axial angle (CAA), C2-7 angle, thoracic kyphosis, lumbar lordosis, pelvic incidence, pelvic tilt, and sacral slope were measured. Correlations between C2-7 angle and these parameters before surgery, and correlations between the correction angle of cervical kyphosis and postoperative changes of these parameters were evaluated.

Results: Negative correlations were found between the C2-7 angle and CAA ($R=-0.640$, $p<0.01$), and C2-7 angle and C0-1 angle ($R=-0.762$, $p<0.001$) before surgery. Negative correlations were found between the correction angle of C2-7 and change of CAA ($R=-0.718$, $p<0.001$), and the correction angle of C2-7 and change of C0-1 angle ($R=-0.672$, $p<0.01$) after surgery **(Figure 1)**.

Conclusions: The present study demonstrated that C0-1 angle and CAA are more important in the compensatory mechanism for kyphotic deformity at the middle/lower cervical spine compared to downward parameters **(Figure 1, 2)**. That is, to maintain horizontal gaze, lordosis increases at the cranio-cervical junction with greater kyphosis at the middle/lower cervical spine. Correction of cervical kyphosis in the middle/lower cervical spine resulted in normalization of the C0-1 angle and CAA because the compensatory mechanism at the cranio-cervical junction for obtaining horizontal gaze was no longer necessary after surgical intervention **(Figure 1)**.

Presentation #55 (cont.)

Figure 1

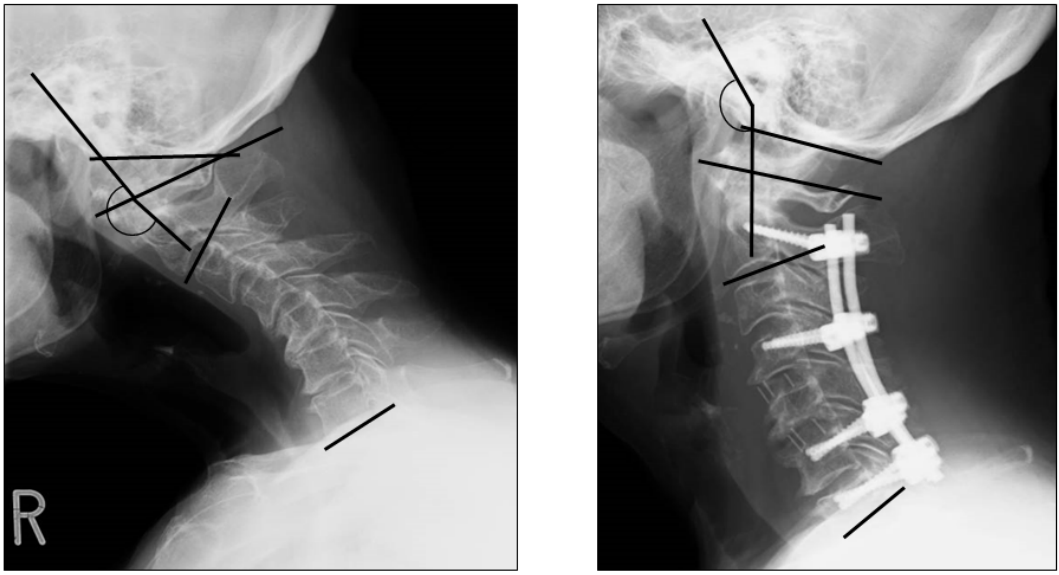
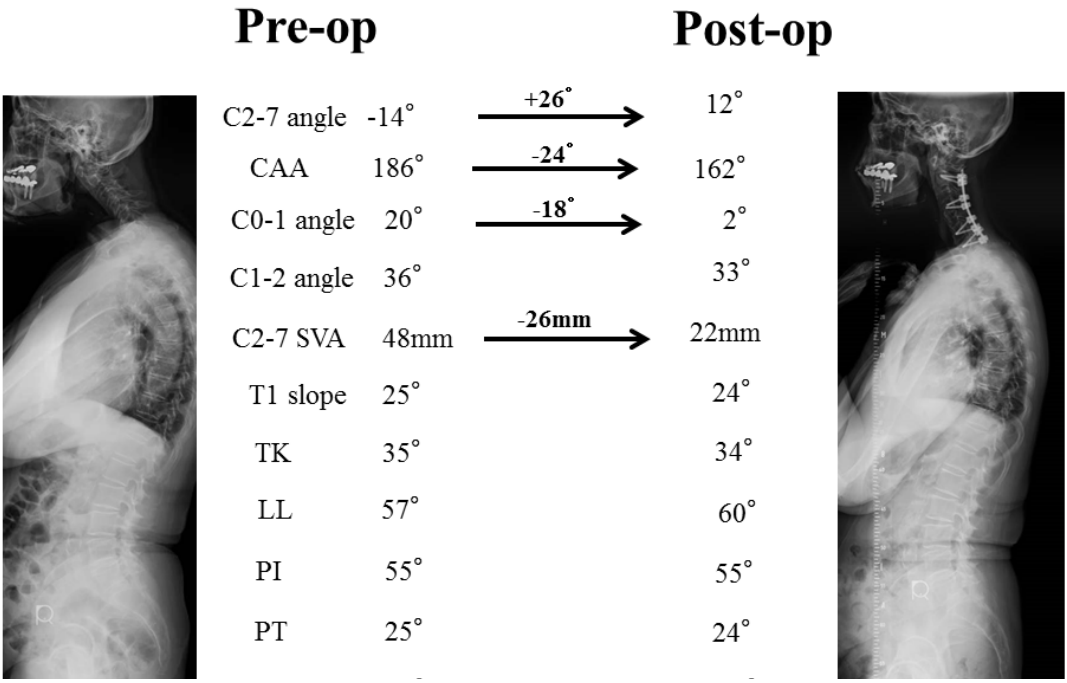


Figure 2



Presentation #56

Validation of a Cervical Spine Deformity Classification System Using a Long-Term Follow-Up Data After Multilevel Posterior Cervical Fusion Surgery

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Background: Recently, previous research proposed a cervical spine deformity (CSD) classification using a modified Delphi approach. However, C2-C7 sagittal vertical axis (SVA) and T1 slope minus C2-C7 lordosis (TS−CL) cut-off values for moderate and severe disability were based on expert opinion.
Objective: To investigate the validity of a CSD classification system.

Methods: From 2007 to 2012, 30 consecutive patients with a minimum 5-yr follow-up having 3- or more level posterior cervical fusion met inclusion criteria. The following radiographic parameters were measured: C0-C2 lordosis, C2-C7 lordosis, C2-C7 SVA, T1 slope, and TS−CL. Pearson correlation coefficients were calculated between pairs of radiographic measures and health-related quality of life.

Results: Average follow-up period was 7.3 years. C2-C7 SVA positively correlated with neck disability index (NDI) scores (r=0.554). Regression models predicted a threshold C2-C7 SVA value of 40.8mm and 70.6mm correlated with moderate and severe disability based on the NDI score, respectively. The TS−CL had positive correlation with C2-C7 SVA and NDI scores (r = 0.841 and r = 0.625, respectively). Regression analyses revealed that a C2-C7 SVA value of 40 mm and 70 mm corresponded to a TS−CL value of 20° and 25°, respectively.

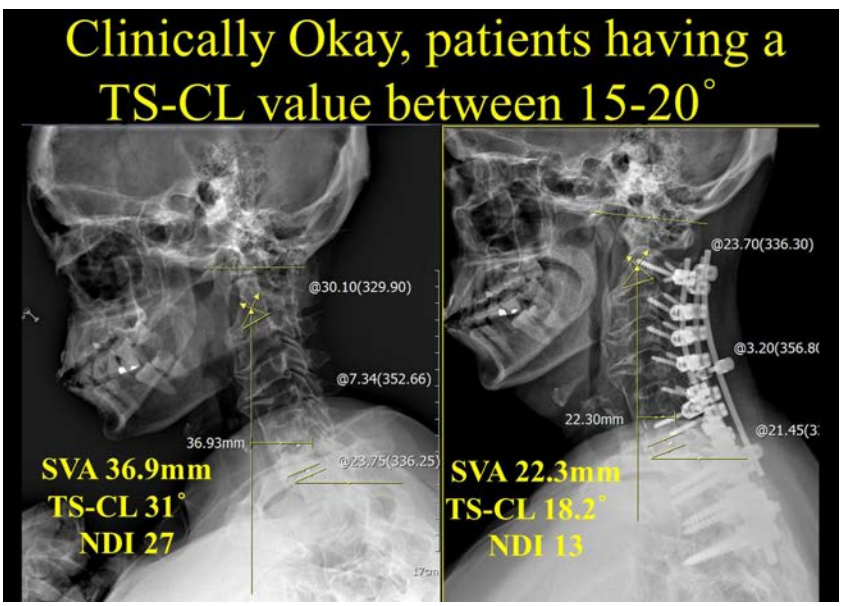
Conclusion: Regression models predicted a threshold C2-C7 SVA (value of 40.8mm and 70.6 mm) and TS−CL (value of 20° and 25°) correlated with moderate and severe disability based on the NDI, respectively. The cut-off value C2-C7 SVA and TS−CL modifier of the CSD classification can be revised accordingly.

Presentation #56 (cont.)

- **C2-C7 sagittal vertical axis (SVA)**
  - **0**: C2-C7 SVA < 4 cm
  - **1**: C2-C7 SVA 4 cm –8 cm
  - **2**: C2-C7 SVA > 8cm
- **Horizontal Gaze**
  - **0**: CBVA 1°–10°
  - **1**: CBVA -10°–0° or 11°–25°
  - **2**: CBVA <-10° or >25°
- **Cervical Lordosis Minus T1 Slope**
  - **0**: TS-CL <15°
  - **1**: TS-CL 15°–20°
  - **2**: TS-CL >20°
- **Myelopathy**
  - **0**: mJOA=18 (None)
  - **1**: mJOA=15–17 (Mild)
  - **2**: mJOA=12–14 (Moderate)
  - **3**: mJOA<12 (Severe)
- **SRS-Schwab Classification**
  - **T, L, D, or N**: Curve Type
  - **0, +, or ++**: PI minus LL
  - **0, +, or ++**: Pelvic Tilt
  - **0, +, or ++**: C7-S1 SVA

→

- **C2-C7 sagittal vertical axis (SVA)**
  - **0**: C2-C7 SVA < 4 cm
  - **1**: C2-C7 SVA 4 cm – 7 cm
  - **2**: C2-C7 SVA > 7 cm
- **Horizontal Gaze**
  - **0**: CBVA 1°–10°
  - **1**: CBVA -10°–0° or 11°–25°
  - **2**: CBVA <-10° or >25°
- **Cervical Lordosis Minus T1 Slope**
  - **0**: TS-CL <20°
  - **1**: TS-CL 20°–25°
  - **2**: TS-CL >25°
- **Myelopathy**
  - **0**: mJOA=18 (None)
  - **1**: mJOA=15–17 (Mild)
  - **2**: mJOA=12–14 (Moderate)
  - **3**: mJOA<12 (Severe)
- **SRS-Schwab Classification**
  - **T, L, D, or N**: Curve Type
  - **0, +, or ++**: PI minus LL
  - **0, +, or ++**: Pelvic Tilt
  - **0, +, or ++**: C7-S1 SVA



Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #57

Changes in Cervical Sagittal Alignment in Adolescent Idiopathic Scoliosis Following Posterior Spinal Instrumented Fusion

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Introduction: Sagittal balance has been strongly correlated to patient reported outcomes. The concept that each spinal segment can affect another is well known. However, little has been reported on cervical sagittal alignment, especially following posterior spinal instrumented fusion (PSIF) in adolescent idiopathic scoliosis (AIS). Empirically, changes in cervical sagittal alignment have been noted following thoracolumbar fusion in this population. Since sagittal balance is interrelated throughout the spine, it is expected that cervical alignment will change following thoracolumbar fusion.

Materials/Methods: Patients 10-25 years old from January 1, 2015 to September 1, 2017 were included if they were treated with PSIF for AIS and had Lenke Type 1 curves. All patients were instrumented with a single standard rod system. Three board certified orthopaedic surgeons performed all surgeries at a major academic medical center. Patients with neuromuscular disorders, revision surgeries, and osteotomies greater than Schwab 2 were excluded. In a retrospective chart review, pre- and post-operative standing scoliosis radiographs were reviewed, with a minimum follow-up of six months. Outcomes of interest were changes in C2-C7 angle, C0-C2 angle, C2-C7 sagittal vertical axis (SVA), McGregor slope (McGS), and T1 slope.

Results: Thirty patients met inclusion criteria. There were five males and twenty-five females. Average age at surgery was 15.1, average body mass index was 22.53 kilograms/meters^2, and average number fusion levels was 7.3. Cervical sagittal alignment changed in all patients post-operatively, with 19/30 (63%) resulting in improved lordosis (mean change of C2-C7 angle of 3.76 degrees). Mean C0-C2 angle change was 1.02 degrees, mean C2-C7 SVA change was 1.81 millimeters, mean McGS change was 0.16 degrees, and mean T1 slope change was 0.37 degrees. See Table 1.

Conclusion: Thoracolumbar fusion in patients with AIS results in changes in post-operative cervical sagittal alignment, with most patients obtaining improved cervical lordosis.

Presentation #57 (cont.)

Table 1. Pre- and post-operative changes in cervical sagittal alignment.

	C2-C7 Angle (deg)	C0-C2 Angle (deg)	C2-C7 SVA (mm)	McGS (deg)	T1 Slope (deg)
Mean	3.76	-1.02*	1.81	0.16	0.37
SD	11.15	9.16	8.32	8.39	6.60
Median	5.45	-2.70	1.00	0.25	-0.15
IQR	(-1.575 - 10.225)	(-5.575 - 3.875)	(-1.75 - 8.75)	(-5.675 - 6.65)	(-3.85 - 4.725)

*Negative value denotes kyphosis

Presentation #58

Recovery Kinetics: Comparison of Patients undergoing Primary or Revision Procedures for Adult Cervical Deformity Using a Novel Area Under the Curve Methodology

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Introduction: Limited data is available to objectively define what constitutes a 'good' versus a 'bad' recovery for operative cervical deformity (CD) patients. Furthermore, the recovery patterns of primary versus revision procedures for CD is poorly understood. The objective of our study was to define and compare the recovery profiles of CD patients undergoing primary or revision procedures with an increased sensitivity, utilizing a novel area-under-the-curve (AUC) normalization methodology.

Methods: Retrospective review of a prospective multicenter CD database. CD patients undergoing primary or revision surgery, with baseline to 1-year HRQL scores were included. Clinical symptoms and HRQLs were compared among groups(primary/revision). Normalized HRQL scores at baseline and follow-up intervals (3M,6M,1Y) were generated. Normalized HRQLs were plotted and AUC was calculated, generating one number describing overall recovery (Integrated-Health-State;IHS). Sub-analysis identified recovery patterns through 2-year follow-up.

Results: 83 patients were included (45 primary, 38 revision). Age (61.3vs.61.9), gender (F: 66.7% vs. 63.2%), BMI (27.7 vs. 29.3), CCI, frailty and osteoporosis (20% vs. 13.2%) were similar between groups($p>0.05$). Primary-patients were more preoperatively neurologically symptomatic (55.6% vs. 31.6%), less sagittally malaligned (cSVA: 32.6 vs 46.6; T1-Slope: 28.8 vs. 36.8), underwent more anterior-only approaches (28.9%vs.7.9%), and less posterior-only approaches (37.8% vs. 60.5%), all $p<0.05$. Combined approaches, decompressions, osteotomies, and construct-length were similar between groups ($p>0.05$). Revisions had longer op-times (438.0 vs. 734.4min, $p=0.008$). Following surgery, complication-rate was similar between groups (66.6% vs. 65.8%, $p=0.569$). Revision-patients remained more malaligned (cSVA, TS CL; $p<0.05$) than primary-patients until 1-year follow-up ($p>0.05$).

Presentation #58 (cont.)

Normalized HRQLs determined primary-patients to exhibit less neck pain (NRS: 0.51 vs 0.83) and myelopathy (mJOA: 1.11 vs 0.97) symptoms through 1-year follow-up compared to revision-patients ($p<0.05$). These differences subsided when following patients through 2-years ($p>0.05$). Despite similar 2-year HRQL outcomes, revision-patients exhibited worse neck pain (NRS) Integrated-Health-State recovery (0.48 vs 0.83, $p<0.05$).

Conclusion: Despite both primary and revision patients exhibiting similar HRQL outcomes at final follow-up, revision patients were in a greater state of postoperative neck pain for a greater amount of time. Revision patients also exhibited significantly worse mJOA scores through 1-year follow-up, although this difference subsided by 2-years.

Presentation #59

Characteristics of Residual Symptoms Following Laminoplasty in Elderly Patients with Cervical Spondylotic Myelopathy: A Prospective Comparative Study of Clinical Outcomes for 1025 Patients

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Introduction: Age at the time of surgery influences the surgical outcome. However, no report has elucidated residual symptoms following surgery in elderly patients with cervical spondylotic myelopathy (CSM). We designed a large-scale cohort study examining the surgical outcomes of CSM in elderly patients from a single surgery. The purpose of this study was to compare the surgical outcomes between non-elderly and elderly patients with CSM and to characterize the preoperative symptoms and postoperative residual symptoms in elderly patients.

Materials and Methods: A total of 1025 consecutive patients with CSM (642 men and 383 women; mean age, 64.4 years; range, 23–93 years) who underwent laminoplasty were included. Patients were divided into three groups based on age: non-elderly (<65 years), young-old (65–74 years), and old-old (≥75 years), and the number of patients in each group was 488, 329, and 208, respectively. The pre- and postoperative neurological statuses were evaluated using the Japanese Orthopaedic Association (JOA) scoring system for cervical myelopathy. The recovery rate (RR) of each function was compared among the three groups. Radiographic data including alignment and range of motion (ROM) were also assessed.

Results: The mean preoperative JOA scores of motor function of the lower extremity in non-elderly, young-old, and old-old groups were 2.8, 2.2, and 1.6, respectively ($P < 0.0001$). Elderly patients showed significantly lower JOA scores for bladder function than non-elderly patients (2.7, 2.5, and 2.2, $P < 0.0001$). Cervical lordosis in the neutral position increased gradually with age. Total ROM decreased with increasing age. After surgery, the mean RRs of motor function of the lower extremity were 57.7%, 38.6%, and 24.0%, respectively. Gait disturbance significantly increased with age ($P < 0.0001$).

Conclusions: Postoperative gait disturbance persisted more than other symptoms in elderly patients than in non-elderly patients.

Presentation #60

How Does Everyone Stack Up? A Risk-Adjusted Ranking Scheme for Surgeons Performing ACDF for Radiculopathy

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Introduction: It is widely known that significant surgeon-level and geographical variation exists for patient-reported outcomes (PRO) after anterior cervical discectomy and fusion (ACDF) for radiculopathy. However, there is currently no means of determining which spine surgeons or centers provide the best (or worst) outcomes. The primary aim of this study is to present a methodology for PRO-based, risk-adjusted rankings of spine surgeons and sites that perform ACDF for radiculopathy. The second aim is to determine whether the choice of surgeon, or QOD site, explains more of the variation in PROs.

Materials/Methods: All patients in the Quality and Outcomes Database (QOD) who underwent elective ACDF for radiculopathy at the top 46 contributing sites were studied. Multivariable regression models were fit for each of the following 12-month PROs, treating QOD site as a fixed effect but surgeon ID as a random effect: Neck Disability Index (NDI), Euro-Qol (EQ-5D), neck and arm pain, and satisfaction. Covariates for these models were: age, gender, body mass index (BMI), ethnicity, education, smoking status, opioid use, comorbidities, pre-operative symptoms, American Society of Anesthesiologists (ASA) grade, symptom duration, worker's compensation and liability, insurance, employment, and baseline PROs. Flat prior distributions for the regression coefficients were assumed for each outcome, and these were combined with patient data to generate posterior distributions for the ranks of each surgeon. The mean values of these posterior distributions of ranks were then computed. Hierarchical Bayesian models were also fit for the same outcomes, treating QOD site as a random effect and surgeon ID as a nested random effect. The posterior means of the variance associated with QOD site and surgeon ID were computed and compared.

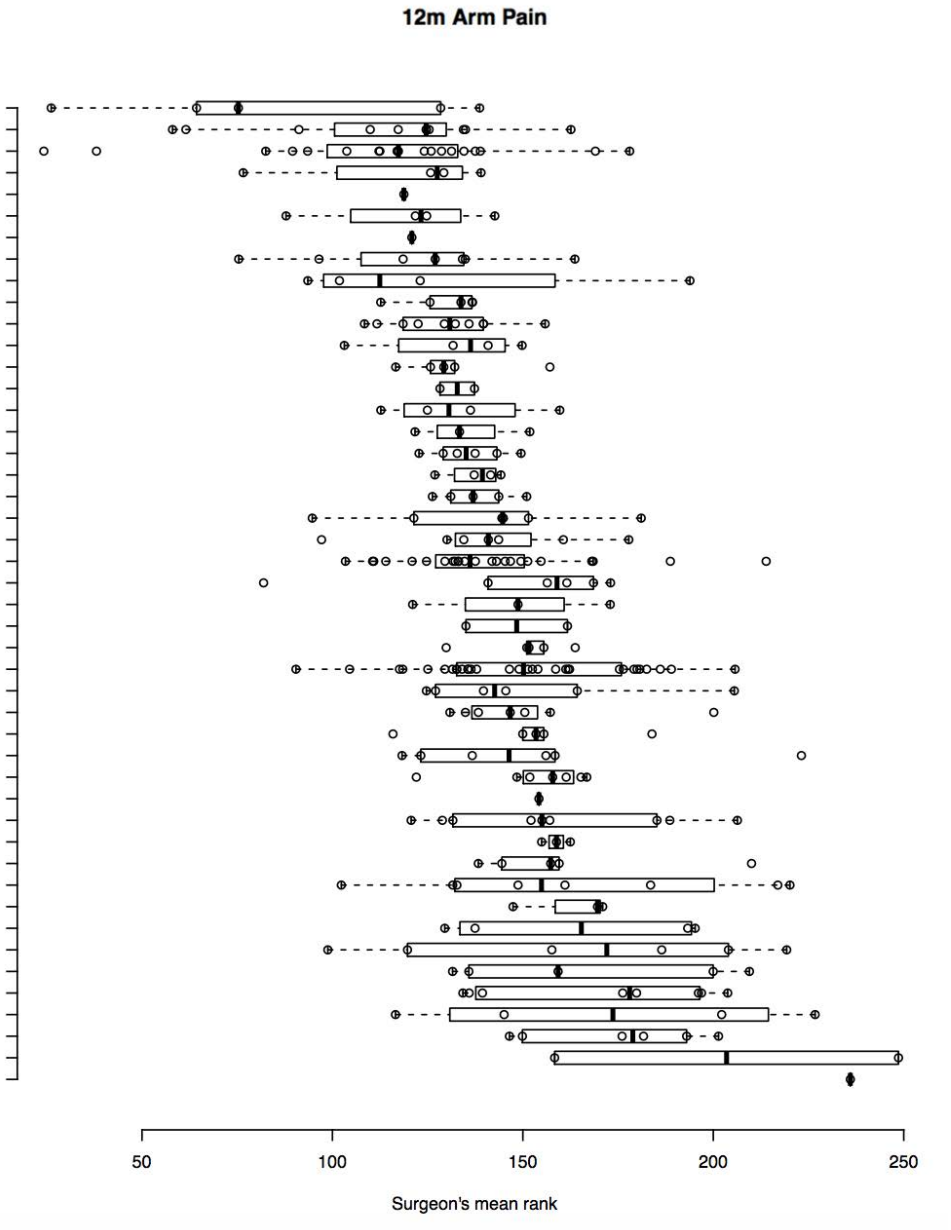
Results: The 46 QOD sites included in this study encompass 285 spine surgeons and 3824 patients. Figures 1 displays risk-adjusted rankings of surgeons for 12-month arm pain. Table 1 provides the variance explained by site and surgeon, and is based on the hierarchical regression models with QOD site as a random effect and surgeon ID as a nested random effect. The variance attributed to site was significantly greater than the variance attributed to surgeon ID for NDI (0.519 vs. 0.250) and EQ5D (0.470 vs. 0.250), but not for VAS neck pain (0.351 vs 0.272), VAS arm pain (0.318 vs 0.128), or satisfaction (0.416 vs. 0.338).

Discussion: Here we present a ranking methodology for surgeons and centers that is 1) risk-adjusted; 2) specific to ACDF for radiculopathy; 3) centered around PROs; and 4) national in scale. We also demonstrate that while the choice of surgeon is a powerful driver

Presentation #60 (cont.)

of PROs, the selection of a particular QOD site is even more consequential for NDI and EQ5D one year after surgery.

Figure 1: Risk-Adjusted Rankings for Arm Pain 12 Months After ACDF for Radiculopathy
Each tick mark represents a de-identified QOD site, and the corresponding boxplot depicts the posterior mean ranks for each surgeon at that site.



Presentation #60 (cont.)

Table 1: Posterior Means of Variance in PROs After ACDF Due to Surgeon and Site

	$\sigma_{surgeon}$		σ_{site}		$\frac{sigma_{surgeon}}{\sigma_{site}}$	
	Posterior Mean	95% BCI	Posterior Mean	95% BCI	Posterior Mean	95% BCI
12m NDI	0.250	0.137, 0.356	0.519	0.379, 0.703	0.496	0.249, 0.789
12m EQ5D	0.250	0.111, 0.373	0.470	0.332, 0.646	0.549	0.222, 0.927
12m Neck Pain	0.272	0.147, 0.380	0.351	0.221, 0.512	0.816	0.370, 1.448
12m Arm Pain	0.128	0.023, 0.265	0.318	0.201, 0.462	0.427	0.069, 1.025
12m Pt Satisfaction Index	0.338	0.180, 0.483	0.416	0.253, 0.604	0.863	0.396, 1.619

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #61

Health Outcomes and Patient Satisfaction After Elective Cervical Spine Surgery for Cervical Spondylotic Myelopathy: A Prospective 24-month Study

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Introduction: Patient reported outcomes and satisfaction are increasing being used as metrics for value in health care. However, for patients with cervical spondylotic myelopathy (CSM) who undergo elective surgery, there is limited data about the time course for change in outcome and patient satisfaction. The purpose of this study was to evaluate the change health outcomes and patient satisfaction during the first 24 months after elective cervical spine surgery.

Materials and Methods: We performed a prospective cohort study of patient outcomes and satisfaction with surgery among adult patients undergoing elective surgery for CSM at a single center. We included patients undergoing elective first-time cervical spine surgery for degenerative conditions. We excluded patients with a diagnosis of trauma, infection, pregnancy, central cord syndrome, concomitant neuromuscular or rheumatologic diagnoses. Health outcomes measured were: modified Japanese Orthopaedic Association survey score (mJOA); Neck Disability Index (NDI); SF-36 Physical Component Score and Mental Component Score (PCS, MCS); survey of patient satisfaction with surgery. Outcomes were measured preoperatively and at 3-, 6-, 12-, and 24-months after surgery. Myelopathy was defined by the treating physician. Linear mixed models were used to identify characteristics significantly associated with health outcomes, and the time course of change in outcome up to 24 months after surgery. Statistical significance was set at 0.05. Informed consent was obtained.

Results: 102 patients were prospectively and consecutively enrolled, of which 10 were lost to follow-up 24-months after surgery. Mean age was 54.9 years; 56% were female. Preoperative mean mJOA was 13.4 (95% CI 12.9, 13.9); NDI 38.9 (95% CI 35.6, 42.3); SF36 PCS 35.5 (95% CI 33.9, 37.0); SF36 MCS 43.3 (40.7, 45.9). At 24 months after surgery, mJOA improved a mean of 0.7 points (95% CI 0.2, 1.1) and median recovery rate was 14.3%. For NDI, 69.6% of patients achieved 20% or greater improvement, and 54.9% achieved at least 15 points of improvement. For PCS/MCS, the mean improvement was 6.3 (4.3, 8.3) and 4.7 (2.4, 6.9) respectively. 74.8% reported that they were extremely/somewhat satisfied with surgery and 72.8% reported they would definitely/most likely make the same decision again. One multivariate analysis, the only characteristic significantly associated with change in mJOA score at 24 months after surgery was the preoperative mJOA score. mJOA scores improved over time but the change did not reach statistical significance. Improvement in NDI plateaued at 6-months after surgery, while PCS plateaued at 3-months and MCS plateaued at 12-months. Satisfaction with surgery and the proportion of patients who would make the same decision for surgery again remained stable from 6- to 24-months after surgery.

Conclusions: Patients undergoing elective surgery for CSM report improvement in health outcomes by 6 months after surgery that are sustained 24 months after elective cervical spine surgery for degenerative changes. Improvements plateau at different time points for each outcome. Satisfaction with surgery and proportion of patients who would make the

Presentation #61 (cont.)

same decision for surgery again does not significantly change between 6- to 24-months after surgery.

Presentation #62

Preoperative PROMIS Score Is Not Predictive of Postoperative Pain or Narcotics Consumption After Anterior Cervical Discectomy and Fusion

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Background Context: The Patient-Reported Outcomes Measurement Information System (PROMIS) was developed to provide a more efficient method of measuring patients' physical health status both pre- and postoperatively. Previous reports in the spine literature have focused on the efficiency of PROMIS as compared to more traditional outcome measures. However, no previous study has identified whether preoperative physical health as measured by PROMIS is a predictive factor for postoperative outcomes. One outcome of interest within spinal surgery populations is immediate postoperative pain and narcotics utilization. These factors are of interest to surgeons due to the necessity of preventing narcotics-associated side effects and long-term dependence in operative patients. Thus, the purpose of this study is to determine if there is an association between preoperative PROMIS physical function score and immediate postoperative pain and narcotics consumption after anterior cervical discectomy and fusion (ACDF).

Materials/Methods: A prospectively-maintained surgical registry of patients undergoing primary, 1-2 level ACDF procedures between 2015-2016 for degenerative pathology was retrospectively reviewed. Patients were grouped into top and bottom halves of preoperative PROMIS score, using a cutoff score of 40. Higher PROMIS scores are associated with better overall physical function. Preoperative PROMIS score groups were tested for an association with demographic and perioperative characteristics using student's t-test and chi-square analysis for continuous and categorical variables, respectively. Multivariate linear regression was utilized to determine if there was an association between preoperative PROMIS score groups and inpatient VAS pain score and narcotics consumption, defined as OMEs, on postoperative day (POD) 0.

Results: 97 patients were included in this analysis. 43.3% (42) of patients has PROMIS ≥ 40, while 56.7% (55) had PROMIS < 40. Patients with lower PROMIS scores were more likely to have Workers' Compensation insurance (43.6% vs 16.7%, p=0.005). There were no significant differences between PROMIS score groups in regards to age, sex, body mass index, smoking status, Charlson Comorbidity Index, operative time, or estimated blood loss (p>0.05 for each; **Table 1**). Lower PROMIS score was associated with longer length of postoperative stay (13.3 vs 8.7 hours; p=0.026). Finally, there were no significant differences between groups in regards to VAS pain scores, hourly narcotics consumption, or total narcotics consumption on POD 0 (p>0.05 for each; **Table 2**).

Conclusions: Patients with worse preoperative physical function as indicated by lower PROMIS demonstrated longer lengths of postoperative stay of approximately five hours.

Presentation #62 (cont.)

However, preoperative PROMIS score was not a predictive factor for immediate postoperative pain and narcotics consumption after ACDF procedures. More work is necessary to characterize the utility of the PROMIS tool within orthopedic spinal procedures.

Table 1. Patient Demographics by PROMIS Score

	PROMIS ≥ 40 (n=42)	**PROMIS < 40 (n=55)**	**†p-value***
Age (mean ± SD)	49.0 ± 10.2	48.7 ± 9.2	0.891
Gender (n)			0.642
Female	42.9% (18)	38.2% (21)	
Male	57.1% (24)	61.8% (34)	
Body Mass Index (n)			0.268
Non-Obese (<30 kg/m^2)	59.5% (25)	48.2% (26)	
Obese (≥ 30 kg/m^2)	40.5% (17)	51.8% (28)	
Smoking Status			0.705
Non-Smoker	88.1% (37)	85.5% (47)	
Smoker	11.9% (5)	14.5% (8)	
Insurance Status			**0.005**
Non-WC	**83.3% (35)**	**56.4% (31)**	
WC	**16.7% (7)**	**43.6% (24)**	
Ageless CCI (mean ± SD)	0.6 ± 1.0	0.8 ± 1.0	0.332

SD = Standard Deviation; CCI = Charlson Comorbidity Index; WC = Workers' Compensation
†p-value was calculated using Student's t-test (continuous) or Chi-square analysis (categorical)
*Boldface indicates statistical significance

Table 2 Operative Characteristics by PROMIS Score

	PROMIS ≥ 40 (n=42)	PROMIS < 40 (n=55)	†p-value*
Operative Time (min)	50.4 ± 13.1	49.3 ± 14.0	0.711
Estimated Blood Loss (mL)	27.9 ± 11.2	29.6 ± 12.9	0.482
Length of Stay (hours)	**8.7 ± 5.5**	**13.3 ± 13.7**	**0.026**
POD 0 VAS Pain Score	4.3 ± 1.9	5.2 ± 2.3	0.052
POD 0 Narcotics (OMEs)			
Hourly OME	4.6 ± 2.7	5.0 ± 6.1	0.734
Total OME	34.2 ± 21.9	34.7 ± 21.3	0.419

POD = Postoperative Day; VAS = Visual Analogue Scale;
OME = Oral Morphine Equivalent
†p-value was calculated using linear regression controlling for insurance status
*Boldface indicates statistical significance

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #63

Limited Morbidity and Radiographic Benefit of C2 vs. Subaxial Cervical Upper-Most Instrumented Vertebrae

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Introduction: Use of cervical deformity (CD)-corrective instrumentation in the subaxial cervical spine is widely considered risky due to the narrow width of subaxial cervical pedicles and anatomy of the vertebral artery between C3-C6. While C2 fixation provides increased biomechanical stability, the literature is sparse on guidelines indicating extension of CD-corrective fusion from the subaxial cervical spine to C2. The goal of this study was to evaluate differences in alignment and clinical outcomes between surgical CD patients with subaxial upper-most instrumented vertebrae(UIV) and patients with UIV at C2.

Methods: Retrospective review of a prospective, multicenter CD database. Operative CD patients(C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°) with baseline(BL) and 1-year postop(1Y) radiographic data, and cervical UIV≥C2. Patients were grouped by UIV: C2 or subaxial(C3-C7) and propensity score matched(PSM) for BL cSVA. Mean comparison tests assessed differences in BL and 1Y patient-related, radiographic, and surgical data between UIV groups, as well as overall BL to 1Y changes in radiographic alignment and clinical outcomes.

Results: PSM analysis included 62 patients(31 C2 UIV, 31 subaxial UIV) undergoing surgery for CD(7.4±3.6 lvls fused, 44% anterior approach, 19% posterior, 37% combined). Groups did not differ in BL comorbidity burden(P=0.175) or cervical sagittal alignment(cSVA,P=0.401). C2 UIV patients were older(64yrs vs 58, P=0.040) and had longer fusions(10 lvls vs 6, P<0.001). Overall, surgery addressed cervical and upper cervical malalignment, including BL to 1Y improvements in TS-CL(41° to 28°,P<0.001), cSVA(39 mm to 33,P=0.003), C0-C2 lordosis(36° to 30°,P<0.001), and McGS(6.0° to -1.8°,P<0.001). There were no BL to 1Y changes in spinopelvic alignment, as assessed by PT and PI-LL(both P>0.05); however, the overall cohort showed BL to 1Y increases in SVA(5 mm to 26, P=0.003) and TK(40° to 44°,P=0.003). While both subaxial UIV and C2 UIV patients showed significant BL-1Y improvements in McGS(both p<0.030), C2 UIV patients improved to a larger degree(7.3° vs 6.2). While not statistically significant, C2 patients had higher UIV inclination angles than

Presentation #63 (cont.)

subaxial patients (27° vs 19°,P=0.076), indicating greater anterior construct inclination. UIV inclination did not correlate with HRQL outcomes (all P>0.05). Overall rates of complications, reoperation, pseudarthrosis, and BL to 1Y changes in HRQL instruments, including NDI, NRS Back/Neck, EQ-5D, and mJOA did not differ between groups(all P>0.05). Patients with C2 UIV showed higher operative complication rates(16% vs 0%,P=0.020).

Conclusion: When presenting with similar preop cervical sagittal deformity, patients with instrumentation ending at C2 showed similar rates of reoperation, non-union, and baseline to 1-year changes clinical outcome measures as patients with instrumentation ending in the subaxial cervical spine. Compared to subaxial UIV patients, C2 UIV patients showed greater baseline to 1-year horizontal gaze improvement, demonstrating the radiographic benefit and minimal clinical downside of extending fusion constructs to C2.

Presentation #64

Quantitative Analysis of Cervical Spinal Cord Pulsation - Sonographic Evaluation in Anterior Intervertebral Decompression

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Purpose: We have been evaluating the decompression status of the neural elements in cervical decompression surgeries utilizing intraoperative sonography. Then we noticed the decompressed spinal cord showed pulsatile motion not only in antero-posterior direction but also in cranio-caudal direction. The purposes of this study were to reveal the cord pulsatile motion quantitively with sonographic videos during anterior intervertebral decompression and to elucidate affecting factors on the cord dynamics.

Methods: Subjects included 29 patients (mean age:63.7 years, 10 females and 19 males) who underwent intraoperative sonographic evaluation during cervical intervertebral decompression procedures. Cases with OPLL or taking corpectomy were excluded in this study. The mean number of treated levels of a patient was 2.31 and sonographic videos were recorded after sufficient decompression at 63 intervertebral levels. As to investigated items, the spinal cord pulsatile motion in antero-posterior direction and in cranio-caudal direction (sliding motion) were quantitatively analyzed using two-dimensional motion measurement software (Move-tr / 2D, Library Co.). In addition, upper and lower cervical alignments (O-C2 angle, C2-C7 angle) during the surgery was measured and statistically analyzed their impacts on the spinal cord motion.

Results: The maximum amplitude of the cord pulsation in antero-posterior direction was 0.37mm (C3/4 : 0.33, C4/5 : 042, C5/6 : 0.39, C6/7 : 0.28). The velocity was 2.50 mm/s (C3/4 : 2.14, C4/5 : 2.67, C5/6 : 2.82, C6/7 : 1.81) at the maximum with mean velocity of 0.55 mm/s. As for the spinal cord sliding in the cranial-caudal direction, the maximum amplitude was 1.13mm (C3/4 : 0.89, C4/5 : 1.47, C5/6 : 1.00, C6/7 : 0.90) and the maximum velocity was 6.53mm/s (C3/4 : 5.49, C4/5 : 7.84, C5/6 : 5.93, C6/7 : 6.00) with mean velocity of 0.77mm/s. Regardless of the direction, the spinal cord pulsations were largest at the C4/5 level. As to correlations between the cervical spine alignments and the cord pulsation, the greater of the C2-C7 angle (mean as 17.1 degrees), the larger of the cord pulsation in all indicators (the maximum velocity, the average velocity, the maximum amplitude both in the antero-posterior direction and in the cranial-caudal direction). On the other hand, the O-C2 angle did not affect the amplitude or the velocity of the cord pulsation.

Discussion: We consider that the spinal cord motion after segmental decompression may exhibit physiological motion of the neural elements. According to the results of this study, the spinal cord pulsation was larger in the cranial-caudal direction than in the antero-posterior direction in general. In addition, we found that the motion of the spinal cord was largest at the C4/5 level, and the degree of the spinal cord motion was affected by the lower cervical alignment (C2-C7 angle). These facts may explain the reason that postoperative segmental palsy often occurs at the C5 myotome particularly in the cases with large cervical lordosis

Presentation #64 (cont.)

of the cervical spine. We should pay attention on the cord pulsatile motion in cervical decompression procedures.

Presentation #65

Cervical Myelopathy Presenting Without Symptoms in the Upper Extremities: Incidence and Presenting Characteristics

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Introduction: The most common signs and symptoms of cervical myelopathy (CM) manifest in the upper extremities and include hand numbness, hand clumsiness, and distal upper extremity weakness. While gait instability is also a common symptom and lower extremity pain, numbness, and proximal weakness may be seen, symptomatology in the lower extremities is typically encountered when coexisting complaints are present in the upper extremities. Cervical myelopathy presenting without symptoms in the upper extremities is rare and the incidence and character of such presentations is not well described.

Materials/Methods: A retrospective chart review of consecutive patients surgically treated for cervical myelopathy from disc herniation, spondylosis, or ossification of the posterior longitudinal ligament (OPLL) over a twelve-year period identified patients presenting without symptoms in the upper extremities. Demographic data and the clinical characteristics of these patients were analyzed.

Results: Of 974 patients treated, 11 (1.1%) had no symptoms in the upper extremities. There were eight male and three female with a mean age of 54 (40-76). All patients complained of difficulty ambulating and 7 of 11 (64%) had objective lower extremity weakness. 9/11 (82%) patients had initially been treated for lumbar degenerative disease prior to diagnosis. On examination, three (27%) had discernable mid-thoracic pin level while 5 (45%) had loss of sensation in the legs and 5 (45%) had prominent sensory loss in the genitalia. 2/11(18%) had hyperrflexia and 1 (9%) had a Babinski sign. Two patients (18%) had a Hoffmann sign. Imaging demonstrated cord compression from either spondylosis or soft disc at C6/7 in six patients, C5/6 in four, and C4/5 and C5/6 in one (Figure 1). No patient complained of urinary dysfunction but six males (54%) reported erectile dysfunction. All patients demonstrated neurological improvement after decompressive surgery. Presenting patient data is summarized on Table 1.

Conclusion: Cervical myelopathy from spondylosis or disc herniation may rarely present without patient complaints of symptoms in the upper extremities and may manifest with numbness in the perineum and legs, lower extremity weakness, and complaints of gait difficulty. The presence of low back pain and leg pain from coexisting lumbar disease may serve to delay the diagnosis. All patients with this mode of presentation had cervical cord compression at either the C5/6 or C6/7 levels and made up 1 percent of patient undergoing cervical decompression surgery. Surgery resulted in neurologic improvement in all patients. Awareness of this atypical pattern of presentation may aid in clinical assessment of a subset of patients with cervical cord compression.

Presentation #65 (cont.)

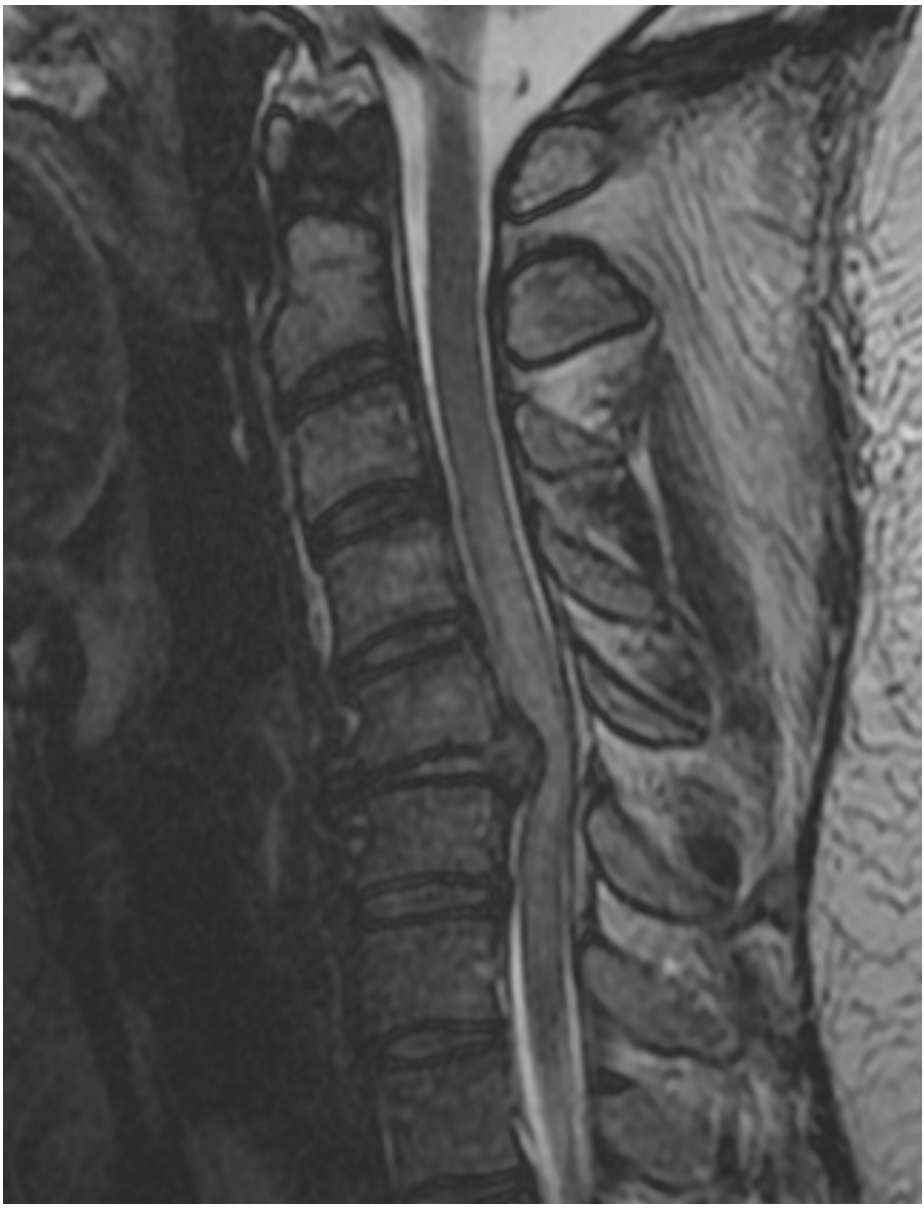

Figure 1. A sagittal T2-weighted MRI demonstrating a large C5/6 disc herniation causing spinal cord compression and T2 cord change in a 40 year-old male presenting with numbness in the genital area and bilateral dorsiflexion weakness but without upper extremity signs symptoms or findings on exam. He underwent an L4/5 laminectomy and transforaminal lumbar interbody fusion to treat severe lumbar stenosis and spondylolisthesis only to develop worsening numbness and weakness in the legs following surgery that prompted additional spinal imaging.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #65 (cont.)

	Number of patients (%)
Total patients	11/974 (1.1)
Gait difficulty	9 (81)
Lower extremity weakness	9 (81)
Lower extremity numbness	5 (45)
Perineum numbness	5 (45)
Mid-thoracic pin level	3 (27)
Lower extremity hyperreflexia	2 (18)
Hoffmann sign	2 (18)
Babinski sign	1 (9)
Cord compression at C5/6	6 (54)
Cord compression at C6/7	5 (46) (one also with C4/5 compression)
T2 cord signal change	4 (36)
Urinary incontinence	0 (0)
Previous treatment of coexisting degenerative lumbar disease	9 (81)

Table 1. Characteristics in 11 patients presenting with cervical myelopathy without clinical complaints in the upper extremities out of a series of 974 consecutive patients surgically treated for cervical myelopathy.

Presentation #66

Assessment of Standing Balance in Normal vs. Cervical Spondylotic Myelopathy Patients

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Introduction: Surgical decision making for Cervical Spondylotic Myelopathy (CSM) relies on subjective reports of symptoms and interpretation of physical exam findings. The Romberg test is used to identify balance issues, but has subjective interpretation. When combined with a force plate, the amount and velocity of sway during the Romberg test can be quantified objectively.

Methods: CSM patients scheduled for surgery who had quantitative balance measurements were identified. Clinical examination findings and imaging results for CSM were reviewed. Quantitative Romberg force plate readings with eyes open and closed were obtained and changes in balance measurements were compared to a normal population (N=28, mean age 39±7 years).

Results: We identified 30 CSM patients with a mean age of 58±10 years. Majority of patients presented with pain (90%) and neurologic symptoms (83%). Cord compression identified in magnetic resonance imaging (MRI) or in CT myelograms, was reported in 90%; only 20% had T2 cord signal changes on MRI. Mean eyes closed Romberg measurements were larger compared to eyes open measurements in CSM patients [$p<0.01$]. There was a larger change in Romberg (ΔR) measurements in CSM compared to normals for total sway area (TSA, 14.18 vs 0.02cm^2, $p<0.001$) and average speed (AS, 2.07 vs 0.23cm/sec, $p<0.001$) (Figure 1; Table 1). The presence of long tract signs produced larger ΔR compared to those without (TSA, 15.10 vs 0.58cm^2, $p<0.001$; AS, 2.17 vs 0.32cm/sec, $p<0.001$). Patients with identified cord compression on imaging also had larger ΔR over patients with no compression (TSA, 15.35 vs 4.29 cm^2, $p=0.03$; AS, 2.21 vs 0.79cm/sec, $p=0.01$). The difference in age was not associated with either measures of balance in CSM [$r^2<0.01$] and normals [$r^2=0.19$].

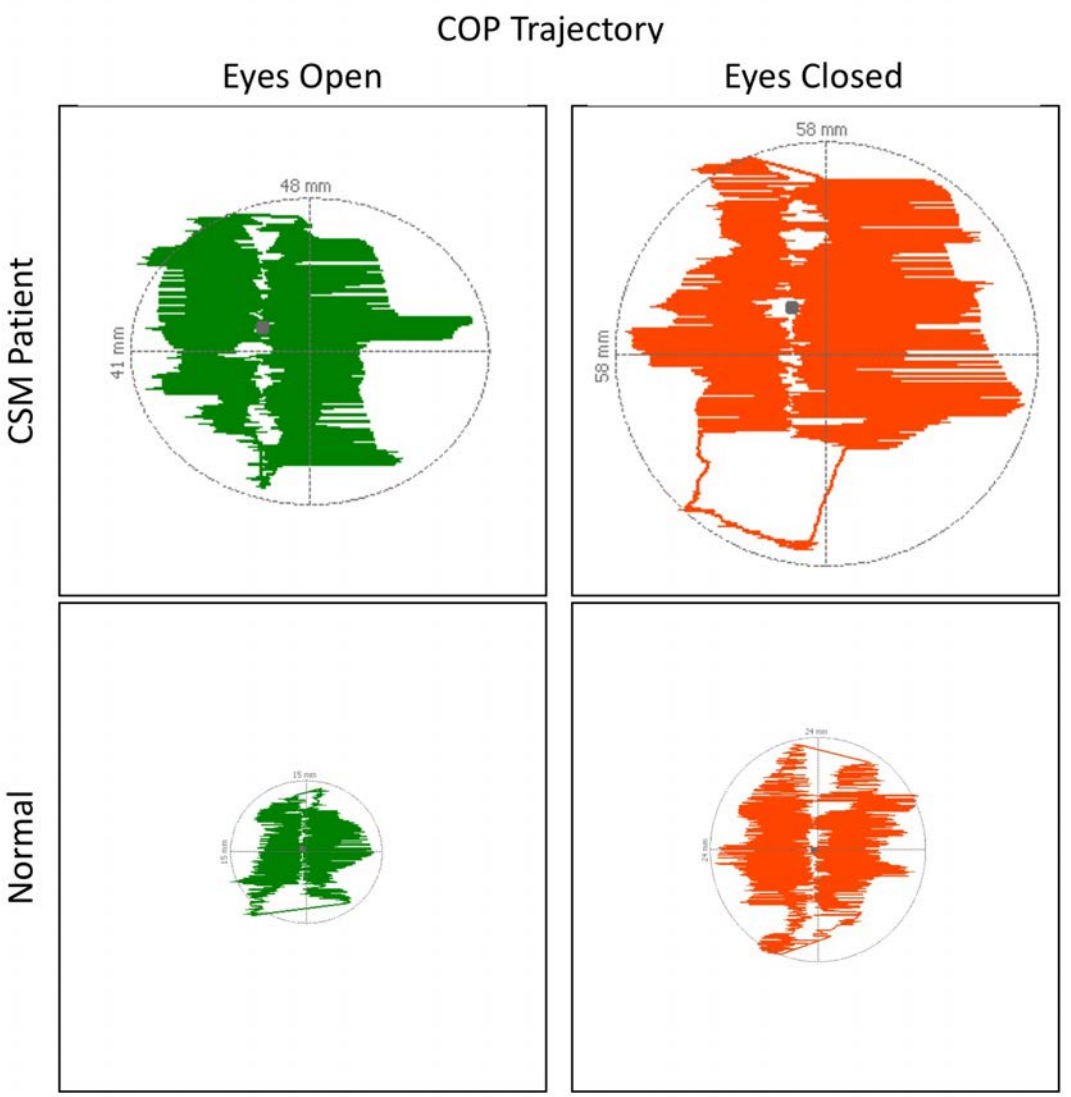
Conclusion: Standing balance can be quantified in patients with CSM and is worse when compared to a normal population. Long tract signs and cord compression in imaging translates to worsening balance in myelopathic patients. The use of quantitative Romberg measurements may help diagnose and evaluate progression of CSM.

Summary: Romberg test is a clinical exam used to identify static balance control in cervical spondylotic myelopathy (CSM) but has subjective interpretation. We demonstrate it can be quantified using force plate measurements. The quantitative Romberg test differentiates worse standing balance in CSM patients compared to a normal population, and distinguishes those with clinical long tract signs and cord compression on imaging. The use of quantitative Romberg measurements can help diagnose and evaluate progression of CSM, with the potential of earlier treatment.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #66 (cont.)

Figure 1. Graphical output of Total Sway Area (cm^2) based on center of pressure trajectory for eyes open and eyes closed examinations.



Presentation #66 (cont.)

Table 1. Comparison of mean change (∆R) in quantitative Romberg examinations between groups.

	Mean Change in Eyes Open and Eyes Closed Romberg (ΔR)					
	Normal vs CSM Patients			Cord Compression		
Parameters	Normal (N=28)	CSM (N=30)	p-value	[-] (N=31)	[+] (N=27)	p-value
Total Lateral COP (cm)	2.22	39.93	0.027	3.66	42.46	0.016
Total Lateral AP (cm)	45.93	38.55	0.793	43.76	40.23	0.890
Total Sway Area (cm2)	0.02	14.18	0.000	0.58	15.1	0.000
Average Speed (cm/sec)	0.23	2.07	0.000	0.32	2.17	0.000
Average Frequency (Hz)	0.06	-0.04	0.159	0.03	-0.02	0.473

Table 1. (continued)

Mean Change in Eyes Open and Eyes Closed Romberg (ΔR)					
T2 Cord Signal Changes			Long Tract Signs		
[-] (N=51)	[+] (N=6)	p-value	[-] (N=42)	[+] (N=16)	p-value
20.85	19.63	0.916	13.63	42.95	0.046
43.67	15.66	0.089	43.28	39.06	0.836
7.34	3.17	0.405	4.29	15.35	0.028
1.13	0.98	0.700	0.79	2.21	0.009
0.02	-0.06	0.731	0.04	-0.06	0.296

Presentation #67

Clinically Predictive Value of Gray Matter Volume Loss in Cervical Spondylotic Myelopathy (CSM): A Prospective Case-Control Study Utilizing 3T MRI and Volumetric Mapping

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Introduction: There is growing evidence to support white matter volume loss as a contributing factor in the development of clinical symptoms in cervical spondylotic myelopathy (CSM). This includes both descending motor fibers as well as the ascending dorsal column and nociceptive fasiculi. Less attention has been focused on the relationship between gray matter volume loss and patient symptoms. The current case-control study utilizes 3T MR imaging to evaluate the impact of volume loss in distinct regions of spinal cord gray matter on symptom development.

Methods: Seventeen patients with CSM (7F/10M, mean age=63±9years, BMI=29.9± 8.0 kg/m^2) and 19 controls (8F/11M, mean age=51±12years, BMI=24.5± 2.9kg/m^2) were enrolled. All patients underwent 3 Tesla MR imaging of the cervical spine. The high-resolution T2*-weighted images of the spinal cord were straightened and aligned with the PAM50 template and the bilateral dorsal horns and ventral horns volumes (number of voxels where 1 voxel = 0.46875 X 0.46875 X 6 mm^3) were calculated using the Spinal Cord Toolbox version 3.0.7, spanning C2 through C7 vertebral levels. Mean volume across all levels and normalized volumes (ratio of volume at any cervical level and at C2-C3) were calculated. Commonly used clinical scores of sensorimotor function and ambulatory status, the modified Japanese Orthopedic Association (mJOA), Nurick scale respectively were collected. Health related quality of scores including the neck disability index (NDI) and neck, and arm Numerical rating scales were also collected. Significant differences ($p<0.05$) between the gray matter volumes of controls and patients were assessed using independent sample t-test; one-way ANOVA and spearman's ρ were used to evaluate relation between gray matter volumetric loss and sensorimotor dysfunction.

Results: CSM subjects had a significantly lower mJOA score (14.2±1.7 vs. 18±0, $p<0.001$) and higher Nurick (1.9±0.8 vs. 0.0, $p<0.001$), NDI (17.5±7.7 vs. 1.6±2.4, $p<0.001$), neck (4.7±2.1 vs. 0.3±0.7, $p<0.001$), and arm (4.8±2.9 vs. 0.2±0.4, $p<0.001$) NRS scores than controls. The mean ventral and dorsal horn volumes were significantly lower in patients as compared to controls (26.73±2.86 voxels vs. 29.46±3.69 voxels, $p=0.018$ and 16.86±2.4 voxels vs. 18.7±2.95 voxels, $p=0.048$) [Fig 1]. Decreasing ventral horn volume loss predicted worse clinical scores of mJOA ($p=0.041$) and Nurick ($\rho = -0.394$, $p= 0.017$) [Fig 2]. Similarly, dorsal horn volumes were correlated with mJOA ($p=0.012$) and Nurick scores ($\rho = -0.413$, $p= 0.017$). Lower gray matter volumes were significantly predictive of increased disability and pain/discomfort. Ventral horn volumes negatively correlated with NDI ($\rho = -0.379$, $p= 0.023$), neck NRS ($\rho = -0.379$, $p= 0.023$), and arm NRS ($\rho = -0.329$, $p= 0.050$). Dorsal volumes were similarly associated.

Presentation #67 (cont.)

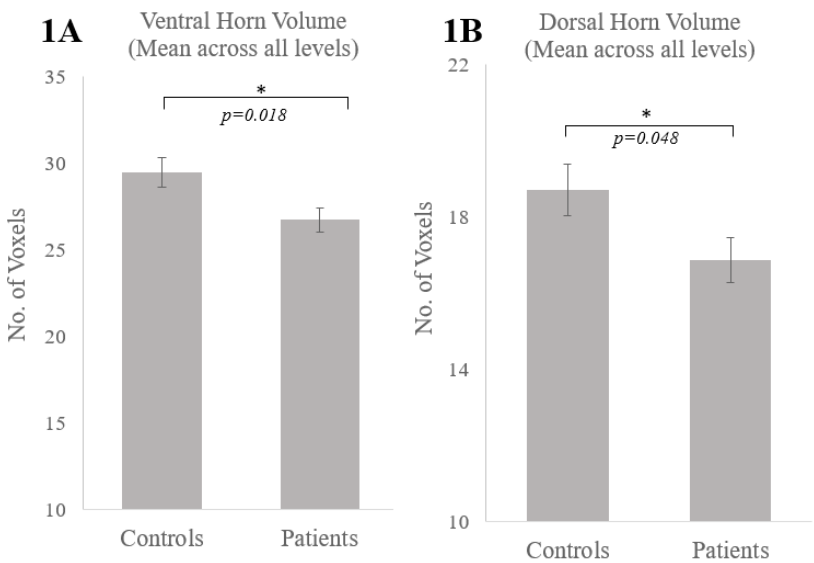

Figure 1. Mean (SE) Ventral and dorsal horn volumes between controls and patients with CSM. *denotes significant differences at p<0.05.

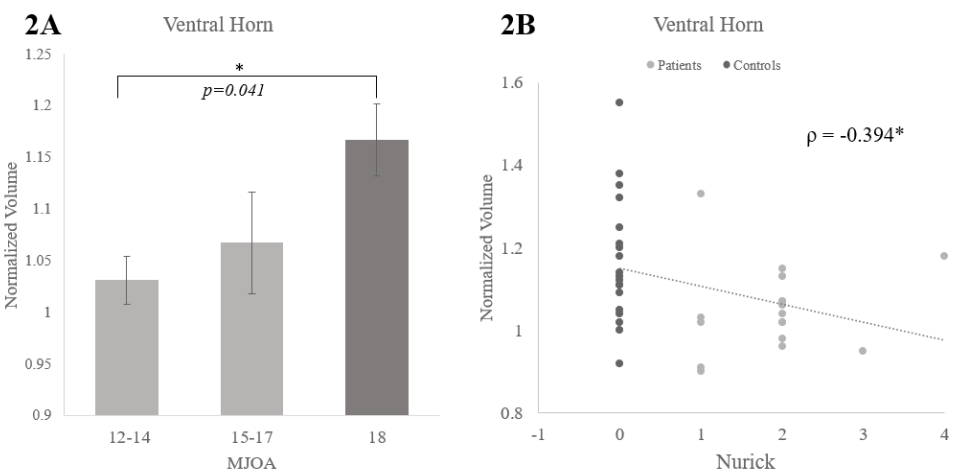

Figure 2. Relation between ventral horn volume and sensorimotor function as measured by mJOA, and Nurick scores. *denoted significant differences (p<0.05).

Conclusions: Use of advanced open- source neuroimaging software- Spinal Cord Toolbox allowed extraction of gray matter volumes. Increased ventral and dorsal volume loss and

Presentation #67 (cont.)

its significant association with sensorimotor dysfunction, disability and pain/discomfort suggests that gray matter volume loss may contribute to CSM symptomology more than was previously understood. Further study however is needed to understand the true nature and pathophysiology of CSM and as it relates to gray matter spinal cord changes.

Presentation #68 – 3rd Place Basic Science Research Award Winner

NF-kB Inhibitor Reduces the Inflammatory Response and Improves Bone Formation in rhBMP-2-Mediated Spine Fusion

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Summary: Loading of absorbable collagen sponges (ACS) with recombinant human bone morphogenic protein-2 (rhBMP-2) is used in the clinic to induce spinal fusion. However, rhBMP-2 has been associated with soft-tissue edema and inflammation. Our study demonstrates that the NF-κB inhibitor, NEMO binding domain peptide (NBD), reduces rhBMP-2 induced edema formation, inflammatory cell responses, and blocks transcription of NF-κB-regulated cytokines in rat. Furthermore, implantation of NBD-/rhBMP-2-loaded ACS during posterolateral intertransverse fusion surgical procedures stimulates spinal fusion compared to rhBMP-2/ACS controls.

Hypothesis: NBD reduces rhBMP-2-induced soft-tissue inflammation and stimulates spinal fusion

Design: Prospective, randomized, in vivo study

Introduction: Loading ACS with rhBMP-2 has been shown to enhance bone formation and induce spinal fusion. However, side effects, such as soft-tissue edema and inflammation, have been reported. NBD inhibits activation of NF-κB, a central regulator of immune response.

Materials/Methods: To evaluate inflammation, ACS with either high dose rhBMP-2, rhBMP-2+NBD, NBD only or buffer only were implanted into intramuscular fusion beds of 32 rats. After 2 days, edema formation at the implant sites was assessed using MRI T2-weighted relaxation time (T2-RT). Mononuclear cell infiltration was measured by histological analysis of the implant-surrounding zones. NF-κB binding and gene expression of inflammatory markers, interleukin(IL)1β, IL6, IL18, chemokine ligand(CCL)2 and CCL3 were analyzed in the implants.
To analyze new bone formation in the presence of NBD, ACS was loaded with rhBMP-2 or rhBMP-2+NBD and implanted during single-level (L4-5) posterolateral intertransverse lumbar fusion surgical procedures in 16 rats and analyzed by manual palpation, μCT and bone histology 3 months post-surgery.

Results: Quantification of T2-RT values at the implant region resulted in a 2.4-fold increase in the rhBMP-2 group compared to ACS ($p<0.05$). Addition of NBD to the rhBMP-2 loaded sponges diminished the increase compared to control ($p<0.05$, Fig. 1). H&E staining of the implant-surrounding zones showed an increase mononuclear cell infiltration in the rhBMP-2 group compared to rhBMP-2+NBD and controls. Relative gene expression was increased

Presentation #68 (cont.)

in the BMP-2 group compared to ACS only group for all genes ($p<0.05$) except TNFα. This rhBMP-2 mediated induction of gene expression levels of IL1β, IL18, CCL2 and CCL3 was blocked in the presence of NBD ($p<0.05$). The NF-κB DNA binding activity was increased in the rhBMP-2 group compared to ACS control. No difference was observed between rhBMP-2+NBD, NBD only and ACS groups.

In spinal fusion, a higher bone volume, reduced trabecular spacing ($p<0.05$), and a higher number of fused spinal segments were detected in the rhBMP-2+NBD group compared to BMP-2 group after sacrifice at week 12. Histological analysis of newly formed bone between the spinal processes L4-5 did not indicate any differences in the spatial distribution of the newly formed bone mass.

Conclusion: NBD reduces rhBMP-2 induced soft-tissue edema formation, reduces mononuclear cell infiltration, diminishes NF-κB binding, and blocks transcription of NF-κB-regulated cytokines in response to rhBMP-2 in rats. Furthermore, NBD stimulates rhBMP-2-mediated spinal fusion. The results of this study might provide the basis to develop new therapeutic approaches using graft material with a combinatory administration of rhBMP-2 and NBD for spinal fusion.

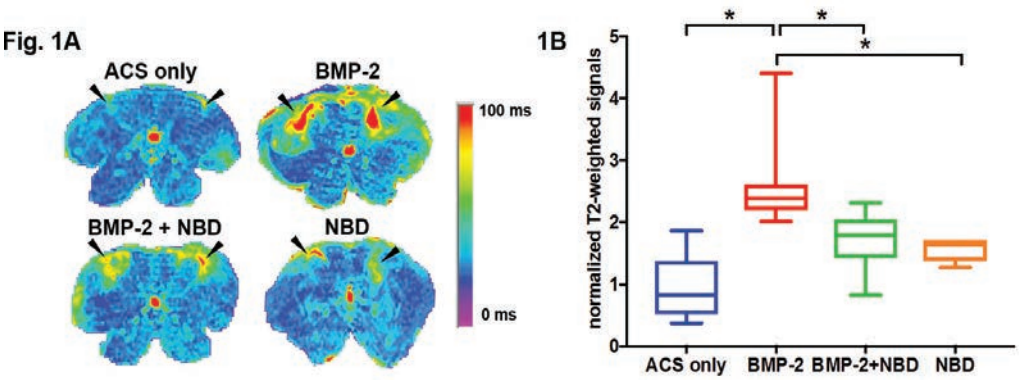

Figure 1. Increase of T2-weighted relaxation time by rhBMP-2 is diminished in the presence of NBD. 1A. Representative T2-weighted MRIs of the sites of the implants at day 2 post-surgery. Black arrows indicate implant sites. 1B. Diagram shows T2-weighted signal intensities normalized to control samples (ACS only). Data were obtained from n=6 sites per condition. *=$p<0.05$.

Presentation #69

A Thienoindazole Derivative Small Compound Prevented and Regenerated Intervertebral Disc Degeneration by Enhancing Extracellular Matrix Production

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Introduction: Degeneration of nucleus pulposus (NP) is a trigger for intervertebral disc degeneration (IDD) and can be a main cause of morbidities caused by IDD. Therefore, regenerative medicine for IDD is targeting NP to stave off the subsequent morbidities. Recently, a small thienoindazole derivative compound (TD-198946 [TD]) was identified as a novel drug for osteoarthritis by inducing chondrogenic differentiation and regenerating degenerated cartilage.[1] Because of the similarity of NP cells with chondrocyte, the TD is also expected to have efficacy on prevention and regeneration of IDD. The purpose of this study aimed to evaluate the effects of the TD on IDD.

Materials/Methods: For in vivo assay, a tail-disc puncture model with 33-gauge needle was used to create IDD on 10-week-old male C57BL6J mice.[2] The control solution or 5 µl of the TD (100nM) was injected into the disc space immediately after the puncture (prophylaxis model) or 2 weeks after the puncture (regeneration model). Mice were sacrificed at 6 weeks after the injection. Micro-CT scanning was performed to evaluate the disc height at 2, 4 and 6 weeks after the injection and the disc height index (DHI: disc height / vertebral body length x100) was calculated as previously described.[3] Histological evaluation with HE, safranin O (SO) and histological grading scale evaluation[3] was performed. For in vitro assay, human NP cells were cultured in 2D micromass. And alcian blue staining, glycosaminoglycan (GAG) production, and expression of genes related to NP were assessed. The differences in the measured variables were calculated by Mann-Whitney U test.

Results: In vivo assay; the DHI in the TD group was significantly higher compared to that of the control group at every time points in both prophylaxis model and regeneration model ($P<0.01$). The results of histological grading scale in the TD group was also significantly better than that of the control group at all points in both models ($P<0.01$). In histology, the NP structure in the TD group was well preserved in both models, but the NP structures of the control group was almost lost and is replaced with fibrous tissue in both models. (Figure 1A, 1B) In vitro assay; the alcian blue staining (Figure 2A) and the GAG production (Figure 2B, $p<0.05$) was enhanced in the TD group and the expression of aggrecan and hyaluronan synthase 2 (HAS2) was increased in the TD group (Figure 2C, $p<0.05$) compared to the control group.

Conclusion: The TD showed the effects on the preservation of disc height and NP structure in both prophylaxis administration and regeneration model. The results in vivo were supported by the results of in vitro study that the TD enhanced extracellular matrix production in human

Presentation #69 (cont.)

NP cells. The TD is a promising small compound targeting mild to moderate disc degeneration by preventing and regenerating of NP. molecule Therefore, our data suggested that the TD prevents and regenerates IDD by stimulating NP cells to produce extracellular matrix.

References:

1. Yano F, et al. Ann Rheum Dis. 2013 May;72(5):748-53.
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Figure 1A
Histology in prophylaxis model at 6 weeks

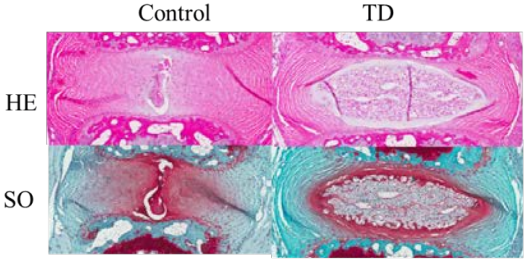


Figure 1B
Histology in regeneration model at 6 weeks

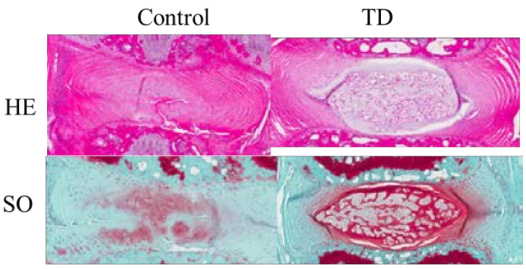


Figure 2A. Alcian Blue staining at 7days

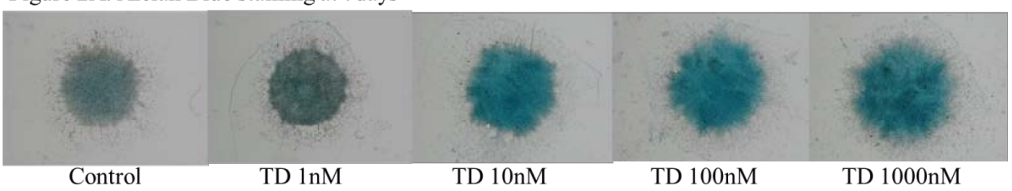


Figure 2B. GAG/DNA at 7days

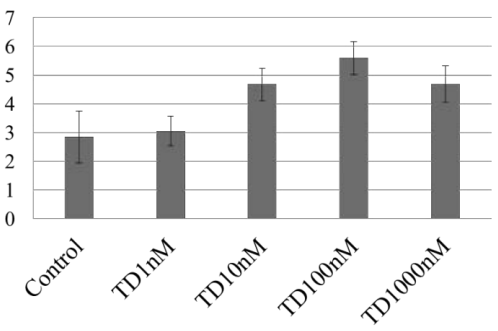
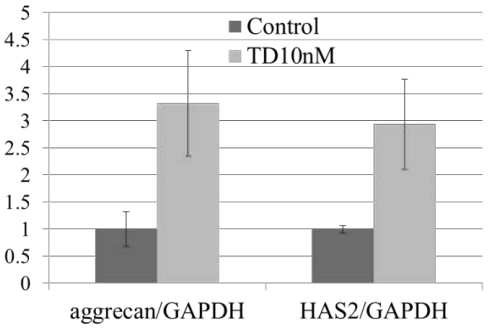


Figure 2C. Realtime PCR at 7days



Presentation #70

Usage Patterns of Intraoperative Neuromonitoring During Degenerative, Non-Deformity, Cervical Spine Surgery: A Survey of the Cervical Spine Research Society

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Introduction: Use of intra-operative neurologic monitoring (NM) is generally considered standard of care when performing spinal deformity surgery, and studies have demonstrated that it can reduce the rate of neurologic complications in that setting. Currently, there are no universally accepted criteria for the use of NM in degenerative cervical surgery. The purpose of the study is to determine current usage patterns of NM amongst cervical spine surgeons performing degenerative, non-deformity cervical spine surgery for radiculopathy and myelopathy.

Materials/Methods: Cervical Spine Research Society (CSRS) members and the attendees at the 2017 Annual Meeting were solicited to complete a survey on NM utilization during cervical radiculopathy and myelopathy surgery that does not involve correction of deformity. The survey consisted of 17 multiple choice questions. The first three questions focused on training background, practice type, and experience. The remaining 14 questions pertained to NM practice patterns in the setting of radiculopathy and myelopathy. Survey results were then compared based on surgeon demographics.

Results (Table 1): 115 spine surgeons responded to the survey. 74 were in academics and 41 in private practices. 95 were orthopaedic and 19 were neurosurgical spine surgeons. No significant difference in NM utilization was found comparing the two surgical subspecialties.

For radiculopathy, 38% routinely (>75% of the time) used NM. Private practitioners were significantly more likely to use NM than academicians (55% vs 28%, p=0.007). Only 51% felt that NM was truly valuable in preventing neurologic injury when used for radiculopathy.

For myelopathy, significantly more respondents (64%) routinely used NM (p<0.001 vs radiculopathy). More private practitioners trended to routinely use NM vs academicians (75% vs 57%, p=0.09). For myelopathy, significantly more respondents (87%) felt that NM was truly valuable in preventing neurologic injury (P<0.001 vs radiculopathy).

The most common reasons cited for using NM in radiculopathy included medicolegal coverage (29.7%) and utility in preventing hypotensive/positioning related neurologic complications (29.7%). The most common reasons cited for using NM in myelopathy included utility in preventing hypotensive/positioning complications (35.4%) and medicolegal coverage (29%). Only 20.7% and 17% in radiculopathy and myelopathy respectively felt that NM truly prevents neurologic complications related to decompression/grafting/instrumentation.

Conclusion: Our data indicates great variation in NM utilization for degenerative cervical cases, particularly comparing private to academic spine surgeons. Overall, routine NM use is significantly more common in myelopathy vs radiculopathy. NM is also thought to be

Presentation #70 (cont.)

of significantly more valuable when used for myelopathy. The most common reasons for usage were to provide medicolegal coverage and prevent neurologic complications occurring outside of the surgical field. These findings are in contrast to the prevailing notion that NM is beneficial for reducing complications related to events occurring inside the surgical field when performing spinal deformity correction (eg, due to a change in the position or alignment of the spinal cord). We believe that this data provides an important baseline for informing best practice guidelines regarding NM use for degenerative, non-deformity, cervical spine surgery.

	Radiculopathy		Myelopathy		
Rate of ION use	**Responses**	**Percent**	**Responses**	**Percent**	**P value**
Never	35	32%	7	7%	<0.0001
Rarely (0-25%)	22	20%	14	13%	
Sometimes (25-50%)	6	5%	8	7%	
Often (50-75%)	5	5%	10	9%	
Routinely (>75%)	41	38%	68	64%	0.0001
ION use rate per surgical approach					
Anterior	9	8%	4	4%	
Posterior	18	17%	16	15%	
Approach is irrelevant	82	75%	87	81%	0.324
ION Modalities Used					
None	29	31%	7	7%	
SSEPs	52	55%	76	80%	
MEPs	48	51%	77	81%	
EMG	45	47%	51	54%	
Rate ION was helpful					
Never	35	32%	8	8%	<0.0001
Rarely (0-25%)	30	28%	28	26%	
Sometimes (25-50%)	17	16%	29	27%	
Often (50-75%)	21	19%	22	21%	
Routinely (>75%)	6	5%	19	18%	

Presentation #70 (cont.)

Rate ION was harmful					
Never	38	35%	9	8%	
Rarely (0-25%)	27	25%	43	40%	
Sometimes (25-50%)	25	23%	35	33%	
Often (50-75%)	14	13%	15	14%	
Routinely (>75%)	5	4%	5	5%	1
ION use valuable?					
Yes	54	51%	92	87%	<0.0001
No	52	49%	14	13%	

Table 1. Results Comparing Radiculopathy vs. Myelopathy

Presentation #71

Posterior Instrumented Fusion Suppresses the Progression of Ossification of the Posterior Longitudinal Ligament: A Comparison of Laminoplasty with and without Instrumented Fusion by 3-Dimensional Analysis

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Introduction: Ossification of the posterior longitudinal ligament (OPLL) had been recognized as one of the main causes of cervical myelopathy and as a progressive disease. Some researchers have suggested that dynamic factors are stimulating progression of OPLL, and that ROM stabilization may lead to decreased progression of OPLL. These results suggest that the additional instrumented fusion following laminoplasty suppresses the progression of OPLL; however, there have been no reports to describe any definitive evidence on the matter. Recently, we reported a novel method involving the creation of three-dimensional (3D) model from computed tomography images to measure the volume of OPLL accurately. The study aim was to evaluate whether laminoplasty with instrumented fusion suppresses the progression of OPLL in comparison with stand-alone laminoplasty by our novel 3D analysis.

Method: The present study included 19 OPLL patients who underwent posterior decompression and fusion (PDF) (PDF group; 14 men, 5 women) for cervical myelopathy between 2006 and 2012. The mean age at operation was 61 years, and the type of OPLL was classified as continuous, segmented, and mixed in 1, 3, and 15 patients, respectively, and spinal canal occupation rate was 51.5%. The control group included 22 OPLL patients (14 men, 8 women) who underwent stand-alone laminoplasty between 2005 and 2012 (LP group). The mean age at operation was 59 years, and the type of OPLL was classified as segmented and mixed in 6 and 16 patients, respectively, and occupation rate was 45.7%. All ossifications of the vertebrae were identified and detached from the posterior aspect of the vertebral body semi-automatically based on CT images using the MIMICS® software (Materialise Japan Co. Ltd., Yokohama, Japan) and a 3D model created automatically (fig 1). The volume of OPLL was evaluated 3 times during follow-up period (1st, 2nd, and 3rd measurement), and volume change of OPLL was compared between the 2 groups.

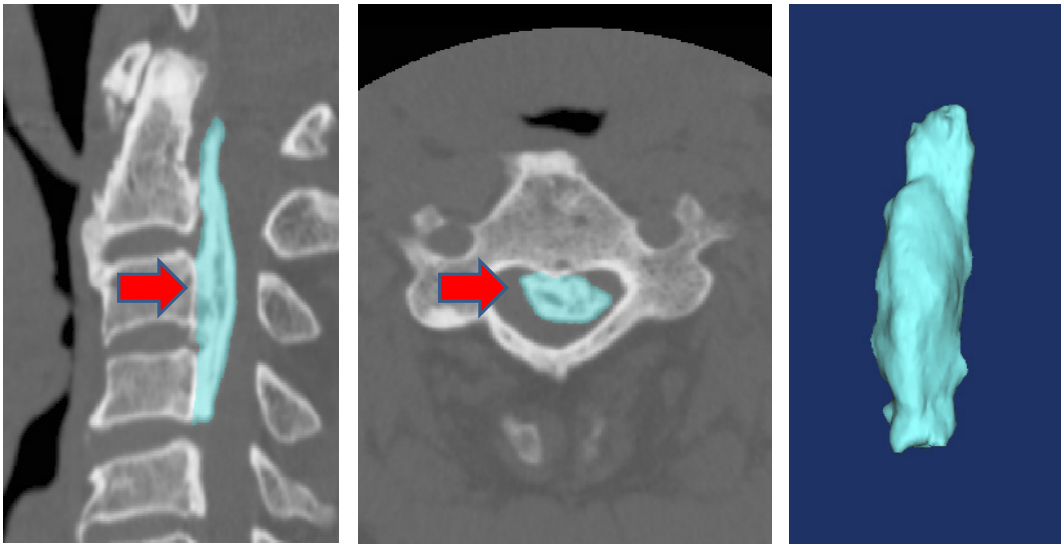
Results: The volume of ossified lesion significantly increased at the final follow-up in both groups (all, $p<0.05$), whereas that from 2nd to 3rd measurement did not change in the PDF group. The PDF group (2.0±1.7 %/year; range, -3.0–5.3) demonstrated lower annual rate of lesion increase compared to the LP group (7.5±5.6 %/year; range, 1.0–19.2) ($p<0.001$). In a notable thing, the mean annual rate of increase was gradually decreasing over time in the PDF group ($p<0.05$).

Conclusions: The present study revealed that additional posterior instrumented fusion following laminoplasty suppresses the progression of OPLL. In an in vitro study, Tanno et al provided evidence that mechanical stress plays a key role in the progression of OPLL through the induction of osteogenic differentiation in spinal ligament cells and the promotion of the mechanism of bone morphogenetic proteins. These results supported hypotheses that

Presentation #71 (cont.)

dynamic factors stimulate the progression of OPLL and that ROM stabilization may lead to decreased progression of OPLL. This is the first report to evaluate 3D model and volume of OPLL using novel 3D analysis, and clearly prove suppressant effect on progression of OPLL by additional posterior instrumented fusion following laminoplasty.

Figure 1.



a b c

(a), (b) The ossification was detached from the affected vertebral body semi-automatically using both the computed tomography axial and sagittal plane, so called segmentation (arrows). (c) The region of ossification was isolated, and a three-dimensional model was created.

Presentation #72

Chronic Obstructive Pulmonary Disease (COPD) is an Independent Predictor for 30-Day Complications and Readmissions Following 1-To-2 Level Anterior Cervical Discectomy and Fusion

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Introduction: Chronic Obstructive Pulmonary Disease (COPD) is a common cause of morbidity and mortality worldwide. Past literature has shown that patients with COPD are at an increased risk of post-operative complications. With an increase in longevity and the number of elderly COPD patients presenting with degenerative spine disease to hospitals, the number of COPD patients undergoing elective spine surgical procedures such as anterior cervical discectomy and fusions(ACDF) is expected to rise. We sought to collate evidence to assess the impact of COPD on 30-day outcomes following 1-to-2 level anterior cervical discectomy and fusion (ACDF).

Materials & Methods: The 2015-2016 American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) database was queried using Current Procedural Terminology (CPT) codes 22551 (single-level)) and 22552 (additional level). Patients undergoing disc arthroplasty, multi-level (>2) fusion, posterior cervical spine surgery, and patients with fracture, tumor and/or infection were excluded. Uni-variate analysis was performed using Pearson-Chi square test to assess for unadjusted significant associations between presence of COPD and 30-day outcomes. A backward elimination logistic regression analysis was performed to estimate the risk of COPD on 30-day complications, while adjusting for all baseline demographic and clinical variables.

Results: Out of 14,835 patients undergoing an elective 1-2 level ACDF, 649 (4.4%) had a diagnosis of COPD at the time of the surgery. Unadjusted uni-variate analysis identified several significant associations between presence of COPD and 30-day outcomes**(Fig. 1).** Following adjusted logistic regression analysis to control for differences in baseline demographic and clinical characteristics, prior history of COPD was significantly associated with a longer length of stay (OR 1.25 [1.04-1.52]; p=0.019), superficial SSI (OR 2.68 [95% CI 1.06-6.80]; p=0.038), discharge destination other than home (OR 1.49 [95% CI 1.05-2.12]; p=0.026), pneumonia (OR 4.37 [95% CI 2.42-7.88]; p<0.001), ventilator use >48 hours (OR 5.34 [95% CI 1.88-15.15]; p=0.002), unplanned reintubation (OR 3.36 [1.48-7.62]; p=0.004) and30-day readmissions (OR 1.69 [95% CI 1.20-2.38]; p=0.003)**(Fig. 2)**.

Conclusions: The findings of this study show that COPD patients are more likely to have post-operative complications and 30-day readmissions, despite elective ACDF itself being a low-risk surgery in general. Results show that majority of the complications were pulmonary in nature, further stressing the need for accurate medical optimization following surgery in these patients.

Presentation #72 (cont.)

Figure 1: Uni-variate analysis for significant complications associated with prior existence of COPD.

30-day complications			
Superficial SSI	5(0.8%)	41(0.3%)	**0.031**
Deep SSI	0	21(0.1%)	0.327
Organ/Space SSI	0	9(0.1%)	0.521
Wound Dehiscence	0	2(~0%)	0.762
Myocardial Infarction	3(0.5%)	19(0.1%)	**0.034**
Cardiac Arrest	1(0.2%)	15(0.1%)	0.714
Deep venous thrombosis(DVT)	2(0.3%)	31(0.2%)	0.635
Pneumonia	16(2.5%)	65(0.5%)	**<0.001**
Pulmonary Embolism	0	25(0.2%)	0.284
Urinary Tract Infection	5(0.8%)	67(0.5%)	0.285
Post-operative ventilator use>48h	5(0.8%)	25(0.2%)	**0.001**
Unplanned reintubation	8(1.2%)	45(0.3%)	**<0.001**
Bleeding requiring transfusion	2(0.3%)	9(0.1%)	**0.025**
Acute renal failure	2(0.3%)	5(0.0%)	**0.002**
Cerebrovascular/Stroke	0	10(0.1%)	0.499
Sepsis	2(0.3%)	17(0.1%)	0.190
Septic Shock	1(0.2%)	5(0%)	0.141
Return to OR within 30-days of surgery	9(1.4%)	178(1.3%)	0.768
30-day Readmission	42(6.5%)	395(2.8%)	**<0.001**
30-day unplanned reoperations	9(1.4%)	178(1.3%)	0.768
Discharge destination			**<0.001**
Non-Home	50(7.7%)	477(3.4%)	
Home	599 (92.3%)	13709 (96.6%)	

Presentation #72 (cont.)

Figure 2: Adjusted analysis of significant post-operative complications in COPD patients undergoing 1-to-2 level ACDF. Each post-operative complication category was entered into a backward elimination multi-variate regression model which adjusting for all baseline clinical characteristics.

Dependent Variables	Odds Ratio [95% CI]	P-Value
Length of stay(days) >1 day	1.25 [1.04-1.52]	**0.019**
Superficial SSI	2.68 [1.06-6.80]	**0.038**
Discharge destination Non-Home	1.49 [1.05-2.12]	**0.026**
Pneumonia	4.37 [2.42-7.88]	**<0.001**
Ventilator use>48 hours	5.34 [1.88-15.15]	**0.002**
Unplanned Reintubation	3.36 [1.48-7.62]	**0.004**
30-day Readmission	1.69 [1.20-2.38]	**0.003**

Adjusted for age, gender, BMI, co-morbidities(diabetes, smoking, dyspnea, functional health status, ventilator dependence, ascites, congestive heart failure, hypertension, acute renal failure, pre-operative dialysis, chronic steroid use, bleeding disorders, transfusions≥1 unit of packed RBCs in 72 hours before surgery, prior systemic sepsis, >10% weight loss in last six months), ASA grade, admission status(inpatient/outpatient), total operative time and anesthesia type.

Presentation #73

Epidemiology of C5 Palsy After Cervical Spine Surgery: 21 Multicenter Studies

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Introduction: C5 palsy is a well-known but severe complication after cervical spine surgery. Some study suggested the possible pathophysiology of C5 palsy as inadvertent injury to the nerve root during surgery, nerve root traction by the spinal cord shifting, spinal cord ischemia caused by decreased blood supply, and reperfusion injury of the spinal cord. However, the pathophysiology of C5 palsy is still unclear. This complication may develop in both anterior and posterior cervical spine surgery and the incidence of C5 palsy is reported to be variable between 0 and 30%. This multicenter study attempts to identify the incidence, the pattern and the prognosis of C5 palsy following cervical spine surgery in Korea.

Materials/Methods: We have conducted a retrospective multicenter study involving 21 centers from the Korean Cervical Spine Study Group. Inclusion criteria included patients who underwent cervical spine surgery between 2012 and 2016. Surgeries of neck such as neck mass and tracheostomy or pain intervention were excluded. We obtained patients characteristics, complications including C5 palsy, diagnosis, and operation name. In patients with C5 palsy, operative methods, disease category, onset time of C5 palsy, recovery time of C5 palsy, C5 MMT grade, and post C5 palsy management were investigated.

Results: We collected 15097 cervical spine surgery cases from 21 centers. Male patients were predominant in this study population (10029/5068). There are 8567 anterior approach surgeries, 6287 posterior approach surgeries, and 257 anterior-posterior approach. From total cervical surgery cases, C5 palsy patients were 88 (0.58%). There are 69 male patients. There are 30 anterior approach surgeries, 57 posterior approach surgeries, and 1 anterior-posterior approach. C5 palsy is more common in male patients ($p= 0.019$) and after posterior surgeries ($p<0.001$). C5 palsy usually occurred within 3 days after surgery (77/88, 87.5%) and more than half of the C5 palsy patients recovered within 6 months (51/88, 57.95%). Thirty C5 palsy patients (34.09%) had motor weakness lower than 2 MMT grade. Among C5 palsy patients, only four patients (4.5%) did not recover during the follow up period. After onset of C5 palsy, posterior cervical foraminotomy was performed 7 cases (7.95%), and steroid was used for 56 cases (63.63%). Twenty six cases (29.55%) were closely observed without any intervention.

Presentation #73 (cont.)

Conclusion: The overall incidence of C5 palsy was relatively low (0.58%) in this study. This study shows that C5 palsy is more common in posterior cervical surgeries and male patients. C5 palsy usually developed within 3 days after the surgery and more than half of C5 palsy recovered within 6 months. This data could be important information to prepare and counsel the patients who need cervical spine surgery. However, further prospective study is necessary to assess the risk factor and proper management of postoperative C5 palsy.

Table 1. Postoperative C5 palsy and operative methods of cervical spine surgery

Type of Surgery	No of cases	No of C5 palsy (%)
ACDF	7952	24 (0.30%)
ACCF	610	5 (0.82%)
Laminoplasty	3343	25 (0.75%)
Laminectomy/Fusion	2935	33 (1.12%)
360 Fusion	257	1 (0.39%)
Total	15097	88 (0.58%)

Table 2. The outcome after C5 palsy MMT grade

C5 palsy onset MMT	No of C5 palsy (%)	C5 palsy recovery MMT	No of C5 palsy (%)
0	2 (2.27%)	0	
1	7 (7.95%)	1	2 (2.27%)
2	21 (23.86%)	2	2 (2.27%)
3	33 (37.5%)	3	12 (13.64%)
4	25 (28.41%)	4	42 (47.73%)
5		5	24 (5.68%)
		Death	1 (1.14%)
		F/U loss	5 (5.68%)
Total	88 (100%)		88 (100%)

Presentation #74

Age Is Not a Significant Predictor of Adverse Events After Cervical Spine Surgery: Analysis from the Michigan Spine Surgery Improvement Collaborative (MSSIC)

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Introduction: Recent emphasis on decreasing the cost of healthcare, while increasing quality and value, has led to efforts to prevent adverse events after surgery. Since more elderly patients are becoming surgical candidates, further research is needed to evaluate their perioperative surgical risks. Previous studies are limited as they focused on single pathologies (ie odontoid fractures), had small samples popualtions, and/or were retrospective. The Michigan Spine Surgery Improvement Collaborative (MSSIC) is a large, prospective, multicenter quality improvement registry, making it uniquely suited to answer complex questions on spine surgery.

Materials and Methods: We sought to use the MSSIC database to investigate whether octogenarians and older patients are at increased risk for adverse events after cervical spine surgery. We hypothesize that age alone is not a strong independent predictor of post-operative complications. Established in 2013, MSSIC is a prospective multicenter quality improvement registry of patients who underwent cervical and/or lumbar spine surgery by both Neurosurgeons and Orthopedic surgeons. To date, there are 26 participating hospitals across the state of Michigan, with more than 40,000 patients enrolled.We sampled all patients who had cervical spine surgery. Inclusion criteria included: surgery for spondylosis and intervertebral disc disease. Exclusion criteria include: age <18yo; traumatic fracture; spinal cord injury; moderate or severe scoliosis; pure thoracic cases; tumor; spinal infection; spinal deformity, Grades 3 and 4 spondylolistheses.

A total of 7896 cervical spine surgery cases were included in MSSIC. All adverse events were identified. Three age groups were chosen for specific analysis (<65yo, 65-79yo, ≥80yo). Multivariate logistic regression was used to account for confounding variables, including gender, race, ASA, myelopathy, ambulatory status, anterior vs posterior approach, surgical levels, length of surgery, and more.

Adverse events up to 90d after surgery were recorded, including but were not limited to readmission, urinary retention, UTI, dysphagia requiring NPO or feeding tube, hematoma, SSI, and DVT.

Results: The adverse events up to 90 days after cervical spine surgery included radicular symptoms (radicular numbness, tingling, pain, or weakness) (10.79%), readmission (7.76%), urinary retention (5.01%), UTI (2.23%), dysphagia requiring NPO or feeding tube (1.9%), hematoma (1.05%), SSI (0.83%), DVT (0.68%), and more.

Three adverse events were selected to undergo multivariate logistic regression. Age comparisons were done to <65yo (reference group). Patients ≥80yo did not have an inceased

Presentation #74 (cont.)

risk for readmission (p=0.698), while 65-79yo were more likely to be readmitted (OR1.29, p=0.013); readmission was better associated with ASA>2 (OR1.72, p<0.001) and preoperative ambulation (OR0.69, p=0.002). Age ≥80yo (p=0.239) and 65-79yo (p=0.056) did not increase postoperative dysphagia; dysphagia was associated with multiple level surgery (OR 1.64, p=0.001) and POD0 ambulation (OR 0.54, p<0.001). While 65-79yo was associated with urinary retention (OR 2.14, p<0.001), ≥80yo was not (p=0.055); Predictors of urinary regention include myelopathy (OR 1.5, p=0.001) and POD0 ambulation (OR 0.67, p=0.002).

Conclusion: Age alone is not the best predictor of readmission and dysphagia. Octagenarians and older are not necessarily at higher risk for postoperative adverse events after cervical spine surgery. More analysis is needed to delineate the relationship between age and postoperative morbidity.

Presentation #75

Frequency of Typical Myelopathic Symptoms in a Large Surgical Cohort of Cervical Myelopathy Patients: Association with the Level of Maximal Cord Compression and MRI T2 Signal Change

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Introduction: Symptoms typically associated with cervical myelopathy (CM) include numbness, weakness, hand clumsiness, gait instability, and sphincter dysfunction. To diagnose CM, at least one or more of these symptoms should be present. However, it is not clear from previous literature how frequently each symptom arises. The purpose of this study is therefore to determine the frequency of various symptoms in a large surgical cohort of CM, and if there is any association with the level of maximal cord compression and T2 signal change.

Materials/Methods: A prospectively maintained database was retrospectively reviewed to identify 484 consecutive CM patients treated surgically between 1/1/2007 and 8/31/2017. Data collection included presence of pre-op axial neck pain (NP), upper extremity pain (UEP), UE sensory deficit (UESD; numbness, tingling, etc.), UE motor deficit (UEMD; weakness, clumsiness, etc.), LE sensory deficit (LESD), LE motor deficit (LEMD; weakness, gait instability, etc.), and sphincter dysfunction (SD; bladder/ bowel). It was noted whether the symptom was a chief symptom (i.e. chief complaint) or an overall symptom (i.e. part of the list of CM symptoms identified by the patient). The most common symptom(s) was determined by a series of chi-square (or Fisher's exact) tests. Pre-op MRI was assessed for the spinal level with maximal cord compression and presence of T2 signal change. The association between presence of each symptom and MRI findings was determined by multivariate logistic regression that controlled for patient demographics and comorbidities.

Results: Of 484 patients (61.3 yrs, 45.5% female, mJOA score 13.4±1.9), the most common chief symptom was UESD (46.5%), whereas the most common overall symptoms were UEMD (82.6%) and LEMD (81.2%) (Table 1). NP was significantly less common (32.6% chief symptom, 55.4% overall symptom), and SD was even less common (0.6% chief symptom, 16.5% overall symptom). When evaluating the distribution of frequency by the level of maximal compression, frequency of UEP as chief symptom was significantly higher if the maximally compressed level was more distal (positive correlation from C1-C2 to C7-T1, Spearman's $p<0.001$). However, no significant association was observed between frequency of other symptoms and the maximally compressed level. There was no significant difference comparing the mean mJOA scores against levels of maximal compression (ANOVA, $p=0.347$), whereas patients with T2 signal change had lower mean mJOA scores (t-test, $p=0.001$). After controlling for demographics and comorbidities (Table 2), T2 signal change was significantly associated with the absence of NP and UEP as chief or overall symptoms, but the presence of LEMD as a chief symptom or LESD as an overall symptom.

Conclusion: CM patients present with a variety of chief symptoms, as evidenced by the

Presentation #75 (cont.)

most common chief symptom (UESD) occurring in less than 50%. UEMD and LEMD were the most common overall symptoms, presenting in more than 80%. UEP was more common with more distal cord compression. Those with T2 signal change and worse myelopathy were less likely to have pain, but more likely to have LEMD and LESD. This information will allow a better understanding of the presentation of CM in clinical practice.

Table 1. Frequency of various chief symptoms and overall symptoms in CM patients

		Neck pain	UE pain	UE sensory deficit	UE motor deficit	LE sensory deficit	LE motor deficit	Sphincter dysfunction	*P* *
No. (%) of patients (n=484)	**As chief symptom**	158 (32.6)	177 (36.6)	**225 † (46.5)**	166 (34.3)	45 (9.3)	146 (29.3)	3 (0.6)	**0.002**
	As overall symptom	268 (55.4)	259 (53.5)	343 (70.9)	**400 ‡ (82.6)**	84 (17.4)	**393 ‡ (81.2)**	80 (16.5)	**<0.001**

* p<0.05 represents frequency of each symptom being significantly different

† Frequency of UE sensory deficit is significantly higher than any other chief symptom (all p<0.05)

‡ Frequency of UE motor deficit or LE motor deficit is significantly higher than any of the other overall symptoms (all p<0.001), but there was no difference between these two (p=0.572)

Presentation #75 (cont.)

Table 2. Multivariate logistic regression for association with the presence of chief or overall symptoms

	Neck pain		UE pain		UE sensory deficit		UE motor deficit		LE sensory deficit		LE motor deficit		Sphincter dysfunction	
As chief symptom	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***
Age ≥ 65	0.524	0.146	1.086	0.698	0.827	0.344	0.989	0.958	**0.227**	**0.001**	0.983	0.940	1.086	0.955
BMI ≥ 30.0	0.799	0.292	1.108	0.624	1.385	0.101	0.983	0.935	**2.801**	**0.002**	1.030	0.892	<0.001	0.995
Female	**1.547**	**0.035**	**1.935**	**0.001**	0.879	0.504	0.874	0.503	0.884	0.718	0.732	0.145	<0.001	0.994
Diabetes	1.786	0.165	1.446	0.222	1.018	0.952	0.923	0.794	0.298	0.119	1.323	0.377	<0.001	0.997
Smoker	0.986	0.471	0.801	0.440	0.790	0.368	1.041	0.881	0.722	0.479	1.673	0.057	<0.001	0.996
Level of maximal cord compression														
C1-C2	4.761	0.404	0.137	0.077	1.223	0.795	2.219	0.286	2.893	0.393	2.803	0.181	<0.001	0.999
C2-C3	2.188	0.090	0.764	0.638	0.721	0.534	0.884	0.817	<0.001	0.998	0.668	0.501	<0.001	0.999
C3-C4	0.962	0.389	0.818	0.352	1.392	0.101	1.122	0.581	1.456	0.294	1.142	0.545	20.295	0.999
C4-C5	0.918	0.107	**0.585**	**0.010**	1.402	0.081	1.343	0.143	0.824	0.579	1.160	0.487	<0.001	0.994
C5-C6	1.122	0.950	1.151	0.510	1.304	0.186	0.795	0.270	1.453	0.301	0.705	0.115	<0.001	0.996
C6-C7	0.829	0.144	0.971	0.909	1.018	0.942	1.256	0.364	0.655	0.352	1.420	0.187	<0.001	0.998
C7-T1	0.475	0.356	1.670	0.438	0.883	0.851	0.981	0.977	**4.956**	**0.045**	1.687	0.432	<0.001	0.999
(+) T2 signal change	**0.385**	**<0.001**	**0.629**	**0.027**	1.319	0.155	0.827	0.349	1.603	0.179	**2.077**	**0.001**	1.086	0.955

As overall symptom	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***	**OR**	***p***
Age ≥ 65	0.741	0.146	0.909	0.638	**0.579**	**0.012**	0.951	0.848	**0.398**	**0.002**	**0.237**	**0.002**	1.343	0.279
BMI ≥ 30.0	0.806	0.292	0.946	0.784	1.270	0.283	1.334	0.277	**1.689**	**0.044**	1.413	0.188	1.098	0.731
Female	**1.524**	**0.035**	**1.629**	**0.013**	1.097	0.668	**1.770**	**0.029**	1.139	0.615	**1.839**	**0.018**	1.652	0.059
Diabetes	1.542	0.165	1.674	0.093	0.562	0.056	0.778	0.501	0.875	0.752	2.322	0.091	1.531	0.239
Smoker	1.214	0.471	0.917	0.742	1.379	0.300	1.212	0.578	0.743	0.399	**2.110**	**0.042**	1.741	0.098

Presentation #75 (cont.)

Table 2, continued

	Neck pain		UE pain		UE sensory deficit		UE motor deficit		LE sensory deficit		LE motor deficit		Sphincter dysfunction	
Level of maximal cord compression														
C1-C2	2.089	0.404	0.528	0.406	1.028	0.972	1.716	0.630	1.337	0.801	0.986	0.990	3.729	0.103
C2-C3	2.843	0.090	1.832	0.267	1.369	0.604	0.378	0.088	0.527	0.425	0.605	0.419	0.533	0.425
C3-C4	0.837	0.389	0.829	0.358	1.020	0.931	1.066	0.811	1.223	0.448	1.277	0.362	1.409	0.208
C4-C5	0.725	0.107	**0.558**	**0.003**	1.053	0.811	1.355	0.236	1.392	0.204	0.937	0.799	1.435	0.174
C5-C6	1.013	0.950	1.138	0.525	1.259	0.305	0.986	0.958	1.282	0.349	0.714	0.194	1.055	0.847
C6-C7	0.693	0.144	0.638	0.070	1.231	0.460	0.761	0.370	1.123	0.717	0.847	0.581	0.590	0.176
C7-T1	0.550	0.356	1.117	0.869	0.923	0.905	1.018	0.983	3.087	0.129	0.693	0.630	1.458	0.662
(+) T2 signal change	**0.411**	**<0.001**	**0.679**	**0.049**	1.463	0.081	1.053	0.839	**2.288**	**0.002**	1.648	0.055	1.379	0.227

OR: odds ratio; Bold and underlined indicates significance at p<0.05

Presentation #76

Effect of Modified Japanese Orthopedic Association Scores on Satisfaction with Outcomes 12 Months After Elective Surgery for Cervical Spine Myelopathy

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Introduction: Degenerative cervical myelopathy (DCM) is a progressive degenerative spine disease resulting from cervical cord compression. The natural progression of DCM is variable; some patients experience periods of stability without progression, while others rapidly deteriorate following disease onset. The modified Japanese Orthopedic Association (mJOA) is commonly used to grade and categorize myelopathy symptoms, but its association with post-operative satisfaction has not been previously explored. This study has two primary aims: 1) determine the influence of baseline and 12-month mJOA post-operative scores on satisfaction scores; and 2) understand surgery's impact on mJOA scores and its relation to satisfaction.

Methods: We collected patients from the quality and outcomes database (QOD), a national, prospective, longitudinal registry established to develop risk-adjusted morbidity and patient-reported outcomes (PROs) for spine surgery. We identified patients undergoing elective surgery for DCM who completed baseline and 12-month mJOA surveys and the North American Spine Society (NASS) satisfaction questionnaire. Patients were divided into mild (mJOA ≥ 14), moderate (mJOA = 9 to 13), or severe (mJOA < 9) categories. A multivariate proportional odds ordinal logistic regression model was fitted with 12-month satisfaction as the outcome of interest. All confounding factors seen in Figure 1 were included in the model. We assumed a linear relationship for baseline mJOA and 12-month mJOA, and a smooth relationship for age and BMI using restricted cubic regression splines with 3 knots (knot locations were chosen based on the sample quantiles). All the other predictors were included as binary or categorical. We used Wald statistics were used to determine the relative importance of the various predictors compared with 12-month satisfaction.

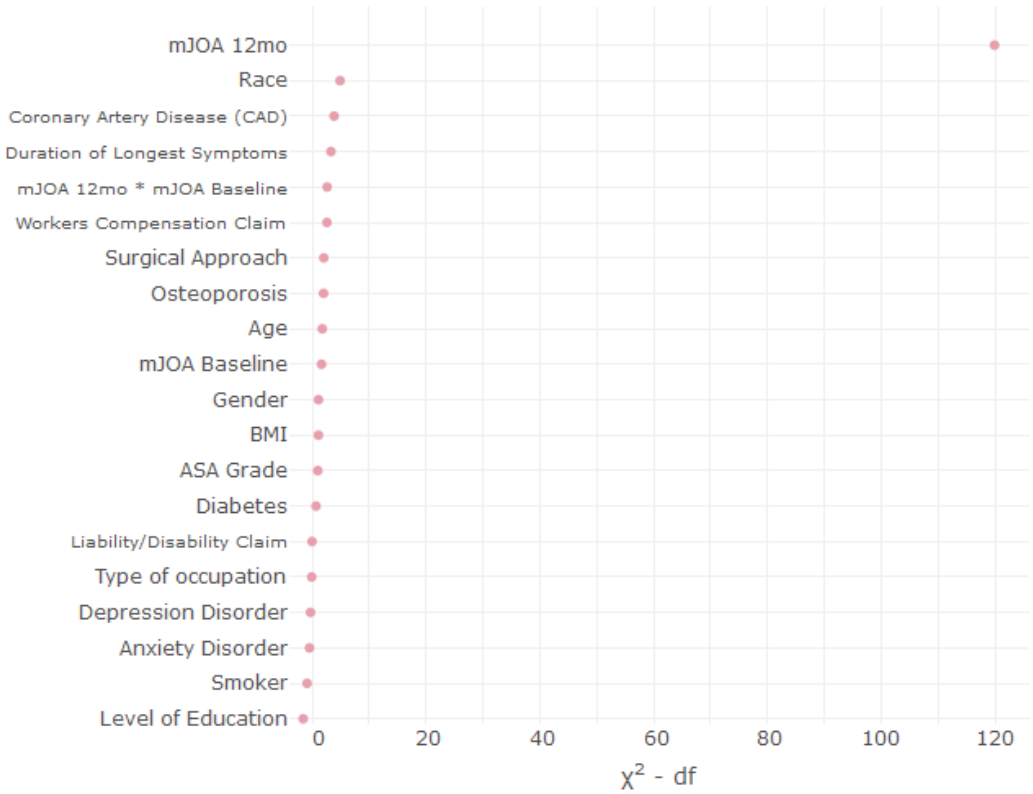
Results: We identified 1963 patients who underwent elective surgery for DCM and completed 12-month follow-ups. Comparing MJOA severity level at baseline and 12 months revealed that 55% remained in the same category, 37% improved, and 7% moved to a worse category. At 12-months, 63% (n=1230) were satisfied at a level where surgery met their expectations (NASS level 1). After adjusting for all baseline and surgery-specific variables, the 12-month mJOA score had the highest impact (p<.001) on patient satisfaction (**fig 1**).

Presentation #76 (cont.)

The highest proportion of patients who were satisfied with surgery were those who were in the mild mJOA category at follow-up, regardless of their mJOA category at baseline (**fig 2**).

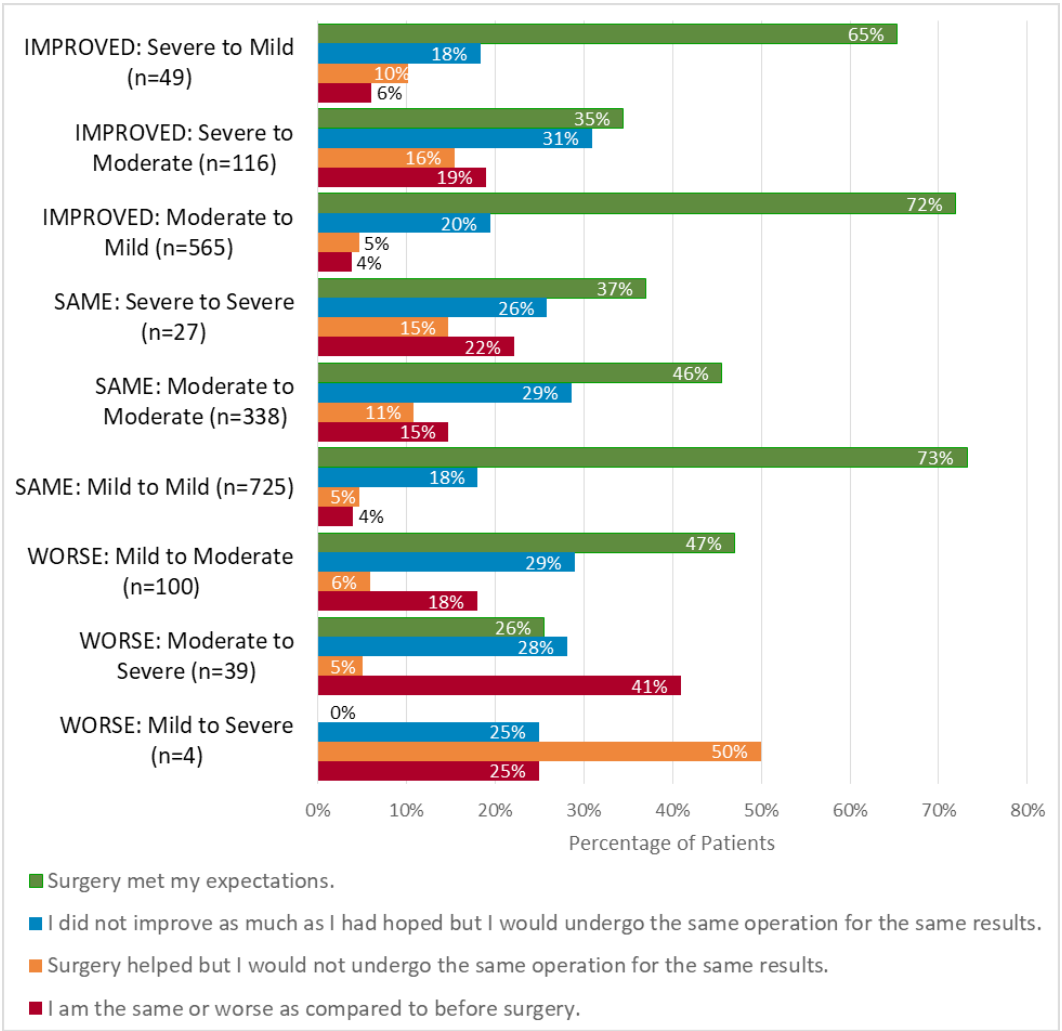
Conclusion: Patient satisfaction is an indispensable tool for measuring quality of care following spine surgery. It is important to understand how patients' disability and functional status impacts post-operative satisfaction, especially with DCM. In this sample, 12-month mJOA scores, regardless of baseline mJOA, significantly correlated with satisfaction. Patients with severe baseline myelopathy required marked improvement to achieve post-operative satisfaction, while those with mild myelopathy need continued mild myelopathy post-operatively to be satisfied. Given these findings, it is important to advise patients of the probability that surgery will change their mJOA score and the changes required to achieve post-operative satisfaction. We found that over half of patients remain in the same category, with approximately 40% improving, and 7% worsening.

Figure 1. ANOVA table demonstrating relative importance of each predictor.



Presentation #76 (cont.)

Figure 2. Percentage of satisfaction level within each MJOA change category



Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #77

Increasing Incidence of Non-Rheumatic Retro-Odontoid Pseudotumor with Varied Etiology in Elderly

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Introduction: Although a non-rheumatic retro-odontoid pseudotumor is relatively rare, it is increasingly recognized as a cause of cervical myelopathy. Since the retro-odontoid pseudotumors are frequently seen in rheumatoid arthritis patients with atlantoaxial subluxation, it is generally considered as a sequela of atlanto-axial instability, and therefore posterior fusion is indicated for the patients with retro-odontoid pseudotumors. However, recent studies showed that the retro-odontoid pseudotumors are not necessarily associated with atlanto-axial instability, suggesting that surgical strategy should be changed according to etiology. In this study, we retrospectively reviewed clinical and radiographic features of the patients with non-rheumatic retro-odontoid pseudotumor exhibiting myelopathy to identify the pathomechanisms and to discuss surgical strategy against the retro-odontoid pseudotumors.

Materials and Methods: Firstly, we performed retrospective surveillance study to examine the causative disorders of upper cervical spine surgeries in one university hospital and 6 branch hospitals between 2006 and 2015. Among 220 upper cervical surgery cases, 25 cases were diagnosed as non-rheumatic retro-odontoid pseudotumor. The number of surgeries against non-rheumatic retro-odontoid pseudotumor became double within 10 years. Then, we reviewed medical records of 22 patients with non-rheumatic retro-odontoid pseudotumors, excluding 3 cases with inadequate or missing records, to assess demographic data, neurologic impairment, radiographs and surgical outcomes.

Results: The patients group comprised 15 males and 7 females with mean age of 76 years (56–87) at the time of surgery. Only 5 of 22 patients (23 %) had atlanto-axial instability (ADI > 4.0 mm). The mean SAC at the level of C1 in the 22 patients was 15 mm. CT and dynamic lateral plain X-ray films revealed that 6 patients (27 %) had ankylosis of craniocervical junction, 7 (32 %) had DISH in the middle and lower cervical spine, and remaining 9 patients preserved physiological segmental mobility. Twelve patients underwent O-C2 fusion, 5 patients underwent C1-2 fusion, and 5 patients underwent C1 laminectomy without fusion. The mean JOA recovery rate was 51.3% in total, 57.2% in the O-C2 fusion group, 49.4% in the C1-2 fusion group, and 41.0% in the C1 laminectomy group. In most cases, pseudotumors shrank with the mean reduction rate of 45.4 % in total, 52.6% in the O-C2 fusion group, 34.5% in the C1-2 fusion group, and 39.2% in the C1 laminectomy group.

Conclusion: Etiology of non-rheumatic retro-odontoid pseudotumor varies and therefore we should select a surgical treatment option appropriate for each pathology. In cases with atlanto-axial instability, O-C2 or C1-2 fusion should be considered; however, radiographic atlanto-axial instability was found in only 23 % in this case series. Our data showed that most cases have C1 hypoplasia and developmental narrow canal, suggesting that posterior decompression can be a treatment option in cases without atlanto-axial instability. Consistent with earlier studies, retro-odontoid pseudotumors were likely to develop as an “adjacent segment disease” in 58 % of our cases. Posterior fusion could be an effective treatment for the cases with ankylosis of adjacent segments; however, posterior decompression should

Presentation #77 (cont.)

be considered in cases with ankylosis in subaxial cervical spine to preserve cervical motion function.

Presentation #78

The Impact of Cervical Sagittal Balance and Cervical Spine Alignment on Craniocervical Junction Kinematic: An Analysis Using Upright Kinematic MRI

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Introduction: Craniocervical junction kinematic is known to be affected by subaxial degeneration and segmental motion. The aim of the current study was to evaluate the effect of cervical sagittal alignment on craniocervical junction kinematic.

Materials/Methods: The study retrospectively evaluated 359 patients (119 cervical lordosis, 38 cervical sagittal imbalances, 111 cervical straight, and 91 cervical kyphosis) who underwent a cervical spine kinematic Magnetic Resonance Imaging (kMRI) from 2010 to 2017. The occipitocervical inclination (OCI) at C3 to C5, occiput-C2 angle (O-C2 angle), occipitocervical distance (OCD), C2-7 angle, cervical sagittal vertical axis (cSVA) were evaluated in flexion, neutral, and extension positions. OCI is the angle formed by the line connecting the posterior border of the cervical vertebral body and the McGregor's line. O-C2 angle is the angle formed by the McGregor's line and the line drawn parallel to the inferior endplate of C2. OCD is the shortest distance of the vertical line between occipital protuberance and the upper most part of spinous process of the Axis. The C2-7 angle was measured as the angle between the tangent lines of the lower endplates of the Axis and C7. cSVA C2-C7 is the horizontal distance between the center of C2 and the posterior edge of the C7 upper end plate. Intervertebral disc degeneration was graded according to Suzuki classification. The C3-5 OCI, O-C2 angle, and OCD were analyzed in neutral, flexion, and extension position, while cSVA and disc degeneration grading were analyzed in neutral position only. The Kruskal-Wallis test was used to detect differences among four groups, and post-hoc analysis was performed by Mann-Whitney U test.

Results: Patients in cervical sagittal imbalance, straight, and cervical kyphosis groups had significantly larger lordosis angle in C3 OCI, C4 OCI and O-C2 angle than the cervical lordosis group ($p<0.0125$). The head motion in relation to C2, C3, C4 (O-C2 angle, C3-4 OCI) in the kyphosis group was significantly more extended than in the cervical lordosis group ($p<0.0125$). The cervical sagittal imbalance had significant larger O-C2 angle than the cervical lordosis group ($p=0.008$). Multinomial regression analysis showed that an increase in O-C2 angle by one degree had a relative risk of 4.3% and 3.5% for a patient to be placed in the cervical sagittal imbalance and cervical kyphosis group.

Conclusions: Cervical sagittal alignment affected craniocervical junction kinematic. This presented as greater extension and motion of the head within the cervical sagittal imbalance and cervical kyphosis groups. The motion of head in relation to C2 can be used as predictor of cervical sagittal alignment.

Presentation #78 (cont.)

Figure 1. Occipitocervical and cervical measurement parameters.

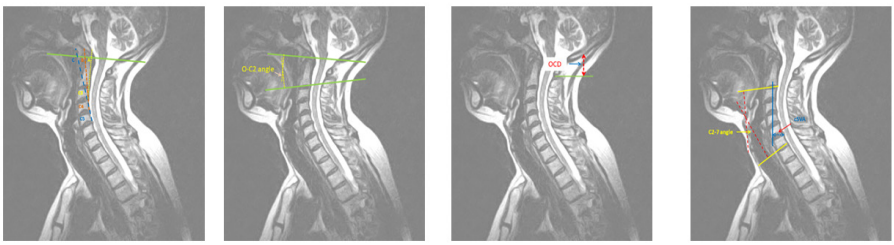
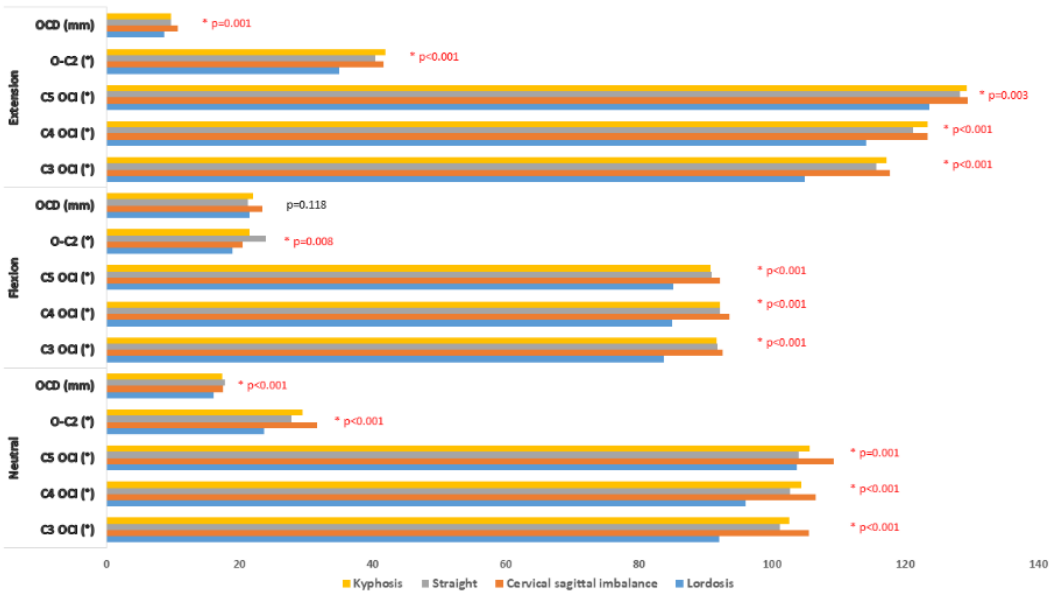


Figure 2. showed the overall data of occipitocervical and cervical parameters between three positions and between cervical alignment groups.



Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #79

Does Target Level Sagittal Alignment Determine Adjacent Level Disc Height Loss?

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Background: Adjacent segment disease (ASD) following ACDF has long been a concern and is likely multifactorial. Sagittal alignment, particularly kyphosis, has been identified as a risk factor for this. Alignment following both ACDF and Cervical Total Disc Arthroplasty (TDA) have been evaluated in the past, however the relationship between long term development of ASD and focal sagittal alignment in a matched cohort of TDA and ACDF patients has not. We prospectively compare the effect of target level sagittal alignment on cephalad disc degeneration in patients undergoing Cervical Disc Arthroplasty (TDA) and Anterior Discectomy and Fusion(ACDF).

Materials and Methods: Seventy-nine patients were enrolled and followed prospectively at 2 centers in a multicenter, FDA, IDE trail for Bryan Cervical Disc Arthroplasty. Neutral lateral radiographs were obtained pre and postoperatively, and at 1-, 2-, 4- and up to 7 years following surgery. The target level cobb angle was measure both pre and postoperatively. Cephalad disc degeneration was determined by a previously described measurement of disc height/anteroposterior distance[1].

Results: 68 patients (N=33 ACDF; N=35 TDA) had complete radiographs and were included for analysis. Preoperatively there was no difference in target level cobb angle between ACDF and TDA. Postoperatively ACDF had a larger segment lordosis compared to TDA (p= .002). Patients who had a postoperative kyphotic cobb angle were more likely to have undergone TDA(p=.01) (FIGURE 1.). A significant decrease in the disc height ration occurs over time (p=.035), by an average of .01818 at 84 months. However, this was not influenced by preoperative alignment, postoperative alignment or type of surgery (FIGURE 2.).

Conclusion: In our cohort of patients undergoing TDA and ACDF we find that preoperative and postoperative sagittal alignment have no effect on ASD at follow-up of at least 7 years. We identified time as the only significant factor affecting ASD.

References:

1. Miller J, Sasso R, Anderson P, Riew KD, McPhilamy A, Gianaris T. Adjacent level degeneration: bryan total disc arthroplasty versus anterior cervical discectomy and fusion. Clinical spine surgery. 2018 Mar 1;31(2):E98-101.

Presentation #79 (cont.)

Figure 1.

	N	C 4-5	C 5-6	C 6-7	ACDF %	TDR %	PreoP Cobb	PostOp Cobb	PreOP K (%)	PostOP L (%)	Postop K (%)	Postop L (%)
TARGET LEVEL VARIABLE												
ACDF	33	2	16	15	100	0	-1.64	1.71*	56	44	21	78*
TDR	35	0	12	23	0	100	-1.12	-1.49	48.4	51.6	53	47
Preop K	29	1	10	18	48	52	-5.05	-2.21	100	0	57	43
Preop L	27	1	6	20	41	59	2.3	2.18	0	100	19	81*
Postop K	25	0	14	11	32	68*	-4.3	-4.52	76.2	23.8	100	0
Postop L	37	2	14	21	59.5	40.5	0.12	2.99	63.6	36.4	0	100
	KEY											
	K= Kyhosis											
	L- Lordosis											
	* p<0.05											

Figure 2.

		Test of Model Effects on Disc Height
	Wald Chi-Square	**Significance**
Variable		
Surgery Type (ACDF vs TDA)	0.906	0.341
PreOP Cobb Angle (Degrees)	0.347	0.556
PostOP Cobb Angle (Degrees)	0.539	0.463
PreOP Kyphosis or Lordosis	0.005	0.944
PostOP Kyphosis or Lordosis	1.172	0.279
Time	21.751	0.001

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #80

Redefining the Cervical Disability Threshold of T1 Slope Minus Cervical Lordosis

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Introduction: A T1 Slope minus Cervical Lordosis (TS-CL) angle of 20°has been described in the literature as a significant cutoff to define cervical deformity, however recent studies suggest that this cutoff needs to be redefined. The aim of this study was to develop a novel TS-CL threshold indicative of moderate to severe cervical disability.

Methods: Single-center retrospective review. Patients age ≥18 years old with a primary cervical diagnosis indicated for surgical treatment were included. Patients with active infection, tumors, or trauma were excluded. We tested possible cutoffs for TS-CL against the percentage of individuals meeting normative, mild, moderate (>25), and severe (>35) NDI scores at baseline. The TS-CL cutoff with the highest sensitivity to predict a normative, mild, moderate (>25), and severe (>35) NDI score was selected.

Results: 69 cervical patients indicated for surgical treatment were included (mean age 55.4 ± 9.9 years, 45% female, mean BMI 29.1 ± 6.6 kg/m2). The average baseline NDI score was 39.9 ± 20.9 for this cohort. At baseline, average TS-CL was 27.3° ± 18.8°, CL was 1.7° ± 17.6°, cSVA was 28.3mm ± 17.3mm. Spino-pelvic alignment parameters at baseline were as follows: PT 16.1° ± 8.3°, PI-LL -2.8° ± 11.9°, TK 38.8° ± 12.7° and SVA -6.3mm ± 51.8mm. Using previously established TS-CL severity breakdowns, 13 (18.8%) patients had mild TS-CL (<15°), 11 (15.9%) moderate TS-CL (15-20°), and 45 (65.2%) had severe TS-CL (>20°). Using this cutoff of 20° as severe TS-CL, it did not correlate with NDI score (P=0.390). After testing possible cutoffs of TS-CL that relate to moderate to severe NDI scores, a novel cutoff of 30.65° for TS-CL was related to an NDI score of ³25 points.

Conclusions: In a cohort of cervical surgery patients, a novel cutoff of 30.65°for TS-CL was predictive of moderate to severe neck disability, as described as an NDI score greater than or equal to 25 points. This criteria can be applied to cervical spine patients to better assess cervical disability.

Presentation #81

Dynamic Changes in the Reflex Exam of Patients with Sub-Axial Cervical Stenosis

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Background: Dynamic changes in the space available for the spinal cord and nerve roots have been well documented with radiographic and anatomic studies. The majority of objective clinical patient assessment continues to be from static imaging and physical exam being done in a single position. Though dynamic changes in the physical exam of patients being evaluated for cervical spine pathology have been reported, there is limited information on the prevalence and clinical features associated with reflex changes in a population undergoing surgical evaluation for cervical spine pathology.

Methods: A retrospective cohort of 51 patients with at least grade 1 cervical stenosis on MRI underwent initial surgical evaluation for cervical spine pathology by a single surgeon over a 4-month period. All patients received complete neurologic examinations including dynamic reflex testing in three positions (neck neutral, extended, and flexed) by 2 spine surgeons (1 neurosurgeon and 1 orthopedic). MRI results were reviewed to ascertain the anterior/posterior orientation of pathology, grade of cervical stenosis, and presence of cord signal change. Continuous variables were compared using a t-test. Categorical variables were compared utilizing chi-squared and Fisher's exact testing as appropriate.

Results: The average age was 58.7 years (range, 34-80), with 28 (55%) patients being male (Table 1). The mean number of cervical levels with at least Kang grade 1 stenosis was 2.2. Stenosis at the symptomatic levels was grade 1 in 18 patients (35%), grade 2 in 11 (21%), and grade 3 in 22 (43%). Twenty-one patients (41%) had a dynamic change in reflex exam. The most common change in reflex exam was seen in the Hoffman's reflex with 14 patients (28%). Patients with grade 3 stenosis were more likely to have a static Hoffman's reflex (64%) compared with grade 1 (17%) and grade 2 (18%) ($p<0.05$). Patients with grade 3 stenosis had a higher rate of either a static or dynamic Hoffman's reflex (82%) compared with grade 1 (44%) ($p<0.05$), but there was no difference between grade 3 and grade 2 (64%) (Figure 1). No correlation was found between the anatomic location of compression and the dynamic reflex exam.

Conclusion: Dynamic changes in reflex exam are commonly seen in patients being evaluated for symptomatic cervical stenosis. The routine neurologic exam can be supplemented with dynamic reflex testing, especially in cases where clinical history or imaging is concerning for cervical myelopathy. Further prospective studies on the clinical implications of dynamic reflex changes are warranted.

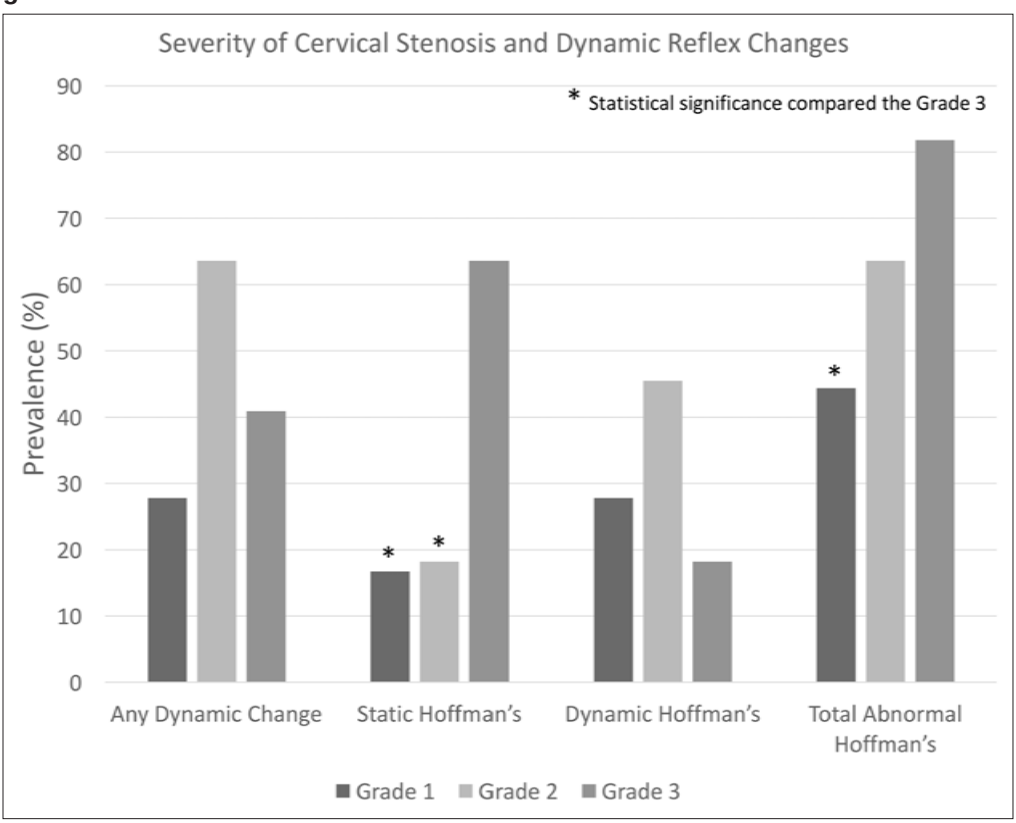
Presentation #81 (cont.)

Table 1. Patient population demographics

Age	Mean years(range)	58.7 (range, 34-80)
Male gender	n (%)	28 (55%)
Diabetics/peripheral neuropathy	n (%)	6 (12%)
Cervical Stenosis		
Number of levels	Mean (±SD)	2.2(±1.2)
Grade 0	n (%)	0
Grade 1	n (%)	18(35%)
Grade 2	n (%)	11(21%)
Grade 3	n (%)	22(43%)
Anterior compression	n (%)	34 (67%)
Posterior compression	n (%)	1 (2%)
Circumferential compression	n (%)	16 (31%)

SD; standard deviation

Figure 1.



Presentation #82

Do Preoperative Cervical Epidural Steroid Injections Affect Outcomes After ACDF for Radiculopathy?

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Introduction: The SPORT trial reported less improvement after a lumbar decompression in patients with spinal stenosis who had previously undergone an epidural steroid injection. Currently there is little evidence to determine if undergoing a cervical epidural steroid injection (CESI) affects the health-related quality of life outcomes (HRQOL) in patients undergoing an anterior cervical decompression and fusion (ACDF) for cervical radiculopathy.

Methods: A cohort study was performed comparing people who had and who had not undergone a CESI prior to undergoing an ACDF for cervical radiculopathy. Patients with cervical myelopathy, patients who underwent surgery for a tumor, trauma or an infection, and patients with less than one year of clinical follow up were excluded. Outcomes evaluated included preoperative and postoperative SF-12 PCS, SF-12 MCS, NDI, VAS arm pain, VAS neck pain, and revision surgery. Multiple linear regressions and multivariate binomial logistic regression analysis were performed to determine the independent effect of preoperative CESI on outcomes while controlling for factors such as age, gender, BMI, smoking, diabetes, number of levels fused, and graft choice (allograft or iliac crest bone graft).

Results: A total of 221 patients were included with a mean follow up of 16 (range 12.0-46.0) months. The mean age was 51.9 (range 23-84) years old; the mean BMI was 29.4 (range 18.8-54.9), and 55% were female. The average number of levels fused was 2.00 (range 1-4), and 93.7% had allograft versus only 6.3% who had iliac crest autograft used. There were 120 patients who had a preoperative CESI and 101 who did not. There were no differences ($p > 0.05$) between the two groups for mean age, gender, BMI, smoking status, diabetes, number of levels fused, or graft choice.

There was a statistically significant improvement in all HRQOL outcomes following surgery ($p<0.014$ Table 1), and this was true for patients who did not undergo a CESI ($p<0.002$), as well as those who did undergo a CESI ($p<0.029$). There were no differences in any of the baseline HRQOL scores between patient who received a CESI and those who did not.

Presentation #82 (cont.)

Similarly, there were no differences in any of the post-operative scores or mean improvement for any of the HRQOL outcomes on both bivariate and multivariate analyses between the two groups (Table 1).

Overall, there was an 8.1% (n=18) rate of revision for pseudarthrosis, which on average occurred 20.2 (8.2-46.8) months after surgery. There was no statistically significant difference in the rate of revision between patients who received a CESI and those who did not, but there was a trend towards a higher rate of revision among those who had a CESI (11.9% vs. 5.0%, p=0.062). Similarly, a logistic regression analysis demonstrated a trend towards a higher probability of undergoing a revision for patients who had a CESI (OR 2.70, 95%CI: 0.99-4.41, p=0.064).

Conclusion: HRQOL outcomes at a minimum of one year after an ACDF were similar regardless of preoperative CESI use. However, there was a trend towards a higher risk of pseudarthrosis for patients who had a preoperative CESI.

Table 1.

Comparison of HRQOL Outcomes						
	Control		Preoperative CESI		*P-value* (Bivariate analysis)	*P-value* (Multivariate analysis)
	Mean	Standard Deviation	Mean	Standard Deviation		
Preop PCS	33.9	8.0	32.8	7.5	0.277	
Postop PCS	41.4	11.6	40.4	11.2	0.539	
Delta PCS	7.5	10.6	7.7	9.7	0.889	0.998
Preop MCS	45.9	12.3	44.8	12.5	0.505	
Postop MCS	48.7	12.3	48.1	12.1	0.705	
Delta MCS	2.8	13.1	3.3	15.1	0.757	0.959
Preop NDI	41.5	18.7	45.7	19.3	0.108	
Postop NDI	25.6	22.8	27.5	23.4	0.535	
Delta NDI	-16.0	21.1	-18.2	20.1	0.429	0.583
Preop Neck Pain	5.6	2.8	6.2	2.6	0.136	
Postop Neck Pain	3.2	2.9	3.4	3.0	0.507	
Delta Neck Pain	-2.5	3.5	-2.7	3.2	0.528	0.623
Preop Arm Pain	4.8	3.2	5.7	3.1	0.079	
Postop Arm Pain	2.6	2.9	3.1	3.0	0.207	
Delta Arm Pain	-2.2	4.0	-2.6	3.8	0.484	0.402

Presentation #83

Perioperative Anesthesia Lean Implementation Is Associated with Increased Operative Efficiency in Posterior Cervical Surgeries at a High-Volume Spine Center

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Introduction: Lean management strategies aim to increase efficiency by eliminating waste or by improving processes to optimize value. These strategies may be applied toward improving efficiency in the neurosurgical operating room (OR). Specifically, targeting strategies that may streamline OR turnover time may increase operative productivity and improve profitability. In the present study, we applied lean methodology for perioperative anesthesia associated with posterior cervical spine surgeries to assess for associations with OR efficiency.

Materials/Methods: Between April 2017 to April 2018, we identified 30 posterior cervical spine surgeries for lean implementation. Patient characteristics were recorded including age, gender, body mass index (BMI), modified Japanese Orthopaedic Association (mJOA) score, American Society of Anesthesiologists (ASA) score and type of surgery, such as fusion or non-fusion. The authors identified the following key steps undertaken during the perioperative anesthesia process (Table 1). The time, in minutes, of each key step was recorded by an independent study coordinator not directly associated with the project during the pre- (Group 1, n = 15) and post-implementation periods (Group 2, n = 15). The first fifteen surgeries (Group 1) were also utilized to identify areas where lean improvements could be applied. Lean methods that were implemented are shown in Table 1. After implementation, the second fifteen surgeries (Group 2) were recorded to assess for process improvement. Univariate comparisons assessed for significant differences between Groups 1 and 2.

Results: Regarding patient characteristics, there were no differences between the two groups with regards to age (65.1 ± 3.0 vs. 64.3 ± 2.8 years, p=0.86), gender (Males: 46.7% vs 53.3%, p=1.00), mJOA score (11.6 ± 1.1 vs. 12.3 ± 0.8, p=0.59), ASA score (2.33 ± 0.2 vs. 2.40 ± 0.1, p=0.75), BMI (25.6 ± 1.7 vs. 25.9 ± 1.1, p=0.89), and type of surgery (fusion versus non-fusion) (Fusion: 60% vs. 73.3%, p=0.70). After the implementation of lean strategies, there was a statistically significant decrease in the amount of time taken in the overall perioperative anesthesia process. (88.4 ± 4.7 vs. 76.2 ± 3.2 min, p=0.04). This was driven by significant decreases in the following steps: Transport and Setup (10.4 ± 0.8 vs. 8.0 ± 0.7 min, p= 0.03) and Positioning (20.8 ± 2.1 vs. 15.7 ± 1.3 min, p= 0.046). The remaining steps were not significantly different between Groups 1 and 2. Of note, total time spent in the operating room (i.e., from room entrance to exit) was lower for Group 2 (270.1 ± 14.6 vs. 252.8 ± 14.1 min) but the result was not statistically significant (p=0.40).

Conclusion: Lean methodology may be successfully applied to posterior cervical spine surgery whereby improvements in the perioperative anesthetic process is associated with significantly increased OR efficiency. This has important implications for multiple stakeholders including for clinicians, patients, and hospitals. This increased efficiency is particularly evident for patient transportation and positioning steps of posterior cervical surgery.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

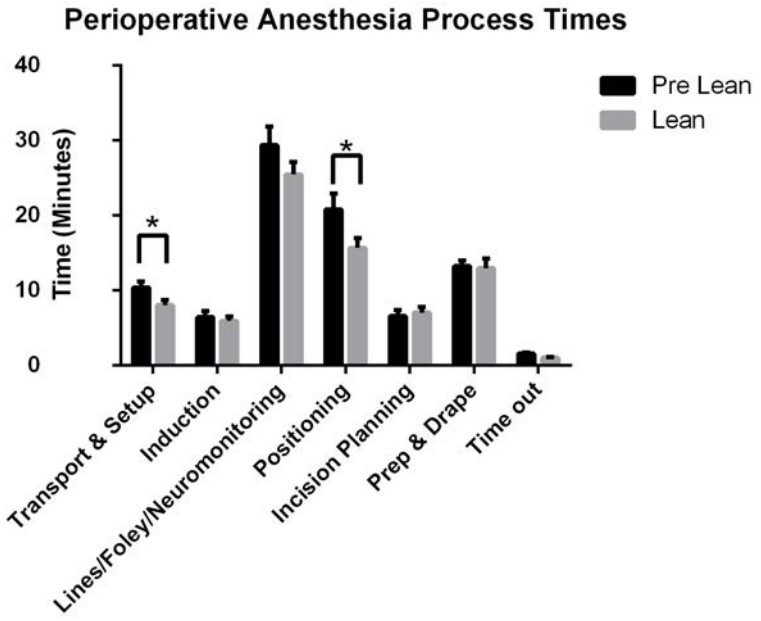
Presentation #83 (cont.)

Table 1.

Steps	Description	Lean Improvement Strategies
Transport and Setup	Patient is transported into OR, and has ECG monitoring and IV lines connected	Preoperative nurses to start PIV in preoperative area
Induction	Patient is injected with propofol and intubated	A-line placement will be placed via ultrasound guidance as soon as patient is intubated
Lines, Foley and Neuromonitoring	Patient has an Arterial Line, Foley, and Neuromonitoring wires placed	Utilize more experienced anesthesia staff, CRNAs, and residents to do the anesthesia for obese or low mJOA patients
Positioning	Patient is flipped and secured for the surgery	Expedite transport and positioning by Increasing manpower for high risk patients
Incision Planning	Patient is shaved and has incision sites are marked. X-ray is done to confirm the location	Experienced X-Ray tech and machine in the OR prior to positioning process

Presentation #83 (cont.)

Figure 1.



* $p < 0.05$

Presentation #84

Undergoing Bariatric Surgery Lowers Complication Rates Following Spine Surgery in Morbidly Obese Patients

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Introduction: Bariatric surgery is an increasingly common treatment for morbid obesity that has the potential to effect bone and mineral metabolism. The effect of prior bariatric surgery on outcomes following spinal surgery has not been well-established. The aim of this study was to assess differences in complication rates following spinal surgery for patients with and without a history of bariatric surgery.

Methods: Retrospective analysis of the prospectively collected New York State Inpatient Database (NYSID) years (2004-2013). Retrospective analysis of the prospectively collected New York State Inpatient Database (NYSID) years 2004-2013. Patient linkage codes allow identification of multiple and return inpatient stays within the time-frame analyzed. Complication rates were compared between bariatric surgery patients now undergoing spine surgery versus morbidly obese patients having spine surgery. Bariatric surgery (BS) patients and morbidly obese patients (non-BS) were divided into cervical and thoracolumbar surgical groups and were propensity score matched for age, gender and degree of invasiveness. Non-obese spine surgery patients were used as a standard.

Results: 1939 spine surgery patients with a history of BS were compared to 1625 non-BS spine surgery patients in the NYSID database. 89% of normal weight spine surgery patients had a decompression and the overall complication rate for these patients is 45%. The average time from bariatric surgery to spine surgery is 2.95 years. BS patients had primarily 2-3 level fusions and decompressions, which is similar to non-BS patients. After propensity score matching for age, gender and invasiveness, 740 BS patients were compared to 740 non-BS patients undergoing thoracolumbar surgery, with similar comorbidity rates between cohorts. The overall complication rate for BS patients undergoing thoracolumbar surgery was significantly lower than non-BS patients (45.8% vs 58.1%, $P<0.001$). The most common complications following thoracolumbar surgery for BS patients were anemia (20.3%), bowel issues (12.3%), device-related complications (6.1%), and digestive problems (5.0%). BS patients undergoing a thoracolumbar procedure experienced lower rates of device-related

Presentation #84 (cont.)

complications (6.1% vs 23.2%, P<0.001), DVT (1.2% vs 2.7%, P=0.039), and hematomas (1.5% vs 4.5%, P<0.001) than non-BS patients undergoing thoracolumbar surgery. Neurologic complications were similar between BS patients and non-BS patients (2.3% vs 2.7%, P=0.62) and this rate was similar to normal weight patients undergoing spine procedures(1.65%). Spine surgery revision rates for BS patients was 14.9% and the average length of stay for BS patients undergoing spine surgery was higher than non-BS patients undergoing thoracolumbar surgery (5.95 days vs 5.14 days, P=0.007). For patients undergoing cervical spine surgery, BS patients experienced lower rates of bowel issues, device-related, and overall complication rates than non-BS patients (all P>0.05).

Conclusions: Bariatric surgery patients undergoing spine surgery experience lower overall complication rates than morbidly obese patients. This study warrants further investigation into these populations to mitigate risks associated with spine surgery for bariatric patients.

Presentation #85

The Risk of Recurrent Laryngeal Nerve Injury with Laterality of Approach in Anterior Cervical Discectomy and Fusion Procedures: A Randomized, Prospective Study Over 10 Years

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Introduction: Recurrent laryngeal nerve (RLN) injury is a well-known, but potentially devastating injury after anterior cervical discectomy and fusion (ACDF) procedures. Although RLN injury is most often transient in nature, there are the associated clinical consequences of dysphonia, impaired phonation or cough reflex, airway obstruction, hoarseness, vocal fatigue, and in some cases, tracheotomy. There has been debate regarding the risk of RLN injury in relation to laterality of approach. There are numerous papers reviewing the complication, but there is no large-scale, randomized prospective single surgeon, single study investigating the correlation of laterality of approach to the risk of recurrent laryngeal nerve injury.

Methods: A fellowship trained spine surgeon prospectively performed ACDFs between the years of 2003-2012. Side of approach was chosen based on contralateral to side of symptoms. Patients were monitored postoperatively for development of recurrent laryngeal nerve palsy symptoms. Patients found to have signs of recurrent laryngeal nerve injury were sent to ENT for evaluation and monitored for recovery.

Results: 411 ACDFs were performed during the 10-year period. 190 right sided and 221 left sided procedures were done. The incidence of recurrent laryngeal nerve injury was 14 (13 primary procedures and 1 revision). 7 nerve injuries were in a right sided approach and 7 were in a left sided approach. The risk of injury was 3.18% in a left sided approach and 3.70% in a right sided approach with a p-value of 0.7723 indicating that there is no significant difference between the sides of the approach.

Conclusion: Our study's analysis showed that there was a 3.18 % chance of RLN with a left-sided approach compared to a 3.70% chance of RLN injury with a right-sided approach (p-Value: 0.7723), indicating that there is no significant difference in RLN injury between the sides of approach. This is similar to an analysis of four spine surgeons reported in 2001 which evaluated 328 ACDFs from 1989 to 1999. Multiple retrospective and prospective trials also failed to show an increased risk. Although there is usually spontaneous resolution of hoarseness, it is important to remember that patients with a vocal cord paresis may be asymptomatic, and patients with symptomatic dysphonia may have no vocal cord paresis. Jung et al found in both pre- and post-operative laryngoscope exams that asymptomatic patients were two to three times more common than symptomatic patients. Multiple studies state that the likelihood of endotracheal intubation causing RLN is greater than retractor placement as the retractors are generally more lateral than the course of the nerve. A retrospective analysis from 1995 to 2005 also used laryngeal endoscopic observation of the vocal cords and assessed 418 patients, and found no statistically significant difference on approach to RLN injury in patients with persistent dysphonia.

In a single surgeon randomized prospective study there was no significant difference was noted between the side of approach and the risk of recurrent laryngeal nerve palsy. There-

Presentation #85 (cont.)

fore the surgeon may safely operate from either side based on handedness, experience, training or anatomic considerations.

Presentation #86

Perioperative Complications of Anterior Decompression with Fusion vs. Posterior Decompression with Fusion for the Treatment of Cervical Ossification of the Posterior Longitudinal Ligament: Propensity Score Matching Analysis Using a National Inpatient Database

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Introduction: Surgical management of compressive ossification of the posterior longitudinal ligament (OPLL) can be challenging. Generally, the surgical treatment of cervical OPLL carries a high risk of complications. Previous studies have reported that perioperative complication rates were higher in anterior decompression with fusion (ADF) than in laminoplasty for the treatment of cervical OPLL. Recently, posterior decompression with fusion (PDF) has been increasingly performed for cervical OPLL, especially for large OPLL. However, to date, no studies have compared ADF and PDF in terms of perioperative complications. In this study, we investigated the perioperative complications of ADF and LAMP for cervical OPLL, using a large national inpatient database in Japan: Diagnosis Procedure Combination (DPC) database. Furthermore, we conducted a propensity score matching analysis to minimize the selection bias and differences in preoperative characteristics when comparing the surgical risks of ADF and PDF.

Methods: Patients undergoing ADF and PDF for cervical OPLL from April 1, 2010, to March 31, 2016, were identified in the Diagnosis Procedure Combination (DPC) national inpatient database. Those who required anterior and posterior fusion at one admission were excluded from the analysis. We investigated systemic and local complications, length of hospital stay, cost for hospitalization, return to operating room, and mortality. Propensity score was calculated from patients' characteristics including age, sex, BMI, smoking index, and preoperative comorbidities, and tone to one matching was performed based on the score. The outcomes were statistically compared between ADF and PDF after the matching.

Results: Propensity score-matching produced 854 pairs of patients who underwent ADF and PDF. There were no differences in preoperative patients' background between ADF and PDF after the matching (Table1). In the comparison of systemic complications of ADF and PDF, the rate of at least one systemic complication was significantly higher in the ADF group ($p=0.004$) (Table2). The incidence rates of postoperative respiratory failure ($p=0.034$) and dysphagia ($p=0.008$) were significantly higher in the ADF group. The rates of pneumonia ($p=0.06$) and hoarseness ($p=0.08$) also tended to be higher in the ADF group. However, no difference was found in the reoperation rate for the systemic complications ($p>0.99$) and in the mortality rate (ADF: 0.2%/ PDF: 0%, $p=0.22$). The rate of blood transfusion was significantly higher in the PDF group ($p=0.001$) (Table 2). In the local complications, spinal fluid leakage was significantly higher in the ADF group ($p<0.001$), but no difference was found in the reoperation rate for the local complications ($p=0.76$) (Table 2). Hospital stay

Presentation #86 (cont.)

was significantly longer in the ADF group (p<0.001), whereas the cost for hospitalization was greater in the PDF group (p<0.001).

Conclusions: The present study, using a large national database, demonstrated that perioperative complications, such as respiratory failure, dysphagia, and spinal fluid leakage, were more common in the ADF group. Hospital stay was longer in the ADF group, whereas the cost for hospitalization was greater in the PDF group. Surgeons should consider the merits and demerits of each procedure when deciding the surgical method of cervical OPLL.

Table1. Patients' characteristics in ADF and PDF after the propensity score (PS) matching

	ADF (n=854)	PDF (n=854)	*P* value
Age, mean (SD), years	62.6 ± 11.2	62.4 ± 10.8	.67
Sex, n (%)			>.99
Male	602 (70.5%)	602 (70.5%)	
Female	252 (29.5%)	252 (29.5%)	
BMI, mean (SD), kg/m²	25.5 ± 4.3	25.6±4.6	.81
Smoking index, median (IQR)	0 (0-738)	0 (0-800)	.47
Admission type, n (%)			.56
Scheduled	775 (90.8%)	787 (92.2%)	
Unscheduled	74 (8.7%)	62 (7.3%)	
Emergency transport, n (%)	17 (2.0%)	21 (2.5%)	.20
Past history of spine surgery, n (%)	16 (1.9%)	17 (2.0%)	.55
Preoperative comorbidities, n (%)			
Diabetes mellitus	274 (23.0)	277 (23.2)	.88
Cardiovascular disease	57 (4.8)	56 (4.7)	.92
Cerebrovascular disease	214 (25.1%)	205 (24.0%)	.61
Chronic obstructive pulmonary disease	52 (6.1%)	43 (5.0%)	.34
Renal failure	14 (1.6%)	11 (1.3%)	.55
Hepatic failure	21 (2.5%)	21 (2.5%)	>.99
Gastric ulcer	4 (0.5%)	5 (0.6%)	.74
Malignancy	8 (0.9%)	9 (1.1%)	.81
Rheumatoid arthritis	29 (3.4%)	29 (3.4%)	>.99

Presentation #86 (cont.)

Table 2. Comparison of ADF and PDF after the PS matching

	ADF (n=854)	PDF (n=854)	*P* value
Systemic complications, n (%)			
Cardiovascular events	19(2.22)	16(1.87)	.61
Cerebral hemorrhage	1(0.12)	0(0)	.32
Cerebral infarction	5(0.59)	2(0.23)	.27
Respiratory failure	9 (1.1%)	2 (0.2%)	.034*
Pneumonia	8 (0.9%)	2 (0.2%)	0.06
Hoarseness	3 (0.4%)	0 (0%)	.08
Dysphagia	21 (2.5%)	7 (0.8%)	.008**
Renal failure	2 (0.2%)	1 (0.1%)	.56
Hepatic failure	2 (0.2%)	3 (0.4%)	.65
Gastric ulcer	38 (4.5%)	28 (3.3%)	.21
Gastric hemorrhage	9 (1.1%)	8 (0.9%)	.81
Pulmonary embolism	1 (0.1%)	0 (0%)	.32
Sepsis	2 (0.2%)	1 (0.1%)	.56
Delirium	3 (0.4%)	3 (0.4%)	>.99
At least one systemic complication	124 (14.5%)	85 (10.0%)	.004**
Reoperation for systemic complications	8 (0.9%)	8 (0.9%)	>.99
Mortality, n (%)	2 (0.2%)	0 (0%)	.16
Blood transfusion, n (%)	65 (7.6%)	107 (12.5%)	.001**
Local complications, n (%)			
Infection	23 (2.7%)	25 (2.9%)	.77
Paralysis	7 (0.8%)	8 (0.9%)	.80
Meningitis	3 (0.4%)	0 (0%)	.08
Spinal fluid leakage	23 (2.7%)	1 (0.1%)	<.001**
Hematoma	5 (0.6%)	5 (0.6%)	>.99
At least one local complication	54 (6.3%)	38 (4.5%)	.09
Reoperation for local complications	21 (2.5%)	23 (2.7%)	.76
Length of stay (mean±SD) (days)	28.7±22.5	32.7 ± 26.7	<0.001**
Cost (mean±SD) (dollars)	22768.0±11296.9	30663.3±12518.2	<0.001**

*: P<0.05, **: P<0.01

Presentation #87

The Clinical Study on a Minimally Invasive Muscle-Splitting Approach to Posterior C1–C2 Fixation for the Treatment of Fresh Odontoid Fracture

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Introduction: Conventional posterior atlantoaxial fixation and fusion is related with a signifcant iatrogenic soft tissue injury through subperiosteal muscle dissection from the axis spinous process, which could increase the incidence of neck axial symptoms of the postoperative patients, as well as the speed-up of lower cervical spine degeneration due to muscle-ligament complex stripping from the axis spinous process. The purpose of this study is to assess the effect of the treatment of fresh odontoid fracture by a minimally invasive muscle-splitting approach.

Methods: A retrospective study was conducted in a group of 46 patients of type II odontoid fractures. 27 of them were treated with conventional surgical approach, and the other 19 were treated with minimally invasive muscle-splitting approach to maintain neck spine muscle-ligament complex structure of C2 spinous process. The operation time, intraoperative bleed and recovery outcomes, the incidence of postoperative cervical axial symptoms and postoperative quality of life were evaluated and statistically analyzed.

Results: 5 of 46 patients showed a non-union of odontoid postoperatively including 3 cases by the conventional approach (11.1%) and 2 cases by the muscle minimally invasive muscle-splitting approach (10.5%), showing no significant difference. The two groups indicated similar operation time and intraoperative blood loss ($P>0.05$). The conventional treated group showed a 25.9% of incidence of postoperative symptoms of axial (7 cases), while the minimally invasive muscle-splitting group showed a much lower level of 15.8% by 3 cases ($P<0.05$) and with an improved postoperative quality of life by SF-36 score.

Conclusion: Minimally invasive muscle-splitting approach group showed an improved surgical effect with reduced incidence of postoperative axial symptoms and better life quality score compared to conventional methods, there is no significant difference on the operation time, intraoperative blood loss and dentate fracture healing between the two groups. Minimally invasive muscle-splitting approach could offer a better option for the treatment of fresh odontoid fracture.

Presentation #88

Short-Term Outcomes Following Cervical Laminoplasty and Laminectomy and Fusion with Instrumentation

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Introduction: Conflicting reports exist in spine literature regarding short-term outcomes following cervical laminoplasty and posterior laminectomy and fusion. The objective of this study was to compare the 30-day outcomes for these two treatment groups for multilevel cervical pathology.

Methods: Retrospective review of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database years 2010-2015. Patients who underwent cervical laminoplasty or posterior laminectomy and fusion were identified in the NSQIP database from 2010 to 2015 based on Current Procedural Terminology (CPT) code. Laminoplasty CPT codes included 63050 and 63051. Posterior cervical laminectomy CPT codes included 63015, 63045, and instrumentation was denoted by CPT code 22842. Patients with pre-op sepsis, wound infection, pneumonia, cancer, emergency cases and trauma, and surgery within the last 30 days were excluded. Outcome Measures: Patient demographics, comorbidities, complications and outcomes compared between patients undergoing cervical laminoplasty or laminectomy and fusion. Patient demographics and comorbidities were compared using bivariate logistic regression. Propensity-adjusted multivariate regressions were performed to assess differences in postoperative length of stay, adverse events, discharge disposition, and readmission.

Results: A total of 3796 patients were included: 2397 (63%) underwent cervical laminectomy and fusion and 1399 (37%) underwent cervical laminoplasty. Both groups were similar in age, gender, body mas index (BMI), American Society of Anesthesiologists (ASA) score and Charlson Comorbidity Index (CCI) (P>0.05 for all). Both groups had similar rates of malnutrition, chronic kidney disease (CKD), diabetes, chronic obstructive pulmonary disease, and history for steroid use. Age > 70 and age <50 were not associated with one treatment group over the other (P>0.05 for all). Compared with laminoplasty patients, laminectomy and fusion patients had increased lengths of stay (LOS) (4.5 vs 3.7 days, P<0.01) and increased rates of adverse events (41.7 vs 35.9%, P<0.01), discharge to rehab (16.4 vs 8.6%, P<0.01) and skilled nursing facilities (12.2 vs 9.7%, P=0.02), and readmission (6.2 vs 4.5%, P=0.05). Both groups experienced similar rates of death, pulmonary embolus, deep vein thrombosis, deep and superficial surgical site infection, and reoperation P>0.05 for all). Patients with CKD that underwent laminectomy and fusion had higher rates of transfusion (6.8 vs 20.4%, P=0.05). Patients older than 70 that underwent laminectomy and fusion experienced high rates of urinary tract infection (6.4 vs 2.6%, P=0.02).

Presentation #88 (cont.)

Conclusions: Posterior cervical laminectomy and fusion patients were found to have increased LOS, readmissions, and complications despite having similar pre-op demographics and comorbidities. Patients and surgeons should consider these risks when considering surgical treatment for cervical pathology.

Presentation #89

Surgical Treatment for Cervical Spine Trauma in Ankylosing Spine with Diffuse Idiopathic Skeletal Hyperostosis; Surgery within 8-Hours After Injury Affects Prognosis

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Study Design: Retrospective study of a consecutive series of operatively managed patients with cervical spinal fractures in the setting of diffuse idiopathic skeletal hyperostosis (DISH) in our hospital over a 10-year period.

Objectives: Assess demographics, surgical techniques and complications, and evaluate the factors affecting the neurological prognosis after cervical spinal cord injury.

Methods: All patients with cervical fractures in the setting of DISH between October 2006 and April 2016 were reviewed retrospectively. Medical records and radiographs were reviewed assessing demographics, injury characteristics, surgical outcomes, perioperative complications, necessity of additional surgery, and neurological prognosis. Neurological evaluations were performed using the American Spinal Injury Association (ASIA) grade at the time of admission and discharge.

Results: Thirty-eight patients with age 71.9±8.8 years were identified. Fracture occurred as follows; 2 case at C3-4, 10 at C4-5, 12 at C5-6, 11 at C6-7, and 3 at C7-Th1. Fractures through the disc space (type 1) were most common (20 cases) overall, whereas fractures through the body (type 2) occurred in 8 patients and fractures through the disc and body (type 3) occurred in 10 patients. 14 patients (36.8%) were ASIA-A on admission, 4 (10.5%) ASIA-B, 7 (18.4%) ASIA-C, and 13 (34.2%) ASIA-D. All patients had posterior instrumented fusion and the average number of instrumented vertebral bodies was 4.5±2.5 (range, 2-7). Additional secondary halo-vest fixation was demanded for 6 cases (15.8%). 8 patients (21.1%) suffered serious pulmonary complications, 4 patients (10.5%) had died within 6 months after initial surgery, and all of these cases were ASIA-A on admission. 17 patients (44.7%) showed more than 1 ASIA-grade improvement, 20 patients (52.6%) had no neurological recovery, and only 1 patient (2.6%) deteriorated. Within 18 complete motor paralysis cases (ASIA-A/B), neither the types of fracture nor mechanism of injury (e.g., falling down at flatlands, high energy trauma) had correlation with neurological prognosis, while the elapsed time from injury until surgery (within 8-hours) had a significant correlation to neurological improvement from ASIA-A/B to ASIA-C or D ($p<0.01$, Pearson's chi-square test).

Conclusion: Even with complete motor paralysis, our data showed that surgery within 8-hours after injury for patients with cervical DISH fracture could improve neurological state from complete to incomplete motor paralysis.

Presentation #89 (cont.)

Summary: Surgery within 8-hours after injury could improve neurological state of cervical-DISH-fracture even with complete tetraplegia.

Presentation #90 – 3rd Place Resident/Fellow Research Award Winner

SMaRT Human Neural Stem Cells to Degrade Scar and Optimize Regeneration After Traumatic Cervical Spinal Cord Injury

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Mohamad Khazaei, PhD, Toronto, Ontario, Canada
Priscilla Chan, Toronto, Ontario, Canada
Jian Wang, MD, Toronto, Ontario, Canada
Jinil Bhavsar, Toronto, Ontario, Canada
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Introduction: Human induced pluripotent stem cell-derived neural stem cell (hiPS-NSC) have the capacity to replace neural circuits, remyelinate denuded axons and provide trophic support making them an exciting regenerative approach after traumatic spinal cord injury (SCI)[1]. Unfortunately, most individuals are in the chronic phase of their injury where dense perilesional chondroitin sulfate proteoglycan (CSPG) scarring significantly impairs neurite outgrowth and regenerative cell migration[2,3]. Scar-modifying enzymes can enhance NSC-mediated recovery, however, nonspecific administration via an intrathecal catheter increases the risk of off-target CNS effects[4]. We aimed to generate a novel, genetically-engineered line of hiPS-NSCs, termed Spinal Microenvironment Modifying and Regenerative Therapeutic (SMaRT) cells, capable of locally expressing a scar-degrading enzyme to enhance functional recovery without the risk of nonspecific administration.

Materials/Methods: Using non-viral techniques, a scar degrading enzyme was genetically integrated into hiPS-NSCs under a human promoter and a monoclonal line was generated by fluorescence activated cell sorting (Fig. 1A). Enzyme expression and activity was extensively characterized *in vitro* by biochemical assays, slot blot, and cell culture assay. T-cell deficient RNU rats (N=60) with chronic (8 week) C6-7 clip-contusion injuries were randomized to receive (1) NSCs, (2) SMaRT enzyme-expressing NSCs, (3) vehicle control, or (4) sham surgery (laminectomy alone). Behavioural asessments are completed to 40 weeks post-injury with analyses ongoing.

Results: The scar-degrading ENZYME and fluorescent reporter are robustly expressed by the transgenic SMaRT cells (Fig. 1B). Importantly, SMaRT cells retain their human NSC characteristics (Fig. 1C, D). The expressed enzyme appropriately degrades human CSPGs and allows neurons to extend into CSPG-rich regions *in vitro* (Fig. 1E). Conditioned SMaRT cell media also degrades *in situ* rodent CSPGs in *ex vivo* injured cord cryosections. While blinded behavioural analyses are ongoing, an interim histologic analysis of several animals shows that grafted human cells are extending remarkably long (medulla to mid-thoracic) axons through rodent white matter at 8 weeks post-transplant (Fig. 2). The graft further evolves by 32 weeks post-transplant demonstrating more numerous, thinner, and longer processes with positive staining for mature neuron markers such as NF200.

Conclusion: This work provides exciting proof-of-concept data that genetically-engineered SMaRT cells can degrade CSPGs *in vitro* and that human NSC grafts can form long axonal processes in the chronic cervical SCI niche.

Acknowledgements: This work is generously funded by the Canadian Institutes of Health Research, the Krembil Foundation, Wings for Life, and Phillip and Peggy DeZwirek.

Presentation #90 (cont.)

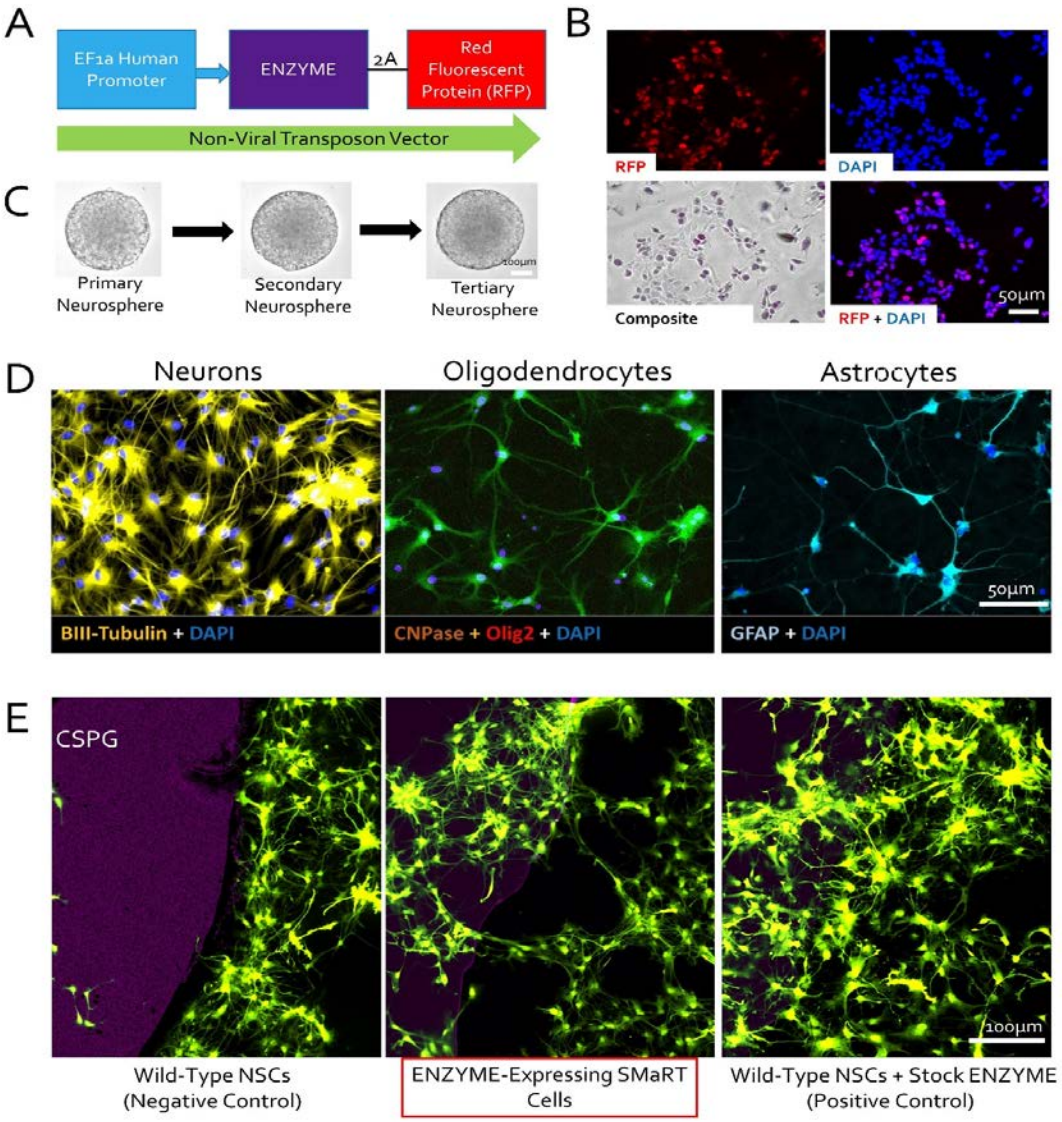

Figure 1. Generation and characterization of ENZYME-Expressing SMaRT human NSCs. (A) A human EF1α promoter driving expression of ENZYME and a red fluorescent protein reporter was transfected using a non-viral transposon vector. (B) A monoclonal line of resultant SMaRT cells ubiquitously expressed the transgene. (C, D) Transfected cells retained key human NSC characteristics including the ability to form neurospheres and differentiate into all three neuroglial lineages. (E) Unlike wild-type NSCs, ENZYME expression by SMaRT cells allowed growth into scar-like CSPG-dense regions.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #90 (cont.)

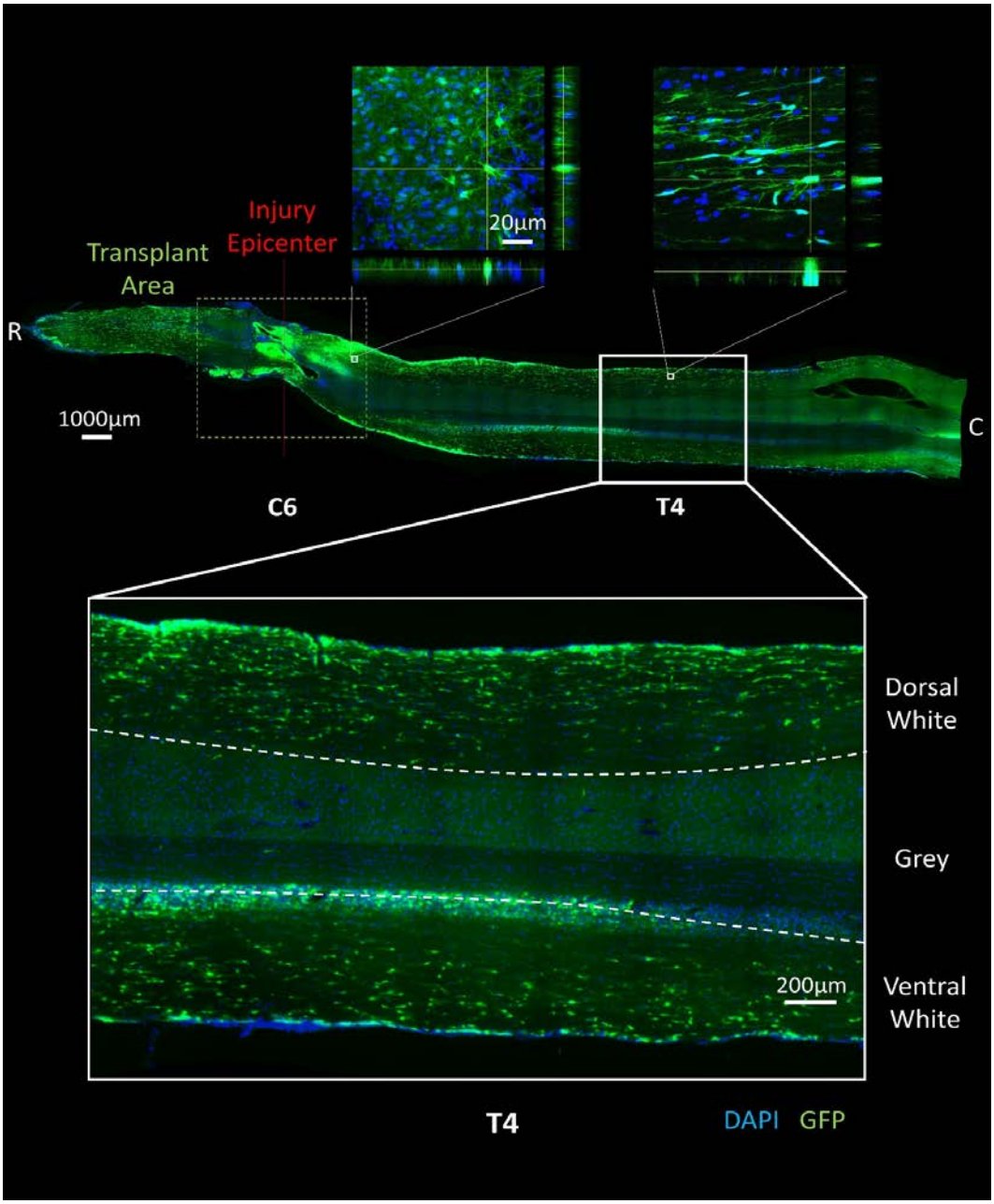

Figure 2. Transplanted human NSCs (GFP+) extend long axonal processes along host white matter tracts after chronic traumatic SCI.

Presentation #90 (cont.)

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Presentation #91

Radiologic Factors to Predict Injury of Transverse Atlantal Ligament in Unilateral Sagitally Split Fracture of C1 Lateral Mass

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Introduction: Unilateral sagitally split fracture (USSF) of C1 lateral mass (LM) is a variant type of C1 atlas fracture. Recently, it is recognized as unstable fracture, which causes late deformity of occipitocervical junction that requires extensive reconstructive surgery. Since USSF of C1 LM is rare, its definite treatment guideline has not been established. The integrity of transverse atlantal ligament (TAL) is a key factor to determine whether to treat surgically or non-surgically in C1 atlas fracture. However, no information is available about which type of USSF of C1 LM is associated with injury of TAL. Therefore, we performed the current study to investigate radiologic factors to predict injury of TAL in USSF of C1 LM.

Material/Methods: 26 consecutive cases of USSF of C1 LM were included from 5 trauma centers of tertiary university hospitals. The fractures associated with other cervical spines, such as C2 and occiput, were excluded from the study. The mean age was 52 years old. 16 were male and 10 were female. Two radiologists determined presence of TAL injury in MRI using Dickman's classification and divided into two groups: TAL injury and TAL intact. If the results of two judgements were not identical, the third radiologist re-evaluated. Three spine surgeons measured radiologic parameters and the averages were used as final results: Total LM displacement (LMD), unilateral LMD at fracture side, atlanto-dental interval (ADI), fracture gap, clivus canal angle (CCA), atlanto-occipital joint axis angle (AOJAA), and basion-dens interval (BDI). The radiologic results were compared between two groups. The incidence of associated other C1 fractures was also investigated and compared between two groups.

Results: 16 were TAL injury group (9 type I and 7 type II) and 10 were TAL intact group. Total LMD and unilateral LMD at fracture side were higher in TAL injury group than TAL intact group (5.9 mm vs 1.2 mm, $p < 0.001$) (4.3 mm vs 1.0 mm, $p < 0.001$), respectively. ADI and fracture gap were higher in TAL injury group than TAL intact group (2.0 mm vs 1.5 mm, $p < 0.05$) (6.9 mm vs 2.1 mm, $p < 0.001$), respectively. However, CCA, AOJAA, and BDI were not statistically different between two groups (155.6 degrees vs 154.9 degrees, $p = 0.824$) (107.8 degrees vs 105.9 degrees, $p = 0.676$) (4.4 mm vs 4.2 mm, $p = 0.751$). Total LMD was positively correlated to unilateral LMD at fracture side (CC = 0.937, $p < 0.001$), ADI (CC = 0.449, $p < 0.01$) and fracture gap (CC = 0.658, $p < 0.001$), but not CCA, AOJAA, and BDI (CC = -0.221, $p = 0.279$) (CC = -0.042, $p = 0.837$) (CC = -0.138, $p = 0.502$). Incidence of associated other C1 fractures was higher in TAL injury group that TAL intact group (87% vs 20%, $p < 0.001$).

Conclusion: Our results suggest that total LMD more than 5.9mm and unilateral LMD at fracture side more than 4.3mm are radiological factors to predict injury of TAL in USSF of C1 LM.

Presentation #92

Treatment Algorithm for Dens Fractures

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Introduction: Based on the literature and on our own experience we established a treatment protocol for dens fractures. We carried out a prospective analysis to correlate between our treatment algorithm and previously published data. We postulated that the differentiation of dens fractures into stable and unstable fractures correlates with a high fusion rate.

Methods: There were 173 patients (2003 until 2017; 90 male, 83 female; age range: 19-99 yrs.; mean: 73 yrs). We prospectively categorized each patient with radiographs and CT-scans to evaluate the type of fracture according, fracture gap (mm), fracture angulation (degrees), fracture displacement (mm) and static- and dynamic dislocations (anterior, posterior). The fractures were stratified as stable (displacement <5mm, angulation <11°, fracture gap <2mm, functional dislocation <2mm) or unstable. Stable fractures were treated with a non-rigid immobilization. Unstable fractures were treated surgically. In patients >75 yrs. we preferred a posterior transarticular C1-C2 fixation, in younger patients a direct anterior screw fixation was the method of choice if suitable. Follow up time: 1 month-11 years (mean: 5.7 months).

Results: We encountered 113 patients with stable (2 Type I, 51 Type II, 60 Type III fractures) and 60 patients with an unstable fracture (35 Type II, 25 Type III fractures). For stable fractures the average fracture gap was 0.6mm, the dens angulation 11° and the fracture displacement 1.8mm. All stable fractures underwent conservative treatment with a cervical collar. 7 patients (6.2%) had a secondary fracture dislocation within 2 months and underwent a posterior fixation. In the remaining patients, the observed non-union rate was 21% (24/113 patients; 15 Type II, 9 Type III fractures) of which 3 patients underwent a secondary C1/C2 fixation. The other 21 patients had either stable non-unions (n=16) or could not undergo a surgical intervention due to preliminary health conditions. Surgical intervention was performed in 60 unstable fractures with an average fracture gap of 1.0 mm, dens angulation of 18° and fracture displacement of 5.1mm. A posterior C1/C2 fusion was carried out in 40 patients (67%). Seven patients (12%) were treated by a C0 onto C4 stabilization. An anterior odontoid screw fixation was performed in 13 patients (22%) (Fig 1). For direct anterior screw fixation there were 2 non-unions, which were revised. For posterior C1/2 fixation, one screw malplacement occurred and had to be revised with a final fusion rate of 100%. Overall screw breakages in 4 patients occurred but with no effect on the consolidation. 17 patients (9,8%) died within 4 weeks after injury (9 non-operative, 8 operative).

Conclusion: Our stratified treatment protocol is associated with a high success rate and to differentiate into stable and unstable fractures is feasible. Our calculations indicate that the need for surgical intervention correlates with a fracture displacement >5mm, angulation >11°, fracture gap >2mm and functional dislocation >2mm as has been published previously. For stable dens fractures a non-rigid immobilization is sufficient. Stable non-unions are acceptable in geriatric patients.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Presentation #92 (cont.)

DENS FRACTURES	Patients (n)	Primary Union	Primary Nonunion	Treatment (Rx)	Fracture displacement (mm)	Dens angulation (degrees)	Fracture gap (mm)	Functional dislocation (mm)
Conservative Rx	113	82	31	Cervical collar	1.8	11.2	0.6	<2
Surgical Rx	60	58	2	NA	5.1	18	1.0	>2
Posterior transarticular fixation	40	40	0	C1/C2 fixation	5.5	21.1	1.0	>2
C0 onto C4 fixation	7	7	0	C0-C4 fixation	6.4	19.6	0.8	>2
Anterior Screw fixation	13	11	2	Ant. fixation	3.4	15.8	0.5	>2

CERVICAL SPINE RESEARCH SOCIETY

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E-Poster Abstracts

Individual Disclosures can be found in the Disclosure Index pages 45-102.

In Vivo Synergistic Effect of Checkpoint Blockade and Radiation Therapy Against Chordomas in a Humanized Mouse Model

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Michael Lim, MD, Baltimore, MD
Jeffrey Bruce, MD, New York, NY
Sheng-fu L. Lo, MD, Baltimore, MD

Introduction: With the advent of immunotherapy (IT) against various cancers, its applications to other cancers have been extensively investigated. However, it has been a challenge to apply IT to chordomas, due to lack of clinically-translatable in vivo models. Currently, there are no well-established murine chordoma cell lines that can be injected to syngeneic mice or no transgenic mouse models that develop chordomas spontaneously, which would allow us to study interaction between murine chordomas and murine immune cells. Hence, we aimed to develop a humanized mouse model, where human immune cells are engrafted into immunodeficient mice, to study interaction between human immune system and human chordomas. We also sought to utilize it to study synergistic effect between IT and radiation therapy (RT) against chordoma.

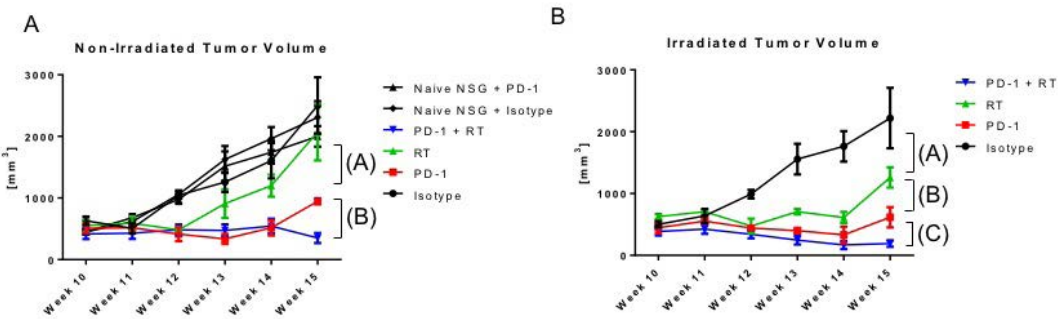
Materials and Methods: Fifteen 10-12-week-old NSG mice, which lacks mouse T cells, B cells, and NK cells as well as functional mouse macrophages, were sub-lethally (1.5Gy) irradiated and then implanted with fetal thymic tissue and CD34+ stem cells that had been harvested from a fetus, whose HLA-type is partially-matched with that of the U-CH1 chordoma cell line. Reconstitution of immune cells in NSG mice was confirmed 8 weeks post transplantation and then each animal (15 humanized NSG mice and 12 naïve NSG mice) was injected with U-CH1 cell suspension bilaterally and subcutaneously. Next, they were treated for 4 weeks as follows: A) control, isotype antibodies (Abs) injection (n=3), B) anti-human-PD-1 Abs (n=4), C) RT + isotype Abs (n=3, unilaterally to the left-sided tumor, 8Gy x 4), D) anti-human-PD-1 Abs and RT (n=5), E) naïve NSG mice (n=6, without the engraftment of human immune cells) + isotype, and F) naïve NSG mice (n=6) + anti-human-PD-1 Abs. During and after the treatment, anti-tumor activities were monitored via tumor size, flow cytometry, qRT-PCR, and immunohistochemistry.

Results: On average, human peripheral blood mononuclear cells (PBMCs) of 43.8% among all PBMCs (human + mouse), human T cells of 23.4% among human PBMCs, human CD8+ T cells of 24.3% among human T cells, and other lymphocytes such as B cells, macrophages, and NK cells were observed in peripheral blood of humanized mice via flow cytometry. One week after the treatment, on the irradiated side, (D) demonstrated lowest tumor volume (Figure 1), highest number of human PBMCs, highest % of CD8+ human T cells, highest % of CD45RO+CD4+ human (memory) T cells, and lowest % of PD-1+CD8+ human T cells in the tumors via flow cytometry (Figure 2), and highest IFN-gamma in the tumors via qRT-PCR, compared to the other five groups with statistical significance. On the non-irradiated side, similarly D) had the smallest tumor compared to the others (P=0.09).

Conclusions: We demonstrated that this humanized mouse model could be a revolutionary platform to investigate IT against rare cancers such as chordomas, where murine

equivalent cell lines are not available to date, which hinders us from utilizing syngeneic or transgenic mouse models to study IT. The direct synergistic effect between IT and RT against chordoma as well as the potential abscopal effect was observed.

Figure 1. Synergistic inhibitory effect of anti-PD-1 antibodies and radiation therapy against chordomas in the BLT NSG humanized mouse model.



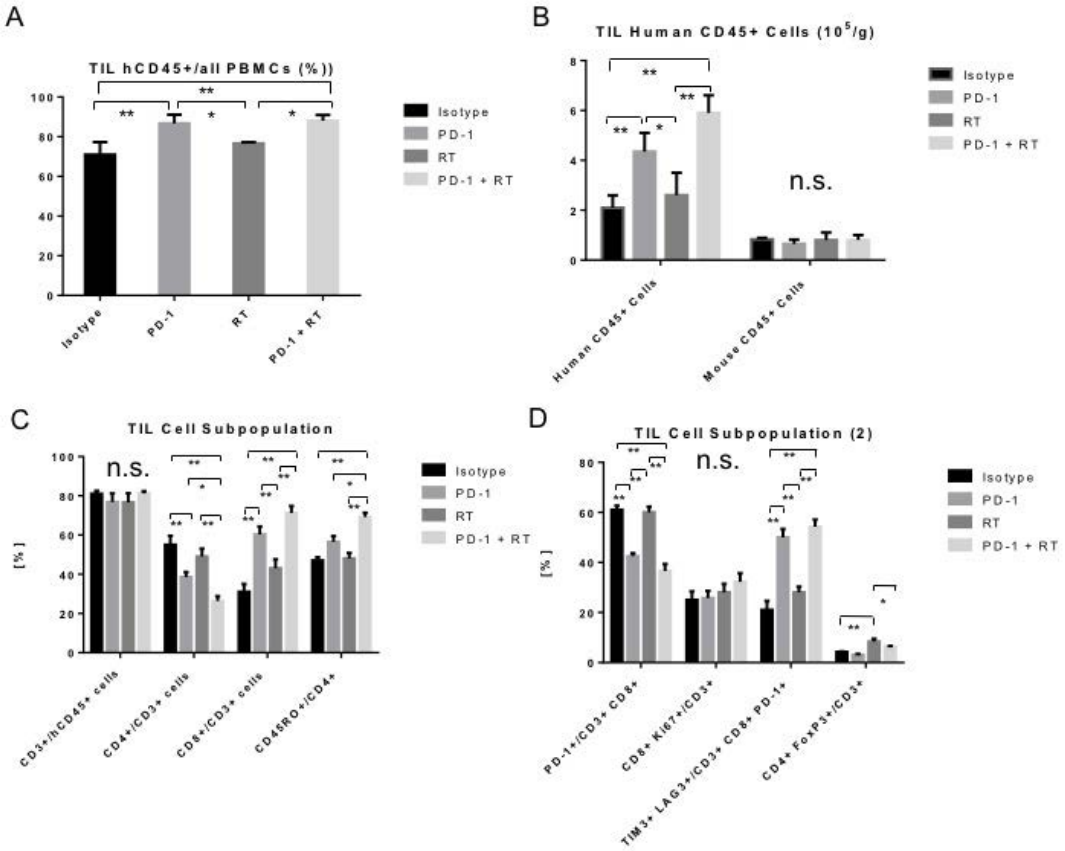
(A) PD-1 versus RT at week 15: **
(B) PD-1 versus PD-1 + RT at week 15: $p = 0.09$

(A) Isotype versus RT at week 15: **
(B) RT versus PD-1 at week 15: **
(C) PD-1 versus PD-1 + RT at week 15: *

(A) on the non-irradiated side (right), the PD-1 + RT group (PD-1 Abs + RT on the contralateral side) harbored the smallest tumor compared to the PD-1 group ($p = 0.09$), the RT-only group (isotype Abs + irradiated on the contralateral side, $p < 0.01$), and the isotype control group ($p < 0.01$). No statistically significant differences were noted amongst naïve NSG mice with isotype-control antibodies, naïve NSG mice with anti-PD-1 antibodies, humanized NSG mice with isotype-control antibodies, and humanized NSG mice with RT on the contralateral side. (B) On the irradiated side (left), the PD-1 + RT group demonstrated lowest tumor volume with statistical significance (versus PD-1 only, $p < 0.05$, versus RT-only, $p < 0.01$, versus isotype, $p < 0.01$)

(A) Tumors in the anti-PD-1 + RT group harbored the highest absolute number of human CD45+ lymphocytes as compared with the others as well as the highest percentage (71.0% (isotype), 76.6% (RT), 86.7 (PD-1), and 88.1% (PD-1 + RT), $p < 0.001$). (B) The number of innate Ly5+ cells infiltrating into chordomas were similar across the groups with no statis-

Figure 2. Flow cytometric analyses of TILs and their immune cell subpopulations.



tically significant difference. (C and D) Further analyses on subpopulations of human TILs demonstrated that synergistic increases in CD8+ cells/CD3+ cells (RT versus PD-1 + RT, p=0.002, PD-1 versus PD-1 + RT, p=0.05) and CD45RO+/CD4+ cells (RT versus PD-1 + RT, p=0.002, PD-1 versus PD-1 + RT, p=0.07) and decreases in CD4+/CD3+ cells (RT versus PD-1 + RT, p=0.002, PD-1 versus PD-1 + RT, p=0.06) and PD-1+ cells/CD3+ CD8+ cells (RT versus PD-1 + RT, p<0.0001, PD-1 versus PD-1 + RT, p=0.26) by the PD-1 + RT combinatorial therapy were identified.

Diagnosis and Treatment of Langerhans Cell Histiocytosis in Atlantoaxial Spine

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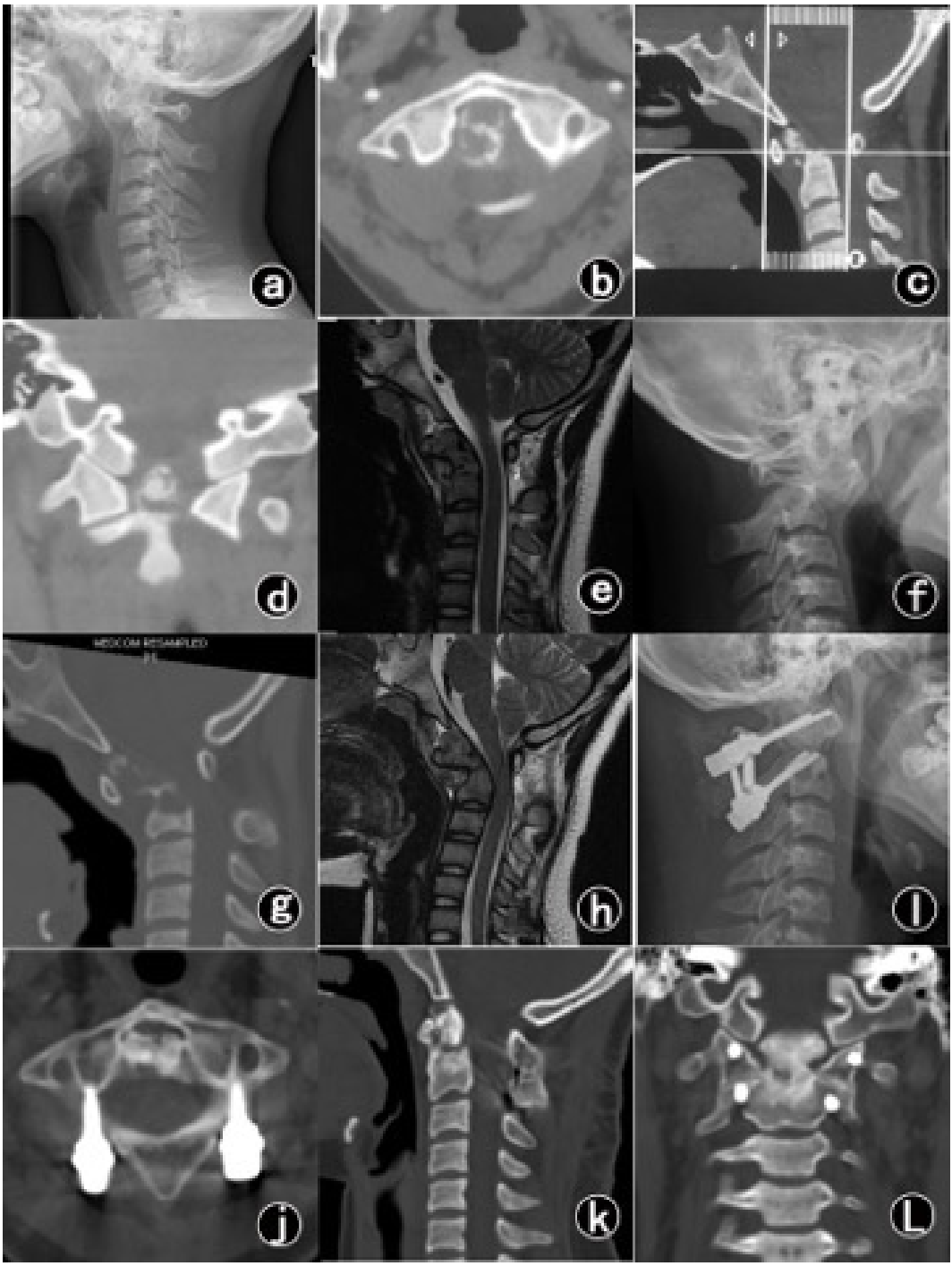
Introduction: Langerhans cell histiocytosis (LCH) of the spine is a relatively rare. The diagnosis and treatment protocols for spine LCH, especially atlantoaxial LCH, remain controversial. In this study, we reviewed the atlantoaxial LCH cases and evaluated the efficacy and safety of our proposed diagnosis and treatment protocol.

Materials/Methods: We retrospectively reviewed 115 spinal LCH patients who had been diagnosed and treated in our hospital from October 1997 to December 2016, including 37 patients with atlantoaxial LCH. All cases were analyzed in terms of age, gender, clinical and radiologic presentation, treatment and follow-up. Atlantoaxial instability was evaluated by radiology examination. CT guided needle biopsy was suggested for suspected malignant atlantoaxial lesion or multiple lesions for pathological diagnosis. Needle biopsy was not necessary for typical atlantoaxial LCH cases unless lesion continued progressing or symptoms got worse after immobilization. In cases with atlantoaxial lesion, immobilization and/or observation were usually first suggested. Halo-vest immobilization or surgery was suggested for AAI and AAD cases. Chemotherapy was suggested for cases with multifocal LCH lesions, and low-dosage radiotherapy was restricted to recurrent solitary lesion.

Results: This series included 21 male and 16 female patients with mean age of 11.2 years old (range, 1–52 years). Pain was the most common symptom (94.6%, 35/37), followed by restricted motion (75.7%, 28/37) and torticollis (27%, 10/37). Definitive pathologic diagnosis was achieved in 28 cases out of 30 cases with CT-guided needle biopsy and 4 cases with open biopsy (2 cases also had needle biopsy). Twenty-seven were diagnosed by CT guided biopsy and its accuracy rate was 90%. AAI or AAD could be observed in 16.2% (6/37) cases. There were more AAI or AAD in the cases with odontoid process lesions than that in the other locations (P=0.014), and the proportion was 38.5% (5/13, all AAD) and 4.2% (1/24, lesion in C1, AAI), respectively. The main treatment of atlantoaxial LCH was immobilization and only 5 cases underwent surgery (Fig 1). The indications of surgery were 4 for AAD, 1 for myelopathy and 1 for thoracic lesion (with halo-vest immobilization for AAD). Thirty-three cases (89.1%) were followed up for an average of 72 (range, 20–152) months. At the last follow up, 9.1% (3/33) cases had slight residual symptoms (restricted motion and/or inflexibility)

Conclusion: The main symptoms of atlantoaxial LCH are pain and restricted movement, and neuropathy is rare. Stabilization is the most common treatment and most cases could achieve ideal outcomes. AAI was often observed in atlantoaxial LCH cases, especially in odontoid lesions. Surgical intervention is indicated for those patients with AAI, AAD and / or myelopathy.

Figure 1.



2nd Place Basic Science Research Award Winner

Peptide Amphiphile Nanoscaffolds Enhance the Delivery of rhBMP-2 in a Rabbit Spine Fusion Model

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Introduction: Recombinant human bone morphogenetic protein (rhBMP-2) is an effective biologic to mitigate pseudoarthrosis after spinal fusion surgery. However, supraphysiologic doses of rhBMP-2 can lead to significant complications, necessitating development of a product that can reduce its therapeutic dose. Our previous work in a rat proof-of-concept model established peptide amphiphile (PA) nanofibers containing rhBMP-2 binding motifs as a potential material to achieve this aim. In this study, we utilized a rabbit posterolateral fusion (PLF) model to validate the efficacy of the BMP-2-binding PA nanofibers in a more stringent bone healing setting.

Materials/Methods: Female New Zealand white rabbits underwent bilateral PLF at L4-L5 utilizing sub-therapeutic doses of 30 μg or 60 μg rhBMP-2 per animal (15 or 30 μg per side). Rabbits received one of three delivery systems: ACS, PA/ACS, or PA/ACS particles. Radiography, manual palpation, and microCT imaging were utilized to establish bone regeneration and successful fusion. Manual palpation was performed by 3 blinded investigators using an established scoring system: 0=no fusion, 1=unilateral fusion, 2=bilateral fusion. Spines that average a score ≥1 were considered fused.

Results: The delivery systems utilizing PA (PA/ACS or PA/collagen particles) achieved 100% fusion at both the 30 μg or 60 μg rhBMP-2 doses. This rate was significantly higher than the fusion rate observed utilizing ACS alone at either the 30 μg (0%, $p<0.001$) or 60 μg (50%, $p<0.01$) dose. Furthermore, both PA delivery formulations at either 30 μg (2.00, $p<0.001$) or 60 μg (2.00, $p<0.01$) had higher average fusion scores relative to ACS alone (1.04), suggesting a greater degree of bone formation.

Conclusion: Although ACS is the only FDA approved rhBMP-2 delivery vehicle for spine fusion, its inefficient retention of the growth factor necessitates supraphysiologic doses to achieve consistent fusion. Our work demonstrates that a BMP-2-binding PA nanofiber scaffold used in conjunction with ACS or collagen particles can significantly potentiate rhBMP-2 action, thus reducing the necessary rhBMP-2 dose and potentially mitigating side effects associated with high doses of the growth factor. Future studies will establish the lower limit of the rhBMP-2 dose required to elicit fusion in the rabbit model.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Peripheral Blood Mobilization of Marrow-Derived Stem Cells to Enhanced Bone Formation and Lumbar Fusion

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Introduction: Spinal arthrodesis is a commonly performed and efficacious surgical intervention for a number of conditions. The gold standard for spinal arthrodesis is iliac crest bone graft, but harvest is associated with significant donor site morbidity, so identification of adjuvants to promote fusion is of significant scientific interest. Mesenchymal stem cells (MSCs) possess significant osteogenic potential, and can serve as a possible adjuvant to promote arthrodesis. However, obtaining and transplanting MSCs remains a resource-intensive hurdle. Strategies to recruit endogenous MSCs to the site of arthrodesis would assist in circumventing these hurdles. The purpose of this study is to assess the effect of various drug and/or growth factor regimens on the ability to induce sustained blood mobilization and osteogenic differentiation of bone marrow-derived MSCs, and their effects on spinal fusion in a rat model.

Methods: In phase 1, 40 Lewis rats (*n*=8/group) were randomized to 5 groups receiving different priming and mobilization regimens (Table 1A). 24 hours after the final injection, whole blood was collected via cardiac puncture. MSC mobilization was assessed via flow cytometry, and osteogenic potential was assessed via alizarin red staining and quantitative polymerase chain reaction (qPCR) of cultured cells isolated from whole blood. In phase 2, 40 Lewis rats (*n*=8/group) received bilateral posterolateral arthrodesis at L4/L5. Transverse processes were decorticated to bleeding bone, and bridged with demineralized bone matrix (0.25cc/side) as a fusion scaffold. Postoperatively, rats were randomized into the treatment regimens described in phase 1, with initial injections at 24 hours post-op. Progression of fusion was assessed via micro-computed tomography (μCT) at 3, 6, and 12 weeks. Bone formation rate was assessed via planar near infrared fluorescence (NIR) imaging using IRDye 680 BoneTag at 3 and 6 weeks.

Results: In phase 1, flow cytometry demonstrates significantly increased blood mobilization of MSCs (CD34-, CD45-, CD29+, CD90+) in BRL37344 and JTE-013 groups compared to Control (Table 1B). Alizarin red staining demonstrates significantly increased osteogenic potential in BRL37344 ($P = 0.002$) and rhG-CSF ($P < 0.006$) groups compared to control, when cultured in media containing osteogenic promoting media (Figure 1). A significant increase in staining was also observed in BRL37344 ($P = 0.004$) and filgrastim ($P < 0.001$) groups compared to control, when cultured in standard media (DMEM). qPCR analysis is ongoing. In phase 2, current μCT results demonstrate significantly increased bone volume in rhG-CSF and BRL37344 compared to AMD3100 (AMD3100: 25.2 mm^3 ± 2.9; rhG-CSF: 31.3 mm^3 ± 3.8, $P = 0.04$; BRL37344: 29.76 mm^3 ± 1.5, $P = 0.03$) and trending increases compared to control (27.6 mm^3 ± 1.4) at 3-weeks post-op (Figure 1B). Current NIR results demonstrate an increase in rhG-CSF compared to AMD3100 at 3-weeks (0.27±0.05 vs. 0.34± 0.05, $P = 0.029$).

Discussion/Conclusion: The results of this study demonstrate that specific drug and/or growth factor regimens, specifically BRL37344 and filgrastim combined with AMD3100, can induce significantly increased sustained blood mobilization of MSCs. Furthermore, these regimens promoted increased osteogenic potential in mobilized cells, and promoted greater early bone formation.

Table 1. Priming and mobilization regimens (A) and whole blood flow cytometry results (B)

A) *Experimental Design*		**B)** *Whole Blood Flow Cytometry*	
Group	*Treatment*	*% Circulating MSCs*	*P-Value*
Control	Days 1-4: SQ Saline Day 4: SQ Saline	0.64 ± 0.11	-
AMD3100	Days 1-4: SQ Saline Day 4: SQ AMD3100	0.84 ± 0.29	0.086
rh G-CSF + AMD3100	Days 1-4: SQ rh G-CSF Day 4: SQ AMD3100	1.03 ± 0.57	0.080
JTE-013 + AMD3101	Days 1-4: SQ JTE-013 Day 4: SQ AMD3100	1.50 ± 1.01	0.031
BRL37344 + AMD3100	Days 1-4: SQ BRL37344 Day 4: SQ AMD3100	0.96 ± 0.11	< 0.001

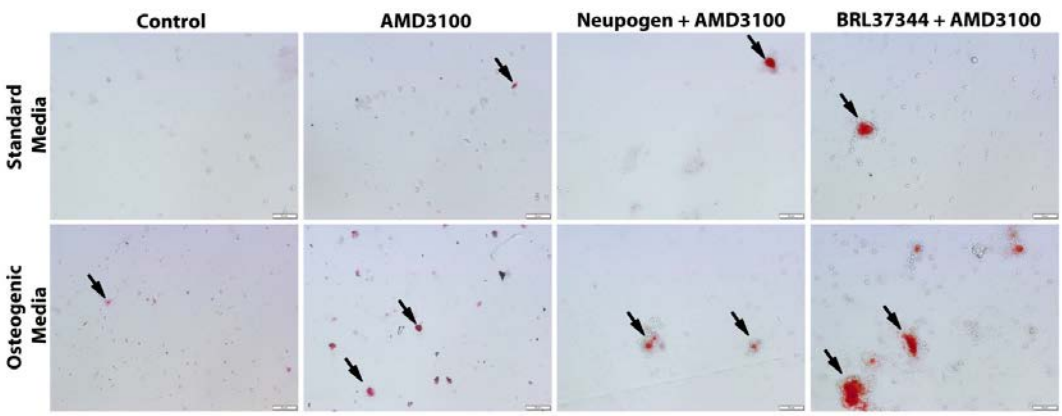

Figure 1. Alizarin red staining demonstrates significantly increased osteogenic potential in the rhG-CSF (Neupogen) and BRL37344 groups compared control, particularly when supplemented with osetogenic media.

Quantitative Age-Adjusted Targets for Ideal Cervicothoracic Sagittal Alignment in Asymptomatic Adults

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Introduction: Recent research has identified increased C2-T3 angle as a risk factor for persistent sagittal malalignment following thoracolumbar surgery. Despite this, no ideal cervicothoracic alignment thresholds exist in the literature. As several studies have demonstrated a clear relationship between the normal aging spine and sagittal spinal alignment, such ideal-alignment thresholds should also account for patient age. This study proposes age-specific cervicothoracic alignment targets using previously published age-specific normative Neck Disability Index (NDI) values.

Methods: Patients >18yrs with cSVA<4cm, available full-body stereographic x-ray imaging, and NDI data at baseline were included. Patients were stratified by age: <35, 35-45, 45-55, 55-64, 65-74. Linear regression modeling allowed for identification of NDI values corresponding to ODI US-norms, as previously published. Linear regression analysis established correlations between C2-T3 angle, age, and NDI. Normative NDI values were then used to establish age specific targets.

Results: Overall, 223 patients (50±20yrs, 65% F) met inclusion criteria, presenting with a mean sagittal vertical axis (SVA) of 17.8±47.7mm, cervical SVA 19.8±11.2mm, T1 Slope-C2-C7 lordosis 24.7°±16.2°, and C2-T3 of 2.1°±16.5°. At baseline, increased C2-T3 angle was significantly correlated with both NDI score ($r=0.266$, $p<0.001$) and patient age ($r=0.458$, $p<0.001$). Baseline NDI showed a significant correlation with ODI ($r=0.751$, $p<0.001$), permitting extrapolation of US-normative NDI scores. US-normative NDI scores increased with age: <35yr: 10.1, 35-45yr: 11.8, 45-55yr: 14.7, 55-64yr: 18.8, 65-74yr: 21.7, >75yr: 27.8. Liner regression analysis showed a significant relationship between NDI score, age, and baseline cervicothoracic alignment, as assessed by C2-T3 angle ($r=0.497$, $p<0.001$). Using US-normative NDI scores and mean age within each patient age group, this regression equation yielded age-specific ideal alignment targets for C2-T3, all of which increased with age: <35yr: -11.6°, 35-45yr: -4.7°, 45-55yr: -1.4°, 55-64yr: 1.8°, 65-74yr: 4.7°, >75yr: 6.7°.

Conclusion: Significant relationships exist between age, neck disability, and cervicothoracic alignment, suggesting broad measurements across the cervicothoracic junction may be

clinically relevant in predicting postoperative outcomes of surgical spine deformity patients. Taking into account patient age and US-normative values of neck disability, this study offers a set of ideal age-adjusted alignment targets for C2-T3. By proposing a set of normative, age-specific cervicothoracic alignment targets, this study better facilitates individual optimization of surgical planning.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Low Pre-Operative Index Level Range of Motion Leads to Increased Adjacent Segment Range of Motion 1 Year Post ACDF

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Introduction: Approximately half of the patients who receive anterior cervical discectomy and fusion (ACDF) demonstrate increased adjacent segment range of motion (ROM) one year after surgery[1]. Factors related to the post-surgical increase or decrease in adjacent segment ROM remain unknown. The objective of this study was to determine if pre-operative ROM at the index diseased segment is related to the change in adjacent segment ROM 1 year post-operatively. We tested the hypothesis that one year post-operatively, adjacent segment ROM would increase only in patients that demonstrated low pre-operative ROM at their index level.

Materials/Methods: 21 patients provided consent and returned for 1-year post-surgical testing in this IRB-approved study (9 M, 12 F; Average Age: 49.7 ± 5.4; Average BMI: 32.6 ± 5.6). 8 patients underwent single-level arthrodesis (1 at C4-C5, 5 at C5-C6, 2 at C6-C7) and 13 underwent two-level arthrodesis (5 at C4-C6, 8 at C5-C7) via standard anterior approach with rigid plate fixation. All participants performed dynamic full ROM flexion/extension (3 trials) while seated within a biplane radiography system. Biplane radiographs were collected at 30 images/s for 3 seconds. Three-dimensional vertebral motion was determined with sub-millimeter accuracy using a validated tracking process that matched subject-specific bone models from CT to the biplane radiographs[2]. Based on pre-operative in-vivo kinematic analysis, patients were grouped into either a Low-Motion Group (<10 degrees of motion at index level pre-operatively) or Normal-Motion Group (>10 degrees of motion at the index level pre-operatively)[3]. Changes in maximal intervertebral flexion/extension at the arthrodesis and adjacent motion segments were then evaluated from pre to 1-year post-operative using the Wilcoxon signed-rank test with significance was set at $p < 0.05$.

Results: Patients with low operated-site motion pre-operatively (N=11) significantly increased flexion/extension ROM at the superior adjacent segment (SA) (11.8° vs 13.7°, $p = 0.005$) and trended towards increased at the inferior adjacent (IA) segment (9.4° vs 13.7°, $p = 0.06$) post-operatively (Figure 1). Patients with normal operated-site motion (N=10) had no change in superior adjacent (16.1° vs 15.5°, $p = 0.492$) or inferior adjacent segment (14.5 vs 16.1, $p = 0.688$) total flexion/extension ROM post-operatively (Figure 2).

Conclusion: The main finding of this study is that patients with low pre-operative motion at the index level demonstrated increased adjacent segment ROM at 1-year post ACDF while those with normal pre-operative motion did not increase adjacent segment ROM 1-year post ACDF. These results suggest that pre-operative index segment motion is a factor that may affect the change in adjacent motion segment after arthrodesis. In-vivo pre-operative kinematics may reveal patients at different time points along the natural history of spondylosis, leading to exacerbation of altered loading patterns at adjacent levels after arthrodesis. Longitudinal

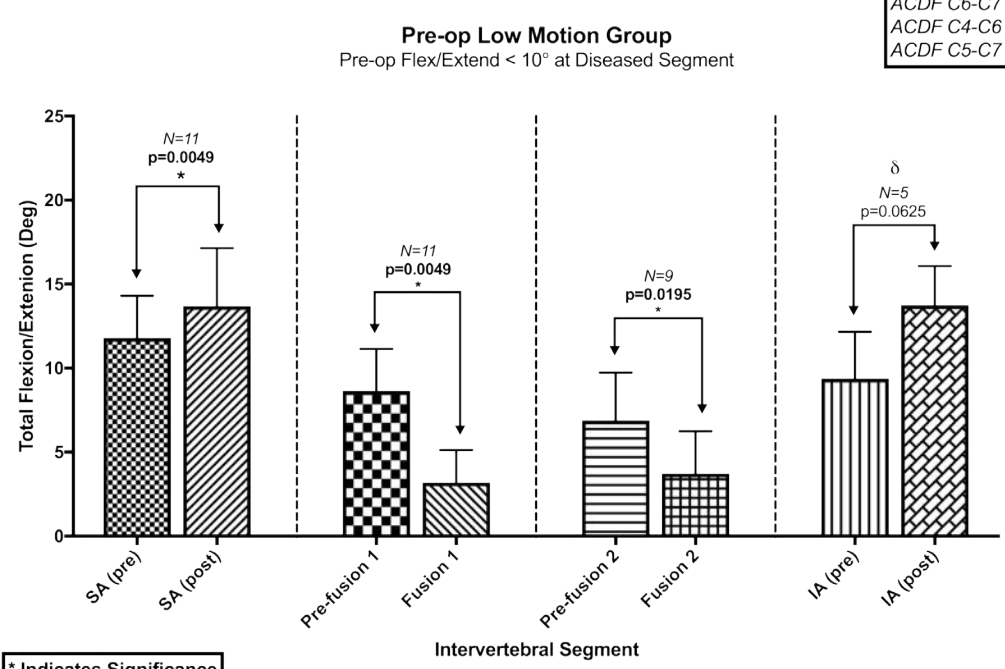
longer-term follow up is underway to reveal if the change in adjacent segment ROM after arthrodesis, rather than the total amount of motion, is related to the development of ASD.

References:

1) Reitman, Spine, 2014, Vol 29, 11, pp E221-E226. 2) Anderst et al. *Spine*, 2012. 3)Liu et al. *J Neurosurg Spine,* 2015

Figure 1. Low Motion: Pre-op vs Post-op Intervetebral Flexion/Extension

ACDF C5-C6 (N=1)
ACDF C6-C7 (N=1)
ACDF C4-C6 (N=4)
ACDF C5-C7 (N=5)

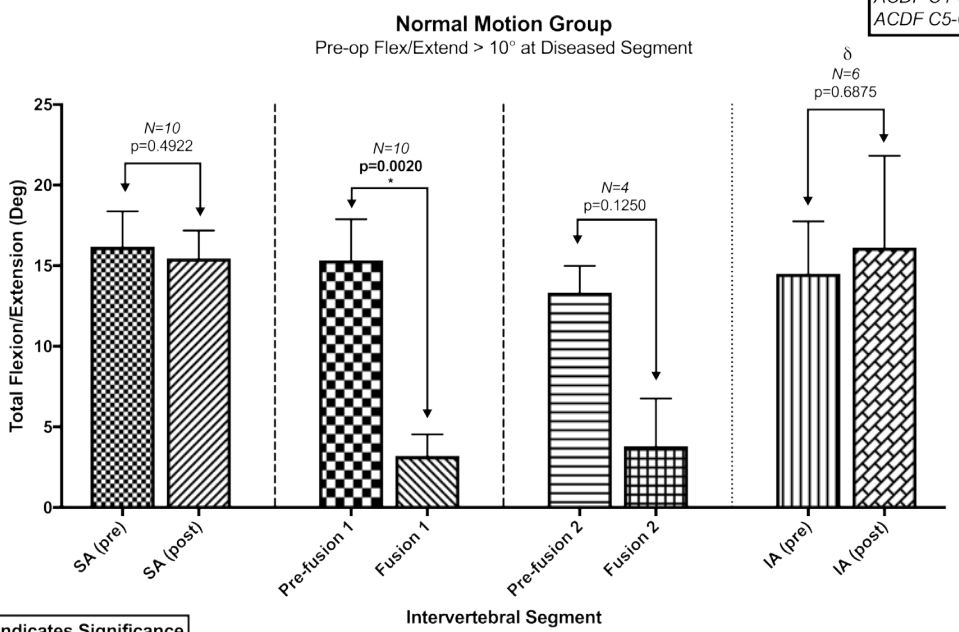


*** Indicates Significance**

**Patient's in this group had <10° of motion pre-operatively at their diseased segment
"Pre-fusion" and "Fusion" represent pre and post-operative fusion segments.
All single level fusion segments are grouped in Pre-fusion and Fusion 1, respectively. If a two level fusion the cranial segment is grouped in Pre-fusion 1/Fusion 1 and caudal segment grouped in Pre-fusion 2/Fusion 2
δ If fusion ended at C6/C7 Inferior adjacent segment was not tracked due to low rate of junctional pathology.

Figure 2. Normal Motion : Pre-op vs Post-op Intervetebral Flexion/Extension

ACDF C4-C5 (N=1)
ACDF C5-C6 (N=4)
ACDF C6-C7 (N=1)
ACDF C4-C6 (N=1)
ACDF C5-C7 (N=3)



*** Indicates Significance**

**Patient's in this group had >10° of motion pre-operatively at their diseased segment
"Pre-fusion" and "Fusion" represent pre and post-operative diseased segments.
All single level fusion segments are grouped in Pre-fusion and Fusion 1, respectively. If a two level fusion the cranial segment is grouped in Pre-fusion 1/Fusion 1 and caudal segment grouped in Pre-fusion 2/Fusion 2.
δ If fusion ended at C6/C7 Inferior adjacent segment was not tracked due to low rate of junctional pathology.

Impact of Post-Discharge Fragmentation vs. Continuity of Care on Short-Term Outcomes, Costs and Length of Stay in Cervical Spine Surgery

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Introduction: Fragmentation of care as a likely predictor for readmission and unfavorable outcomes following surgical procedures is often debated. In liver transplants and cancer surgery, post-discharge fragmentation has been implicated with increased risk of mortality. Despite increased focus on care coordination on a national level, limited or no information exists on how post-discharge fragmentation affects spine surgery outcomes. The purpose of this study was to assess the impact of fragmented readmissions within 30-days after cervical spine surgery on outcomes and resource utilization.

Materials/Methods: The National Readmission Database 2013-2014 was queried to identify adult patients that were readmitted via emergency department (ED) visit within 30-days after cervical spine surgery [ICD-9 codes 81.01-81.03, 81.31-81.33, 84.61-84.66]. Continuity of care was defined as patients presenting to the ED of original (index) hospital where cervical spine procedure was performed. On the contrary, patients incurring ED visits to non-indexed hospitals were labelled to have a fragmented care. Multivariable regression techniques including ordinary least square, log-binomial models fitted with generalized estimating equations to account for clustering of outcomes by hospitals, and *logit* models incorporating propensity score matching were utilized to assess the association of post-discharge fragmentation on outcomes and costs following cervical spine surgery.

Results: Overall, 1203 patients presented to the ED within 30-days following cervical spine surgery and incurred a readmission. Of these, 929 (77.2%) utilized ED services of the index hospital where the procedure was performed, while 274 patients (22.8%) incurred ED visits to a non-index hospital. In unadjusted analysis, patients readmitted to index hospitals had relatively shorter hospital stay (average in days: 7.37 vs 7.8), lower costs ($17785 vs $18878), and low non-routine discharge to rehabilitation (51% vs 61%; p=0.003) despite having higher comorbidities as stratified by Charlson Comorbidity Index (2.3 vs 2.1) compared to patients readmitted at non-index hospitals.

In a multivariable analysis controlled for confounders, post-discharge fragmentation was significantly associated with higher likelihood of being discharged to a rehabilitation facility (OR: 1.53; p=0.009). [Fig. 1] No statistical differences were noted in the likelihood of developing venous thromboembolisms (OR:1.05) and acute renal failure (OR:1.26), although such trends were higher in the fragmented care cohort. Likewise, longer hospital stays (+0.68 days) and higher costs were observed (+$1567) when care was fragmented. Interestingly, patients with fragmented care were noted to have lower odds of incurring wound complications (OR: 0.17) and infections (OR: 0.36).

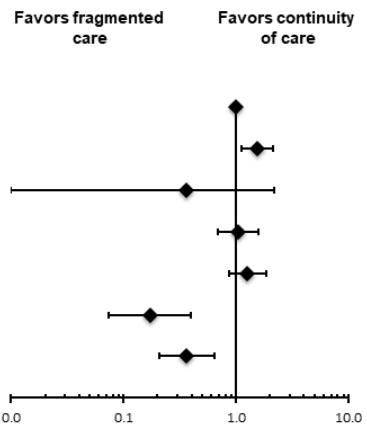
Conclusion: Approximately 25% patients readmitted within 30-days after cervical spine

surgery will experience post-discharge fragmentation and are at increased risk of incurring an unfavorable discharge disposition (to rehabilitation). Interventions targeted at understanding causal mechanisms and factors associated with poorer outcomes in fragmented care (non-index admissions) are recommended to improve outcomes in cervical spine surgery.

Figure 1: Forest plot diagram demonstrating the association of 30-day post-discharge fragmentation with outcomes and costs after cervical spine surgery derived from multivariable regression models.

Association of 30-day post-discharge fragmentation with outcomes (discharge disposition, complications, LOS) and costs after cervical spine surgery*

OUTCOMES	OR	95% CI		P-value
Original hospital (index)	1.00	1.00	1.00	Reference
Discharge to facility (unfavorable)	1.53	1.11	2.11	**0.009**
Neurologic Complications†	0.36	0.01	2.19	0.303
Venous thromboembolism	1.05	0.69	1.58	0.826
Acute Renal Failure	1.26	0.86	1.86	0.241
Wound Complications	0.17	0.07	0.40	**<0.001**
Infections	0.36	0.21	0.64	**<0.001**
	Marginal difference	**95% CI of marginal difference**		
Length of Stay, days	+0.68 days	-0.31 to +1.67		0.176
Adjusted cost, US$#	+$1567	-$821 to $3956		0.198



*Model was adjusted for patient demographics (age, gender, payer, income); Hospital characteristics (bedsize, ownership); weekend admission; smoking status, total number of inpatient procedures; type of lumbar surgery (revision vs primary); medical comorbidities were stratified using the modified Charlson et al comorbidity index that includes a mix of 18 comorbidities, bowel/bladder dysfunction and osteoporosis.

† Estimates derived by fitting log-binomial model with a Firth penalized log-likelihood approach for first-order bias correction of parameter estimates and to prevent infinite parameter estimates to introduce instability in regression coefficients

Represents inflation adjusted dollar value for every patient based on the month of admission to depict cost value as of Oct 2017

Bold-face p-values depicts statistical significance derived at Type I error set at 5%

Does Hospital Compare Ratings Correlate with Objective Outcomes in Cervical Spine Surgery? Insights into Patient Characteristics, LOS, Costs and Outcomes

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Introduction: The Centers for Medicare and Medicaid Services (CMS) initiative such as Hospital Compare ratings has emerged as a notable public-reporting system to gauge hospital quality. In addition to objective outcomes [mortality, readmissions], these ratings consider subjective patient-reported measures such as patient experience, effectiveness and timeliness of care, hospital cleanliness. As proposed reforms, the Medicare Access and CHIP Reauthorization Act, advocate integration of subjective measures into future reimbursement models, assessment of these measures on surgical outcomes are pertinent. The current study investigates the association of subjective CMS hospital ratings with objective outcomes after cervical spine surgery.

Materials/Methods: The Nationwide Inpatient Sample 2009-2011 was queried for adult patients that underwent elective cervical spine surgery. The cohort was merged with publicly available data from the Hospital Compare, a public reporting platform of the CMS that rates hospitals (scores 1 to 5) based upon a mix of subjective-objective measures. Primary endpoints were mortality, discharge disposition, length of hospital stay (LOS), hospital charges/costs (inflation adjusted to 2018-dollar value) and post-operative complications. Hospitals were labelled as high-CMS rating (overall scores ≥4) or low-CMS rating (overall score 1-3) based upon 75th percentile cutoffs. Multivariable logistic and ordinary least-square models, fitted with generalized estimating equations to account for clustering of outcomes by hospitals and propensity score matching techniques, investigated the association of hospitals with high-CMS ratings with reference to low CMS ratings with primary endpoints.

Results: Overall, 57188 patients (median age:53 years; 52% female) underwent cervical spine surgery across 569 hospitals. Of these, 24,837 (43.4%) underwent surgery at high-CMS rating hospitals (n=214; mean CMS rating score: 4.35) whereas remainder 27,242 (47.6%) at low-CMS rating hospitals (mean CMS rating score: 2.22). No differences were noted in terms of patient's age (mean: 54.23 vs 54.04; p=0.057) and gender (female: 52.4% vs 52.2; p=0.833). However, low-rating hospitals had higher proportion of patients insured with Medicare (27.4% vs 26.6%; p=0.041) and Medicaid (7.2% vs 4.8%; p<0.001) as compared to privately-insured (52.2% vs 57.3%, p<0.001). In unadjusted analysis, patients undergoing surgery at higher-rating hospitals had significantly lower unfavorable discharge (5.6% vs 6.1%;p=0.023), lower LOS (2.02 days vs 2.15 days; p<0.001), charges ($62,489 vs $75,342;p<0.001) and costs ($22,812 vs $23,179;p=0.023), and lower postoperative adverse cardiac events (0.3% vs 0.5%; p=0.002) [Table a]. No differences were observed in terms of mortality, never events such as venous thromboembolisms, acute renal failure and other complications [Table a]. In multivariable models adjusted for confounders, high-rating hospitals were associated with significantly lower unfavorable discharge disposition (OR:0.91; p=0.04), shorter LOS (-0.12 days; p<0.001), lower hospital charges (-$16,217; p<0.001) and costs (-$975; p<0.001). [Fig. 1]

Conclusion: Merging a comprehensive all-payer national cohort with data from the CMS Hospital Compare website, the study demonstrates an association of high-CMS overall hos-

pital ratings with favorable discharge disposition, LOS, hospital charges and costs following cervical spine surgery. As CMS ratings are based upon overall hospital profiling and does not segregate individual specialties, patients and policy-makers should weigh upon such limitations prior to selecting care and reimbursements, respectively.

Table a.
Patient characteristics and outcomes across hospitals with low versus high overall CMS ratings for cervical spine surgery

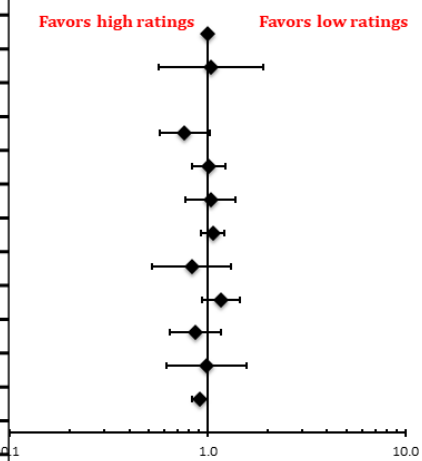
Characteristics	**Low CMS-rating hospitals (Overall scores 1-3) N=32,351**	**High CMS-rating hospitals (Overall scores≥4) N=24,837**	***P* value**
Mean age ± SD (in years)	47.0 ± 9.13	54.9 ± 13.98	**<0.001**
Female gender, %	38.8	58.0	**<0.001**
Race, %			
Caucasians	80.5%	86.5%	**<0.001**
African Americans	8.9%	6.8%	**<0.001**
Hispanic	6.5%	3.3%	**<0.001**
Asians	6.5%	3.3%	0.229
Others	2.7%	1.9%	**<0.001**
Income, %			
Lowest quartile	19.6%	13.8%	**<0.001**
Second quartile	25.1%	24.3%	**0.025**
Third quartile	27.3%	28.5%	**0.002**
Fourth quartile	27.9%	33.4%	**<0.001**
Bed size, %			
Small	7.9%	12.1%	**<0.001**
Medium	21.2%	23.6%	**<0.001**
Large	70.9%	64.3%	**<0.001**
Region, %			
Northeast	25.1%	17.2%	**<0.001**
Midwest	12.2%	16.3%	**<0.001**
South	37.1%	31.7%	**<0.001**
West	25.7%	34.8%	**<0.001**

Postoperative outcomes, %			
Mortality	0.1%	0.1%	0.814
Discharge to rehabilitation (unfavorable)	**6.1%**	**5.6%**	**0.023**
Length of hospital stay	**2.15 days**	**2.02 days**	**<0.001**
Hospital charges (inflation-adjusted 2018)	**$75,342**	**$62,489**	**<0.001**
Hospital costs (inflation-adjusted 2018)	**$23,179**	**$22,812**	**0.023**
Cardiac complications	**0.5%**	**0.3%**	**0.002**
Neurological complications	0.9%	0.9%	0.677
Respiratory complications	0.4%	0.4%	0.923
Gastrointestinal complications	0.1%	0.1%	0.225
Wound	0.7%	0.8%	0.103
Infections	0.2%	0.2%	0.909
Venous thromboembolism	1.8%	1.9%	0.313
Acute renal failure	0.4%	0.4%	0.319

Figure 1. A multivariable (GEE) models demonstrating the association of CMS hospital ratings with objective outcomes after cervical spine surgery

Association of high-CMS hospital ratings with objective outcomes in cervical spine surgery in multivariable models

Outcomes*	OR	95% CI		*P* value
		Lower	Upper	
Low CMS rating (1-3) hospitals	1.00	1.00	1.00	Reference
Mortality	1.03	0.56	1.90	0.920
Postoperative Complications				
Cardiac	0.76	0.57	1.02	0.065
Neurologic	1.01	0.83	1.22	0.955
Respiratory	1.03	0.77	1.38	0.848
Venous Thromboembolism	1.06	0.93	1.21	0.421
Gastro-intestinal	0.83	0.52	1.31	0.423
Wound	1.17	0.94	1.46	0.172
Acute Renal Failure	0.86	0.64	1.17	0.342
Infections	0.98	0.62	1.57	0.940
Unfavorable Discharge	0.91	0.84	0.99	**0.040**
	Δ	**95% CI for Δ**		
Length of hospital stay, days	-0.12 days	-0.17 to -0.06 days		**<0.001**
Hospital charges, US$†	-$16217	-$17227 to -$15207		**<0.001**
Hospital costs, US$†	-$975	-$1290 to -$660		**<0.001**



*Models were risk-adjusted for patient demographics (age, gender, race, payer, income); Hospital characteristics (bedsize, teaching status, region); total number of inpatient procedures; general medical comorbidities were stratified by Charlson et al comorbidity index while spine-specific symptoms included motor deficits, osteoporosis and bowel/bladder dysfunction.
†Inflation adjusted to represent 2018 US dollar value

Congenital Sandwich Atlantoaxial Dislocations: A Retrospective Case Series of 41 Patients

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Introduction: In the setting of congenital C1 occipitalization and C2-3 fusion, significant strain is placed on the atlantoaxial joint. Vertebral blockage both above and below the atlantoaxial joint ('sandwich') creates substantial instability **(see figure 1)**. This unique congenital disorder can be associated with Klippel-Feil syndrome. To the best of our knowledge, the clinical presentation of this unique group of AAD patients has not yet been studied, and its treatment strategy has not been well established. We describe clinical features and the surgical treatment of Sandwich atlantoaxial dislocation (AAD).

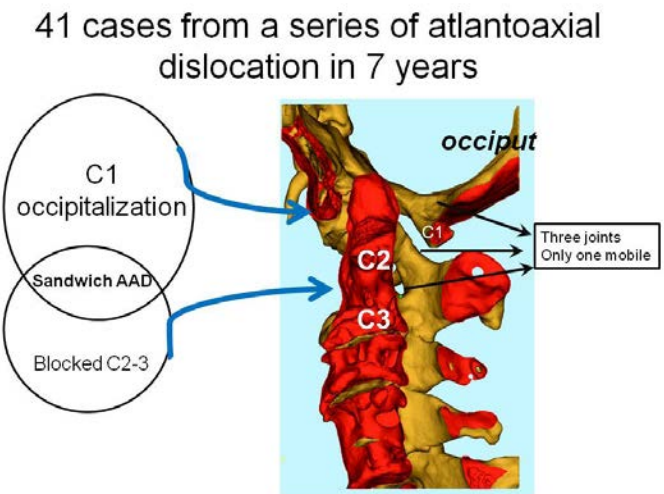

Figure 1: A subgroup from AAD: sandwich mechanism

Methods: Forty-one patients with "sandwich" AAD were retrospectively reviewed. The clinical features and the surgical treatment results were assessed utilizing descriptive statistics.

Results: All patients had sandwich deformities, including the concurrent presence of C1 occipitalization, C2-3 congenital fusion and atlantoaxial dislocation **(see Figure 2)**. The mean patient age was 40.2 years (range: 5-71), 22 patients were male, and 19 were female. 35 cases (85.4%) had myelopathy, with JOA scores ranging from 4-16 (Mean: 12.3). 8 cases (19.5%) were involved in cranial neuropathy, including dysphagia (8), dysarthria (3), and nystagmus (2). Mean age of presentation was 35.5 years(range 0 to 70), with ages 31 - 40 being most common (13 cases,31.7%). Clinical symptoms averaged 71.7 months in duration. The most common symptoms of the "Sandwich" AAD were weakness, numbness and clumsiness of limbs(31 cases,75.6%). The most common associated malformations included cervical-medullar compression (35 cases, 85.4%), syringomyelia (12, 29.3%), and Chiari malformation(10, 24.4%). 12 cases underwent computed tomographic angiography

(CTA), 6 of which (50%) had vertebral artery anomalies, including an anomaly below the C1 arch, tortuous vertebral arteries, high-riding vertebral artery invading the C2 pedicle, and vertebral artery hypoplasia. All 41 cases underwent surgical treatment. The surgery included posterior occipito-cervical fusion (reducible dislocation, 31 cases), and transoral release followed by posterior fusion (irreducible dislocation, 10 cases). The average follow-up time was 50.5 months (24 months to 120 months). 3 patients suffered complications (7.3%), none of which were spinal cord or vertebral artery injury. In 35 patients with myelopathy, the mean JOA increasing 5 to 17 (mean, 13.9), and the mean improvement rate was 36.3 % .

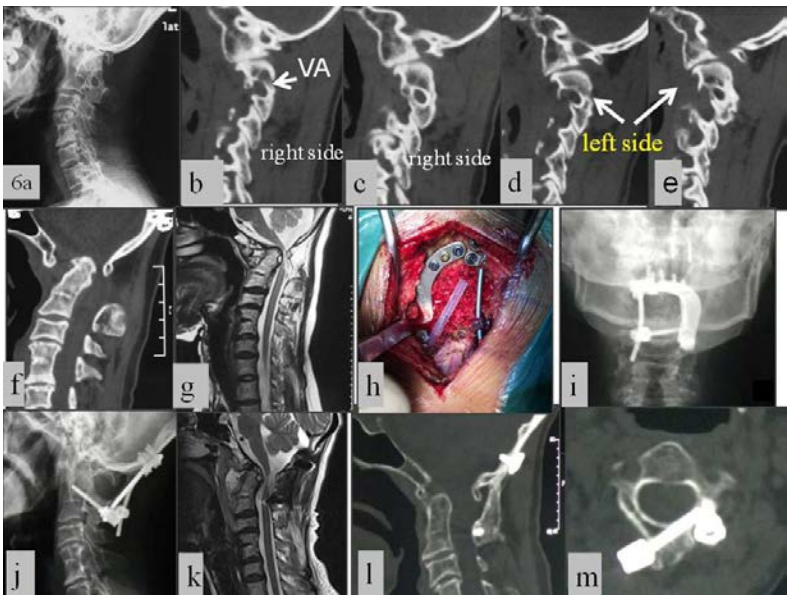

Figure 2: a 44-year-old woman showed sandwich AAD: Pre-op and Post-op.

Conclusion: "Sandwich" AAD, a unique subgroup of AAD, has distinctive clinical features and associated malformations such as the Chiari malformation. Surgical treatment of AAD, which included posterior occipito-cervical fusion and trans-oral release followed by posterior fusion, was associated with myelopathy improvement, and minimal complication occurrence.

The Influence of Surgical Intervention and Sagittal Alignment on Postoperative Frailty Status in Cervical Deformity Patients

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Introduction: Frailty, a decrease in physiologic reserve and increased vulnerability to adverse outcomes, falls, disability, and hospitalization, is a new area of study for patients with cervical deformity (CD). Recently, a cervical deformity frailty index (CD-FI) was described for utilization in preoperative risk stratification. Little is known about how operative intervention influences frailty status in CD patients. The goal of this study was to investigate drivers of postoperative frailty score, and which component variables within the CD-FI algorithm respond to surgical intervention most greatly.

Methods: Retrospective review of a prospective adult cervical deformity database. CD patients (cervical kyphosis >10°, coronal scoliosis >10°, cSVA >4cm, TS-CL >10°, or CBVA >25°) ≥18 years old, undergoing multilevel fusions with complete baseline(BL) and 1Y CD-FI scores. The CD-FI is scored on a scale between 0 and 1 (no frailty: 0-0.2, frailty: 0.2-0.4, severe frailty: >0.4). Descriptive analysis identified cohort demographics, radiographic parameters, and surgical details. Pearson bivariate correlations, independent and paired t-tests gauged associations between complication occurrence, radiographic parameters, and postoperative change in CD-FI total and component scores. Forward hierarchal linear regression models determined the effect of successful surgical intervention (achieving lowest level Ames classification modifiers) on change in frailty total and component scores.

Results: 138 patients were included (Mean age: 61.0, 61.5% F, 91.6% White, mean BMI: 29.9, CCI: 1.2). BL radiographic parameters: Cervical Lordosis: -6.1, cSVA 39.8, TS-CL 38.7, CBVA 2.9, SVA -6.1, PI-LL 1.6, and PT 19.9. Surgical approaches included 48.4% posterior, 34% combined, 17.6% anterior; mean levels fused was 3.4 anteriorly, 9.0 posteriorly; mean op time was 489.4min, mean EBL was 822.5ccs. Following surgical correction, CD-FI score improved at 1Y (BL:0.44 vs. 1Y:0.27, $p<0.05$). Patients who experienced a minor intraoperative complication displayed significantly worse change in CD-FI score (Δ-0.06 vs. Δ-0.15, $p=0.045$). Of the CD-FI components, 13/40 variables (32.5%) improved with operative intervention; including weakness, bladder issues, impaired gait, EQ5D Anxiety, Activity, Mobility, mJOA lower extremity, SWAL 9A-E, NDI Concentration and Recreation (all

P<0.05). Correlations between frailty improvement, change in CBVA (R:0.876, p=0.022), PI-LL (R:0.358, p=0.001), PT (R:0.243, p=0.021), and SVA (R:0.237, p=0.029) were observed. CD-FI components of CSDI Reading (R: 0.998), SWAL 9C Feeling Tired (R: 0.574), SWAL 9E Feeling Exhausted (R: 0.574), and NDI Driving (R: 0.523) were the greatest component drivers of postoperative change in frailty (all p<0.001). Achieving lowest level Ames modifiers significantly predicted postoperative Δ in frailty (R^2: 0.173, p=0.036), with achieving lowest level Ames TS-CL Modifier as the strongest independent predictor (B: 0.274 p=0.024).

Conclusion: Intraoperative complications, correction of sagittal alignment, and improving a patient's ability to read, drive, and chronic exhaustion all significantly influenced postoperative frailty status. This analysis is a first step towards a greater understanding of the dynamic relationship between frailty and correction of cervical deformity.

Recovery Kinetics following Spinal Deformity Correction: A Comparison of Isolated Cervical, Thoracolumbar, and Combined Deformity Morphometries

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Introduction: Postoperative recovery profiles of cervical, thoracolumbar, and combine cervical and thoracolumbar deformity patients, all relative to one another, are poorly understood. Clear, objective benchmarks are needed to quantitatively define a 'good postoperative recover' across multiple follow-up (f/u) visits and varying deformity types. The purpose of this report was to quantify the velocity and totality of recovery in operative cervical, thoracolumbar, and combined deformity patients.

Methods: Retrospective review of two prospective, multicenter adult spinal and cervical deformity databases. Operative deformity patients >18y/o, with baseline(BL) to 2-Year HRQLs were included. Patients were stratified by cervical only ([C]: C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°), thoracolumbar only ([T]: coronal scoliosis≥20°, SVA ≥5cm, PT≥25°, or TK≥60°), and combined deformities [CT]. HRQL outcomes were compared within and between deformity groups. A novel method of area-under-the-curve (AUC) normalization generated normalized HRQL scores at BL and all f/u intervals(6wk, 3M, 6M, 1y, 2yr). Normalized scores were plotted against follow-up time interval. AUC was calculated for each f/u interval, and total area was divided by cumulative follow-up length, determining overall, time-adjusted HRQL recovery (Integrated Health State-IHS).

Results: 170 patients were included (27 C, 27 T, 116 CT). Mean age: 61.99 (p=0.852); 73.5% Female. C patients had significantly higher BMIs (C 45.5, T: 27.90, CT 32.51, P<0.001), and T patients had the highest CCI (C 0.696, T 1.815, CT 1.699). Posterior surgical approaches were most common (62.9%) followed by combined (28.8%) and anterior (6.5%). At baseline, all deformity groups had similar ODI-NDI and EQ5D scores (p>0.05). Standard HRQL analysis found no significant differences among groups regarding HRQL scores and recovery rates. After HRQL normalization, CT patients exhibited a significantly higher ODI-NDI recovery rate (IHS) over a 2-Year period in comparison to C patients (C: 0.23 vs T: 0.41 vs CT: 0.48, p=0.027). Despite trending towards immediate faster postoperative recovery, C patients exhibited significantly less patients meeting ODI-NDI MCID at 1Y postop (34.6% vs 53.8% vs 58.7%, Adjusted Residual: -2.2), although this difference diminished at 2Y postop (Adjusted Residual: -0.6).

Conclusions: Cervical deformity patients exhibited quicker rates of immediate postoperative recovery, despite exhibiting less 2-year overall Integrated Health State ODI-NDI improvements compared to patients with combined deformity morphometries. This study is a step towards creating objective recovery benchmarks for multiple deformity morphometries over a 2-Year follow-up interval. Physicians should be aware of unique recovery patterns across multiple deformity morphometries, and plan expectations accordingly for varying postoperative follow-up visits.

Cervical Deformity Correction Fails to Achieve Age-Adjusted Spino-Pelvic Alignment Targets

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Introduction: Alignment outcomes following cervical deformity (CD) corrective surgery focus primarily on achieving improvements in cervical alignment parameters however, less is understood about the thoracic and lumbar compensation that occurs following alignment correction in the cervical spine. Previously established age-adjusted alignment targets for spino-pelvic parameters have yet to be investigated in a surgical CD population. The aim of this study was to assess surgical CD patients for meeting spino-pelvic age-adjusted alignment targets, reciprocal changes that occur after CD surgery, and lower limb compensation changes.

Methods: Single-center retrospective review. CD was defined as meeting at least one of the following radiographic criteria: C2-C7 lordosis>10°, cSVA>4cm, or TS-CL>20°. CD patients >18 years undergoing surgical correction were included with complete baseline and post-operative imaging. Published formulas was used to create age-adjusted alignment targets for pelvic tilt (PT), spino-pelvic mismatch (PI-LL), sagittal vertical axis (SVA). Actual alignment was compared to age-adjusted ideal values. Patients that matched exact ± 10 year thresholds for age-adjusted targets were compared to unmatched cases (under- or overcorrected).

Results: 120 CD patients were included (mean age 55.1 years, 48.4% female, mean BMI 28.8 kg/m2). For PT, only 24.4% of patients matched their age-adjusted alignment ideals, with 51.1% being overcorrected for PT and 24.4% being undercorrected. For PI-LL, only 27.6% of CD patients matched age-adjusted alignment target for this spino-pelvic parameter, with 49.4% being overcorrected and 23% being undercorrected post-operatively. 40% of CD patients met their age-adjusted alignment target for SVA, 41.3% were overcorrected and 18.8% were undercorrected. For CD patients who worsened in TS-CL or cSVA post-operative, they displayed an increased in thoracic kyphosis (-41.1° to -45.3°, P=1.06). In looking at lower extremity compensation, CD patients decreased in ankle flexion angle post-operatively (6.1° to 5.5°, P=0.036),and trended towards smaller SFA (199.6mm to 195.6mm, P=0.286) and knee flexion (2.6° to -1.1°, P=0.269).

Conclusions: In response to worsening CD post-operatively, patients increased in thoracic kyphosis and recruited less lower limb compensation. Shockingly, almost 75% of CD patients did not meet previously established spino-pelvic alignment goals, of which a subset of patients were actually made worse off in these parameters following surgery. This raises the question of whether we should be looking at the entire spine when treating cervical deformity.

Cervical, Thoracic and Spinopelvic Compensation After Proximal Junctional Kyphosis – Does Location of PJK Matter?

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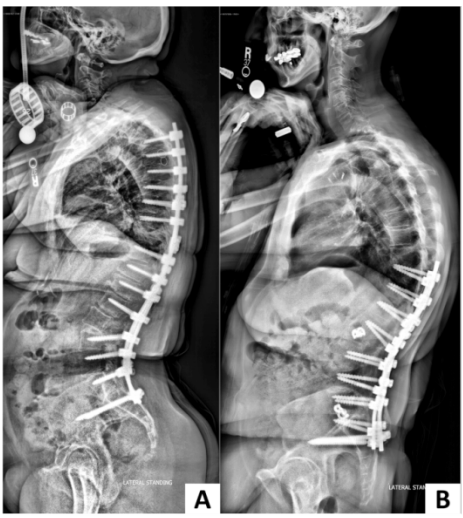
Introduction: Proximal Junctional Kyphosis (PJK) can occur at any segment along the spine, but the compensation mechanisms at levels proximal to an area of PJK have not clearly been characterized. Understanding compensation mechanisms may help in determining optimal level selection when performing revision surgery for PJK. The purpose of the study was to evaluate the difference in compensatory mechanisms between thoraco-lumbar and thoracic PJK.

Methods: This study is a retrospective review of prospective database of ASD patients. PJK location was based on UIV location: LT (T8-L1) or UT (T1-7). Inclusion criteria were fusion > 5 Levels with S1/Ilium as LIV. PJK was defined by Glattes criteria. Alignment parameters were compared between PJK patients separated by UIV Group. Correlation Analysis was conducted between PJK magnitude and global/cervical alignment within UIV groups. Percentage of patients reaching criteria for cervical deformity according to cSVA (>4cm) were calculated overall and within each subgroup.

Results: There were 369/496 eligible patients (73.2%) for 2 year follow-up included in the analysis; mean age of 63, BMI 28 and 81% female, LT (n=193) vs. UT (n=176). The overall rate of radiographic PJK was 49%with comparatively higher rate in the LT group (55% vs. 42%, p =0.01). No significant differences were found in global alignment between PJK patients, with the exception of TK being larger for PJK patients (UT:-49.4 vs -59.0; LT: -46.5 vs -56.4; all p <0.001). Significant differences were noted in all cervical radiographic parameters (p<0.05) between PJK vs non-PJK in the UT group (table 1) while only T1S and C2-T3 SVA (CTS) were significantly different between PJK and non-PJK groups in the LT group (table 1). When comparing UT vs. LT PJK patients, UT patients had more posterior global alignment with smaller TPA (15.4 vs 20.3 p=0.002), SVA (1.7 vs 4.2 p=0.001) and a trend towards larger PT (20.9 vs 23.9 p=0.051), associated with larger anterior cervical alignment compared to LT patients (table 1). Correlation analysis of PJK angle magnitude with compensatory mechanisms within UIV group demonstrated a moderate association between increase in PJK angle and increase in CL, T1S and CTS (r=0.59, 0.44, 0.55 respectively) in UT. In the LT group, PT increased with PJK angle (r=0.17), but no significant

correlations were noted with SVA, cSVA or TS-CL. The rate of patients meeting inclusion criteria for cervical deformity following PJK were overall 29.2% with a significantly higher percentage in the UT group (40.3% versus 21.7%).

Conclusions: PJK location results in different compensation mechanisms of the cervical and thoracic spine. The LT group compensates with an increase in PT and CL to maintain an acceptable cSVA. The UT group increases their CL to counter the increase in T1S but continues to have TS-CL mismatch with an elevated cSVA due to maximum compensation at the cervical level. As a result, increase in cSVA led to 40.3% of patients meeting criteria for CD. Future studies should investigate the surgical strategy to treat PJK depending on the location of the focal deformity.



Case example of patient recruiting different compensatory mechanism depending on PJK location: A) Upper thoracic PJK with maximum extension of CL B) Lower thoracic with increase PT, Flattening TK and increase CL

	UIV LT		Non-PJK vs PJK	UIV LT		Non-PJK vs PJK	UT PJK vs LT PJK
	Non-PJK	PJK		Non-PJK	PJK		
T1 Slope	32 ± 13.7	42 ± 13.5	<0.001	29.4 ± 12.4	33.2 ± 11.4	0.028	<0.001
C2-C7	11 ± 15.6	16.6 ± 16.3	0.025	9.3 ± 16.3	13 ± 15.1	0.108	0.131
cSVA	30.6 ± 14.4	38.4 ± 13.8	0.001	27.1 ± 15.2	30.8 ± 12.8	0.079	<0.001
TS-CL	20.5 ± 11.5	25.6 ± 10	0.003	19.9 ± 11.9	20.4 ± 11.5	0.788	0.002
C2-T3	7.7 ± 15.5	1.6 ± 18	0.021	6.6 ± 18.3	11.5 ± 16.1	0.053	<0.001
C2-T3 SVA	64 ± 24.6	82.4 ± 22.7	<0.001	57.6 ± 24.5	66.5 ± 20.7	0.008	<0.001

Risk Benefit Assessment of Major vs. Minor Osteotomies for Flexible and Rigid Cervical Deformity Correction

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Introduction: Cervical deformity (CD) correction has become increasingly more complex and challenging. Osteotomies are commonly performed to correct sagittal malalignment, however the risks and benefits of performing a major osteotomy for cervical deformity correction have been understudied. The purpose of this study was to investigate the risks and benefits of performing a major osteotomy for CD correction.

Methods: Retrospective review of a multicenter prospective CD database. CD was defined as at least one of the following: C2-C7 Cobb>10°, CL>10°, cSVA>4cm, CBVA>25°. Patients stratified based on having a major osteotomy (MAJ-pedicle subtraction osteotomy or vertebral column resection) or minor(MIN). Propensity score matching (PSM) was performed controlling for baseline cSVA and T1S. Flexibility of the deformity was assessed using C2-C7 lordosis and T1S change greater than 10º between flexion and extension. Outcome Measures: Cervical alignment parameters: cervical sagittal vertical axis (cSVA), C2-7 cervical lordosis(CL), T1 Slope minus CL (TS-CL). Upper cervical/cranial parameters: Slopes from C0, C1, and C2, and C0-2 angle. Health-related quality of life (HRQL) measures: Neck Disability Index (NDI), EuroQol-5, modified Japanese Orthopaedic Association (mJOA), at baseline, 3M, 6M, 1Y. Independent *t*-tests and Chi-Squared tests were used to assess differences between MAJ and MIN.

Results: 89 CD patients were included (62yrs, 65%F). 19(21.3%) CD patients underwent a MAJ osteotomy. MAJ and MIN had no differences in any baseline radiographic parameters, with the exception of cSVA (MAJ:59.3mm, MIN:41.9mm,p=0.007). After PSM for cSVA, 38 patients were included (60yrs, 60%F). 19 (21.3%) CD patients underwent a MAJ osteotomy (14 pedicle subtraction osteotomy, 5 vertebral column resection). MAJ patients underwent more invasive surgeries, with more levels fused(10.6 vs 7.1,p<0.001) and blood loss(1442cc vs 802cc, p=0.036), despite similar operative time and intra- and post-operative complication rates as MIN patients. At 3M post-op, MAJ and MIN patients had similar NDI, mJOA, and EQ5D scores, however by 6M and 1Y post-op MAJ patients reached MCID for NDI less than MIN patients(10.5% vs 57.9%,p=0.003). In a sub-analysis comparing patients with fixed

versus non-fixed CL, MAJ patients with non-fixed lordosis trended towards improvement in NDI (p=0.30) but also trended towards higher complication (78% vs 43%,p=0.182) and reoperation rates(44% vs 0%,p=0.069) than fixed deformities. Rigid deformities trended towards more improvement in TS-CL (43% improve vs 33%,p=0.54) and cSVA (14% vs 0%,p=0.49) for MAJ patients than MIN and lower overall complication rate(MIN most commonly had DJK and reoperation)(43% vs 100%,p=0.09).

Conclusions: Cervical deformity patients who underwent a major osteotomy had similar clinical outcomes at 3-months but worse clinical outcomes at 6-months and 1-year, assessed by NDI and EQ-5D, as compared with patients with minor osteotomies, in part because patients undergoing major osteotomies have more severe deformities and have more prolonged recovery kinetics. Patients with flexible curves showed similar alignment and clinical outcomes but increased complication risk when undergoing a major osteotomy. Contrarily, patients with rigid deformities who underwent a major osteotomy trended towards radiographic and clinical improvement and lower rates of DJK and reoperation.

Improved Diagnostic Accuracy of Motor Evoked Potential Monitoring During Cervical Spine Surgery with Total Intravenous Anesthesia: A Review of 56,023 Procedures

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Introduction: Transcranial electric motor evoked potentials (MEP) have become an important component of multimodality intraoperative neuromonitoring (IONM) during spine surgery. The value of MEPs during these procedures depends on their accuracy in detecting evolving neurologic injury and the timeliness of interventions in the face of MEP alerts. The present study investigated the impact of anesthesia on diagnostic accuracy of MEPs by comparing sensitivity and specificity of MEPs recorded under total intravenous anesthesia versus volatile anesthesia during cervical spine surgery.

Methods: We retrospectively reviewed a multi-institutional database of 56,023 extradural cervical spine procedures in adult patients monitored with multimodality IONM that included MEPs between May, 2013 and March, 2018. New onset neurologic deficit rates in the immediate postoperative period, sensitivity and specificity of MEPs, and rates of unmonitorable MEP baselines were assessed among two groups: patients receiving total intravenous anesthesia (TIVA) and patients receiving either pure inhalational anesthesia or a balanced anesthetic that included volatile agent (MIXED), using multivariable logistic regression models. The model for sensitivity controlled for patient age, number of vertebral levels addressed, and duration of surgery. The model for MEP baseline monitorability additionally controlled for gender and surgical approach, while the model for specificity further controlled for MEP baseline monitorability. The model for new deficits also added an interaction between anesthetic regimen and status of IONM alerts at close of surgery. For all analyses, no change or a fully resolved change in MEPs was a negative test and an unresolved MEP change was a positive test.

Results: Among all patients, 61.3% fell into the MIXED group and 38.7% the TIVA group. Overall, 180 patients (0.32%) experienced a new-onset post-operative neurologic deficit. Sensitivity of the MEP modality was notably higher for the TIVA group (.802) compared to the MIXED group (.561), a difference that was confirmed in the logistic regression results; odds of true positive result for the TIVA group were 4.1 times that of the MIXED group (95%CI: [2.0-8.5], $p<0.001$). Specificity was slightly lower for the TIVA group (0.965 for TIVA vs 0.970 for MIXED, $p=0.0014$). Additional regression analyses revealed that the TIVA group had reduced odds of an unmonitorable MEP baseline (OR=0.56, 95%CI: [0.54-0.59], $p<0.0001$). Finally, there was a stronger association between an unresolved MEP alert at closure and new immediate-onset neurologic deficits for the TIVA group than the MIXED group (OR=2.0, 95%CI: [1.3 – 3.0], $p<0.05$).

Conclusion: These results suggest superior monitorability and diagnostic accuracy for intraoperative MEPs recorded under total intravenous anesthesia compared to volatile

agents. Routine use of TIVA will improve MEP reliability when monitoring motor function during cervical spine surgery and increase surgeon confidence when acting on intraoperative MEP changes.

PET Imaging of Immature/Differentiation-Resistant Neural Cells Following Human Induced Pluripotent Stem Cell-Derived Neural Stem/Progenitor Cell (hiPSC-NS/PCs) Transplantation

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Introduction: We have previously reported the beneficial effects of transplanting human induced pluripotent neural stem progenitor cells (hiPSC-NS/PCs) into the spinal cord of contusive spinal cord injury model rodents. However, transplanting certain hiPSC-NS/PCs that are known to have tumorigenic properties resulted in the deterioration of motor function secondary to the oncogenic transformation. Tumors derived from these “bad clones” consisted of immature undifferentiated human-specific NESTIN positive cells. Current imaging modalities that are available to us in the clinical settings have not succeeded in visualizing potential tumorigenic changes of hiPSC-NS/PCs. It is known from previous studies that NS/PCs co-express 18kDa translocator protein (TSPO) with neural stem cell marker such as NESTIN or SSEA-1. Therefore, the purpose of this study is to develop a method that allows us to visualize the immature neural tissues using TSPO ligand PET.

Methods: *In vitro* : We assessed TSPO expression following neuronal differentiation and maturation of 253G1-NS/PCs (oncogenic clones) and 414C2-NS/PCs (benign clones). *In vivo*: Each hiPSC-NS/PC or PBS was injected into the striata or intact cervical spinal cord of immunodeficient (NOD/SCID) mice. These cells were cultured and labeled with firefly luciferase genes via lentiviral transduction. After transplantation, we monitored the growth of transplanted cells through weekly Bio-imaging. Four to eight weeks later, gadolinium enhanced MRI was performed followed by PET with ^{18}F-TSPO ligand (^{18}F-FEDAC). The mice were immediately sacrificed and the brain and spinal cord were dissected out for *ex vivo* autoradiography (ARG). The correlation between the *in vivo* imaging data and immunohistochemistry results were evaluated.

Results: As neuronal differentiation progressed, TSPO expression decreased in the 414C2-NS/PCs (Fig.1). Bio-imaging revealed that the cells had been successfully engrafted in all mice. Among them, the 253G1 group demonstrated rapid cell proliferation. MRI revealed a region with gadolinium enhancement and high intensity T2 weighed area at the transplanted site in the 253G1 group, whereas there were no significant findings in the 414C2 or PBS group. ^{18}F-FEDAC PET revealed a significant increase in tracer uptake at the transplanted site in 253G1 group compared to the others (Fig2). We found that there was a higher binding of ^{18}F-FEDAC at the transplanted site in the 253G1 group using ARG compared to the others ($p<0.05$). Immunohistochemistry showed a high level of TSPO^{+}/NESTIN^{+} in the transplanted site of 253G1 group.

Conclusion: We successfully detected the remnant immature neural tissues of hiPSC-NS/PCs using ^{18}F-FEDAC PET. In the future, we aim to monitor the dynamics of transplanted cells using PET to identify any time-dependent metabolic changes.

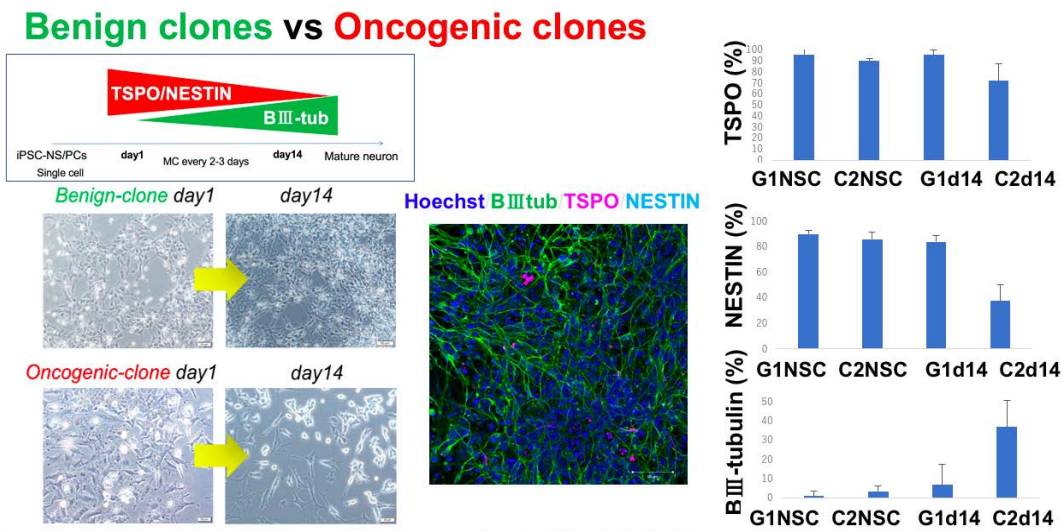

Fig1. Neuronal differentiation of hiPSC-NS/PCs

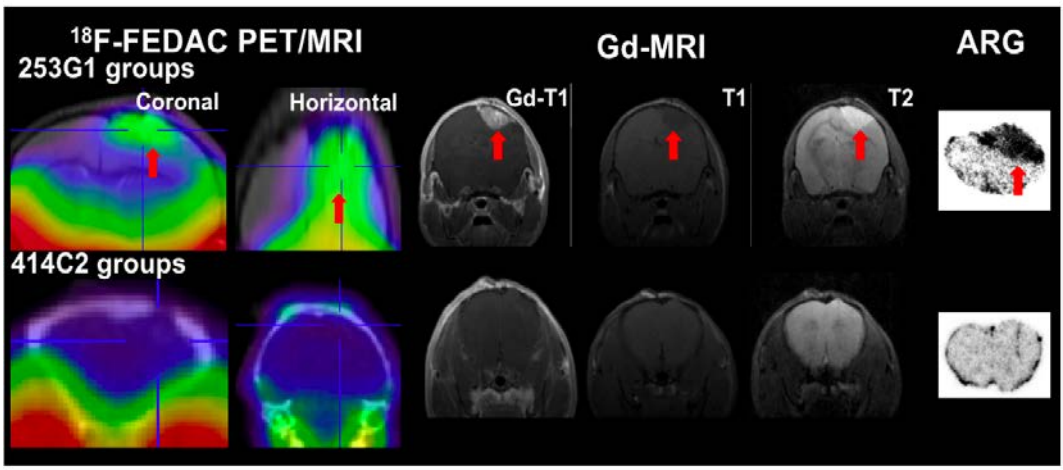

Fig2. PET/MRI imaging of tumorigenicity of hiPSC-NS/PCs

Post-Operative Resolution of MRI Signal Intensity Changes and the Associated Impact on Outcomes in Degenerative Cervical Myelopathy – Analysis of a Global Cohort of Patients

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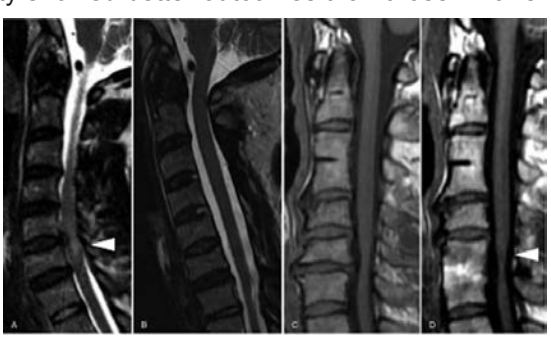
Study Design: Sub-analysis of the prospective AOSpine CSM North America and International studies.

Objective: To describe the post-operative changes in MRI spinal cord signal intensity in degenerative cervical myelopathy (DCM) patients and to investigate the impact of its post-operative resolution on clinical outcomes.

Summary of Background Data: When examining the spinal cord, hyperintensity found in MRI T2-weighted images and hypointensity in T1-weighted images are known to correlate with pre-operative severity of DCM and to predict post-operative neurological recovery. However, the clinical importance of these signal intensity changes in post-operative images has not been established.

Methods: Among 757 surgical DCM patients enrolled in two prospective multicenter studies, post-operative MRI images obtained between 6 to 24 months after the operation were examined with a focus on T2 hyper- and T1 hypointensity in the spinal cord. The 2-year post-operative Nurick grade, modified Japanese Orthopaedic Association (mJOA) score and mJOA recovery rate (RR) were analyzed between patients with or without resolution of signal intensity changes.

Results: A total of 167 patients with pre-operative T2 hyperintensity were included with complete post-operative MRI images. Of these patients, 11% showed resolution of signal intensity changes, 70% retained T2 hyperintensity only, and 19% showed both T2 hyper- and T1 hypointensity post-operatively. There was a stepwise trend toward worse post-operative outcomes, with the no signal intensity change group showing the best outcome and the T1 hypointensity group showing the worst (mean RR: 72% vs. 51% vs. 36%, p=0.02). Patients who exhibited resolution of T2 hyperintensity showed better outcomes than those who retained it (RR: 72% vs. 47%, p=0.04), but the resolution of T1 hypointensity was not associated with improved outcomes (RR: 38% vs. 26%, p=0.36).



Conclusions: Post-operative resolution of T2 hyperintensity in DCM patients was associated with the best clinical outcomes, while those with T1 hypointensity showed the worst.

Modic Changes in the Cervical Spine: Prospective 20-year follow-up Study in Asymptomatic Subjects

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Purpose: Modic changes, which are degenerative changes of the vertebral body adjacent to the intervertebral disc. Although initially focused on the lumbar spine, Modic changes are also seen in the cervical spine and are associated with pain, disc degeneration, cervical curvature, and range of motion. However, almost all studies of the clinical relevance of Modic changes in the cervical spine are cross-sectional. Here, we evaluated Modic changes of the cervical spine that developed over a 20-year period in a healthy cohort, and sought to clarify the relationship between Modic changes and the development of clinical symptoms.

Materials/Methods: For this prospective follow-up study, we recruited 193 subjects from an original cohort of asymptomatic volunteers who underwent MRI of the cervical spine between 1993 and 1996. Each cervical level from C2/3 to C7/T1 was assessed on current MRIs as normal or showing type 1, 2, or 3 Modic change, and we asked about symptoms related to the cervical spine. Relationships between the presence of Modic changes and patient characteristics or clinical symptoms were evaluated by logistic regression analysis.

Results: At baseline, Modic change affected one subject (0.5%) at one disc. After 20 years, Modic changes affected 39 subjects (20.2%) at 61 discs. Type 2, found at 39 discs, was the most frequent (63.9%), followed by type 1 at 20 discs and type 3 at two discs. Modic changes were most frequent at the C5/6 segment (34.4%). The presence of Modic changes correlated with male gender (odds ratio 3.23, 95% confidence interval 1.46–7.15) and neck pain (odds ratio 2.84, 95% confidence interval 1.18–6.88).

Conclusions: Modic changes were most frequent at C5-6 and were associated with male gender but not age, BMI, or smoking, and with neck pain, but not with shoulder stiffness or arm pain or numbness.

Association Between the Ossification of the Longitudinal Ligament and Arterial Sclerosis: A Propensity-Matched Analysis

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Introduction: There have been several factors which are related to the morbidity of the ossification of the longitudinal ligament (OPLL), such as diabetes mellitus, obesity, race, and diet. However, most of the epidemiological reports in the past were based on the evaluation using plain radiographs, which sometimes makes it difficult to give a precise diagnosis on OPLL. On the other hand, computed tomography (CT) scan has been shown to have higher diagnostic accuracy for identifying OPLL. The purpose of this study was to investigate the prevalence of OPLL in the cervical spine and reveal new risk factors in healthy subjects using the data of complete medical checkup including whole body CT scan.

Materials/Methods: One thousand eight hundred and twenty-seven subjects who underwent complete medical checkup including whole body CT scans between January 2011 and December 2011 were enrolled in this study. Diagnosis of cervical OPLL was defined when there was a bony lesion of 2 mm or more extending from the posterior wall of the vertebral body into the spinal canal. The relationship between OPLL and other several factors, such as age, gender, body mass index (BMI), abdominal girth, blood test, bone density, and the extent of arterial sclerosis in coronary artery and carotid artery were investigated, by using a propensity-matched analysis.

Results: OPLL in the cervical spine was found in 129 subjects (7.1%). As we compared demographic data of subjects with an without OPLL (129 subjects versus 1698 subjects), sujects with cervical OPLL showed significantly higher age (62.8/58.6, $p = 0.013$), higher body weight (69.5kg/64.4kg, $p = 0.017$), larger abdominal girth (90.1cm/85.9cm, $p = 0.031$), elevated HbA1c (5.7%/5.5%, $p = 0.026$), higher incidence in the calcification of coronary artery (61.4%/42.3%, $p = 0.003$), and higher incidence in the plaque of carotid artery (88.6%/69.7%, $p = 0.012$). Next, an equal number of 129 were selected from the 1698 subjects without OPLL by using the propensity score-matching technique. Even after adjusting for age, sex, HbA1c, and BMI, the prevalence of the carotid plaque and the calcification of coronary artery was significantly higher (OR 2.32, $p < 0.05$; OR 1.89, $p < 0.05$) in the subjects with OPLL.

Conclusion: As expected, the association between OPLL and obesity or diabetes mellitus were revealed, which was comparable to the past reports. Moreover, the incidence of arterial sclerosis was higher in the subjects with OPLL, even after adjusting for factors which can influence on the etiology of arterial sclerosis, such as age, BMI, and HbA1c. To the best of our knowledge, this is the first reported which revealed an association between OPLL and arterial sclerosis. Although we speculate the involvement of inflammatory cytokines as a mechanism which commonly lies in the pathogenesis of OPLL and arterial sclerosis, further study will be necessary to clarify the underling mechanism.

The Effect of Footprint Mismatch on Heterotopic Ossification After Cervical Disc Replacement

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Introduction: The exact prediposing and influencing factors of heterotopic ossification (HO) after cervical disc replacement (CDR) have not been fully eluciated. The purpose of this study was to evaluate the effect of footprint mismatch on HO after CDR.

Methods: The preoperative and postoperative radiographic data of patients undergone CDR with Prestige LP or Discover prothesis in Tongji hospital from July 2012 to December 2015 were reviewed. HO was graded according to McAfee classification and classified according to Jin's morphologic classification. Footprint matching degree was evaluated using 3D CT images. Cervical sagittal alignment, FSU height and ROM were measured on radiographs. Pre-existing degeneration was scored using Walraevens' scoring system. Postulated risk factors including general factors, cervical sagittal alignment, FSU height, ROM, postoperative biomechanical changes, pre-existing degeneration, number of surgical levels, prosthesis type, use of NSAIDs and footprint matching degree were analysed by first univariate tests and then multivariate logistic regression to examine the relation with HO occurrence. Effect of footprint mismatch on type 1 HO of morphologic classification was evaluated.

Results: Data of 46 patients were collected, 43 were finally evaluated with a total 57 protheses implanted, and a mean follow-up duration of 41.16±12.49 months. No significant differences of basic characteristics existed between two prosthesis groups except follow-up time. Incidence of HO was 66.7%. Mean footprint matching degree in sagittal plane was 0.877±0.068 (range 0.711-1.004), in coronal plane was 0.852±0.092 (range 0.589-1.017). Mean overall footprint matching degree evaluated by a ratio of footprint area to endplate area was 0.699±0.102 (range 0.388-0.993). Prothesis type and footprint matching degree were significantly related with HO among all postulated risk factors in both univariate and multivariate analyses ($p<0.05$), the latter had larger Exp(B). Type 1 HO occurrence significantly related with footprint mismatch ($p<0.001$).

Conclusions: Incidence of HO after CDR was high and serious footprint mismatch existed. HO occurrence was significantly related with prosthesis type and footprint matching degree, the latter played a more important role.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Nogo Receptor Antagonist LOTUS Promotes Inhibition of Neuronal Apoptosis and Axonal Regeneration After Clinically Relevant Contusive Spinal Cord Injury in Adult Mice

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Introduction: Natural recovery following spinal cord injury (SCI) is extremely limited in mammalian adults. One of the major reasons is the inhibition of the axonal regeneration. This prevention of axonal regeneration is mainly due to Nogo receptor-1 (NgR1) signaling. The ligands of NgR1, such as Nogo, MAG, OMgp, BLyS and CSPG bind to NgR1, causing collapsing of growth cone and inhibition of neurite outgrowth following SCI. Lateral olfactory tract usher substance (LOTUS), a NgR1 antagonist, binds to NgR1 and inhibits these five ligand, resulting in the decreased collapse of growth cones and inhibition of neurite outgrowth. The purpose of this study is to determine the therapeutic efficacy of LOTUS using a clinically relevant contusive SCI model.

Materials/Methods: Contusive SCI was induced at the tenth thoracic level in LOTUS overexpressed mice (LOTUS group; n=20) and wild-type mice (control group; n=16). Hindlimb motor function was evaluated weekly for six weeks using BMS scores; and the DigiGait footprint analysis and rotarod test was performed on the sixth week post-injury. On this sixth week, biotinylated dextran amine (BDA) was injected into the primary motor cortex to trace corticospinal tract, or Fluoro-Gold was injected into the lumbar enlargement to trace reticulospinal tract. Two weeks later, electrophysiological analysis using spinal cord-evoked potential was conducted. After the mice were sacrificed, histological analyses were examined. Additionally, histological analyses at 7 and 14 days post-injury were also performed.

Results: Tracing analyses showed that the corticospinal tract labeled with BDA increased significantly at the rostral to the lesion in the LOTUS group compared to the control group. However, these tract fibers were not detected in the two groups caudal to the epicenter. On the other hand, reticular nucleus neurons retrogradely labeled with Fluoro-Gold increased significantly, implying that LOTUS overexpression increased reticulospinal tract fibers across the injury site. Immunohistochemistry revealed that the NF-H, 5-HT and p-GAP43 positive fibers increased significantly at the caudal sites. As for the 5-HT positive raphespinal tract, a major contributor of motor functional recovery, a significant increase was seen in the LOTUS group 14 days after SCI and continued to increase up to 56 days (Fig.1). Furthermore, cleaved caspase-3, a marker for apoptosis, staining revealed that LOTUS suppressed cellular apoptosis during the acute phase. Significant improvements in BMS scores was seen in the LOTUS group compared with that in the control group at one week following SCI and thereafter (At week six: LOTUS group; 4.13±1.11 vs. control group; 2.25±0.32, $p<0.01$). DigiGait analysis also revealed significantly longer stride length (2.93±0.59 vs. 2.21±0.36, $p<0.01$) and narrower stance angle (23.8±23.4 vs. 46.7±16.4, $p<0.01$) at 42 days after SCI in the LOTUS group, and the rotarod test showed significant longer total run time (Fig.2). Electrophysiological analysis revealed significantly shorter latency and larger amplitude in the LOTUS group (Fig.2).

Conclusion: LOTUS overexpression showed beneficial effects for functional recovery in clinically relevant contusive SCI model through promoting neuroprotection and axonal regeneration. Thus, the administration of LOTUS in the treatment of SCI could be a promising strategy through promoting endogenous restoration and locomotor improvement.

Fig. 1 LOTUS promotes axonal regeneration of raphespinal tract

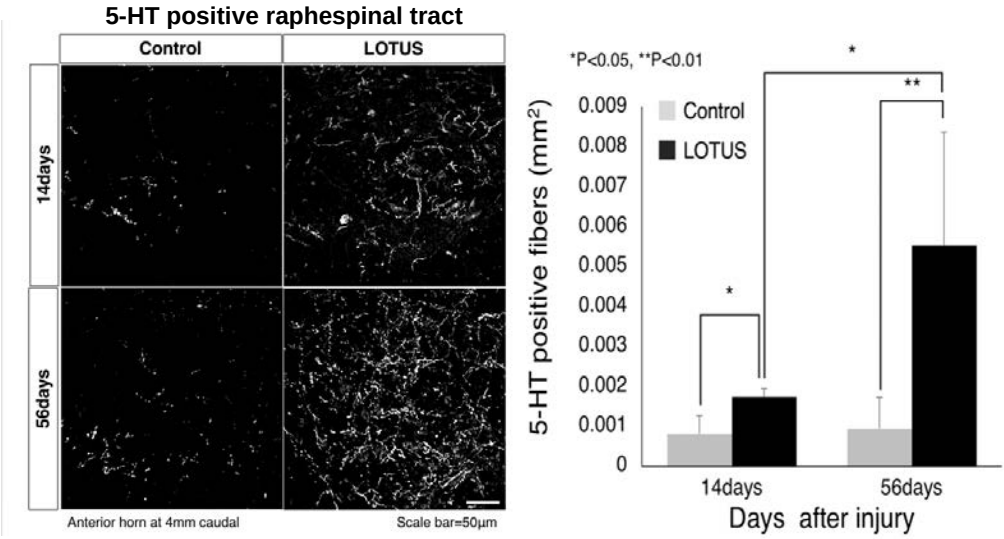
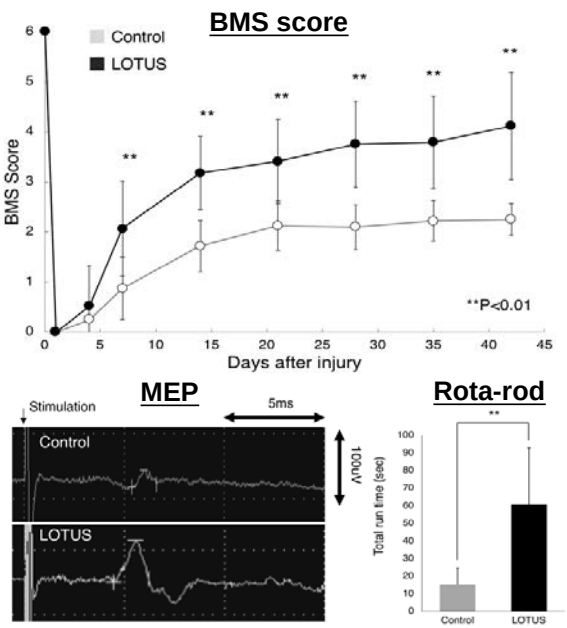


Fig. 2 LOTUS enhances fanctional recovery



Individual Disclosures can be found in the Disclosure Index pages 45-102.

Progression of Cervical OPLL After Laminoplasty or Laminectomy with Posterior Instrumentation

Moo Sung Kang, MD

Introduction: Posterior approach is indicated in the condition with extension of ossification of posterior longitudinal ligament (OPLL) more than three levels or spinal canal infiltration above half. Posterior laminoplasty is now recognized as standard technique, however, posterior decompression and instrumentation has its own benefit for the patients without severe stenosis.

OPLL is a progressive disease, and growth in the area of ossification has been reported in several studies. In recent years, there has been an increasing interest in mechanical stress on OPLL, which is assumed to have a serious effect on progression OPLL. So far there has been little discussion about the course of OPLL after posterior decompression and fixation. Mechanical stress is presumed to be increased at the adjacent segment.

Materials/Methods: Fourteen patients who were available of serial radiographs or computed tomography (CT) after cervical posterior decompression and instrumentation and 36 patients with laminoplasty were included. The progression of ossification was assessed using midline sagittal images of CT of the cervical spine and divided by follow-up period to induce progression rate. Radiographic parameters including C2-7 Cobb's angle, C2-7 range of motion (ROM), adjacent cranial and caudal segmental range of motion were measured. And difference between preoperative and postoperative radiographic parameters were calculated to reflect biomechanical stress. The associations between the progression rate of OPLL and the radiographic parameters were also analyzed.
The patients were divided into two groups based on progression rate and risk factors and its odds ratio were surveyed with logistic regression analysis.

Results: We included 14 posterior instrumentation and 36 laminoplasty patients. The mean age (54.7 ± 9.5 vs 50.1 ± 8.0 year-old, p=0.094) and sex (M:F =10:4 vs 25:11, p=1.000) showed no significant difference between groups. Mean follow-up period were 28.9 ± 20.8 and 37.6 ± 16.8 months. (p=0.069)

After surgical treatment, both groups showed loss of cervical lordosis (9.2 ± 6.9 ° vs 5.3 ± 8.2 °, p= 0.220). ROM in C2-7 segment also decreased in both groups (14.6 ± 13.5 ° vs 13.1 ± 12.2 °, p= 0.861). In cranial adjacent segment, ROM decreased more in laminoplasty group (0.7 ± 4.1 ° vs 1.4 ± 5.5 °, p= 0.453) ROM of caudal adjacent segment decreased in laminoplasty, whereas increased in posterior instrumentation (-1.4 ± 6.2 ° vs 2.6± 5.1 °, p=0.041)

Progression rate was 2.15 ± 1.31 mm^2/month in posterior instrumentation group and 1.53 ± 1.04 mm^2/month in laminoplasty group. (p=0.041) Mean progression rate in total patients was 1.71 mm2/ month. The patients were divided into 2 groups based on this mean progression rate. With the logistic regression analysis, posterior instrumentation had odd's ratio 12.917 for higher progression rate. (p=0.024, 95%CI 1.397-119.443)

Conclusion: The rate of progression of cervical OPLL after posterior decompression and

instrumentation was significantly higher than that of laminoplasty. Increased biomechanical stress in adjacent segment after posterior instrumentation may have an effect on progression of OPLL.

Is Modified K-Line a Powerful Tool of Surgical Decision Making for Patients with Cervical Spondylotic Myelopathy?

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Introduction: We have reported that insufficient posterior decompression could be often seen after laminoplasty for cervical spondylotic myelopathy (CSM) in patients with preoperative anterior clearance of the spinal cord less than 4mm based on the modified K-line (mK-line). However, there is no study investigating whether mK-line plays a role for surgical decision making to CSM patients. The purpose of the present study was to assign anterior decompression with fusion (ADF) or posterior method (PM) for CSM patients using mK-line and compare clinical and radiologic outcomes between these two techniques.

Methods: Eighty-seven cases who underwent a surgery for the treatment of CSM between 2011 and 2015 at our hospital and could be followed up for at least 2 years were enrolled. ADF was selected as a more favorable procedure than posterior surgery in patients with anterior spinal clearance of less than 4mm on preoperative mid-sagittal MRI. The Japanese Orthopedic Association (JOA) scoring system for cervical myelopathy, recovery rate of the JOA score at the time of 2 years after surgery were investigated as clinical outcomes to compare these two groups.

Results: The mean age was 65.1 (± 12.9) years for ADF group (N=26) and 70.5 (± 8.6) for PM group (N=61). In PM group, ten patients received posterior decompression with fusion. The mean pre- / postoperative JOA score was 10.5 / 14.1 points for ADF group and 9.8 / 13.1 points for PM group, indicating that there was no a significant different in terms of recovery rate of JOA score between ADF (58.9%) and PM (47.1%) groups. Average pre-/postoperative C2-7 lordotic angle was 11.8/13.7 degrees in ADF group and 15.8/15.4 degrees in LAMP group. Mean C2-7 range of motion was 36.9/27.5 degrees in ADF group and 33.0/27.4 degrees in LAMP group.

Conclusion: Although our prospective study, where anterior or posterior surgery was alternatively applied to CSM patients every other year, have demonstrated that anterior procedure was superior to posterior method, the present study revealed that clinical outcomes were almost similar between both surgical treatments. This result indicates that surgical selection using preoperative mK-line might predict residual anterior compression of the cord after posterior decompression.

Are HRQOL Outcomes of ACDF Influenced by Smoking Status?

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Introduction: While it is clear that smoking affects the fusion rates for patients undergoing an ACDF, the relationship between smoking and health related quality of life (HRQOL) outcomes after an ACDF is less clear.

Methods: A cohort study was performed comparing patient based on their smoking history. Patients with tumor, trauma, infection, previous cervical spine surgery, or those with less than a year of follow-up were excluded. Outcomes including NDI, SF-12 MCS, PCS, VAS arm pain, VAS neck pain were evaluated. Outcomes were compared among Non-smoker, smoker, and former smoker) using linear mixed effect models, controlling for age, sex, and BMI. Results were reported with 95% confidence interval.

Results: 264 patients were included, and the average follow up was 19.8 (range: 12-46.6) months. The mean age was 53.1 (range: 18-84) years old, and the mean BMI was 29.6 (range 18.7-54.9). There were 43 smokers, 152 non-smokers, and 69 former smokers in the cohort.

The NDI improved significantly for all cohorts, with an average improvement of 16.8 points (95%CI: -19.93, -13.72, $p<0.001$). Non-smokers had lower pre- and post-operative NDI ($p=0.033$) scores than both current smokers and former smokers; however, while there was not a significant difference between current smokers and former smokers baseline NDI score ($p = 0.62$) postoperatively, current smokers reported worse mean improvement ($p=0.01$), which lead to worse final NDI scores ($p = 0.02$) than both non-smokers and former smokers. The improvement of NDI for non-smokers, former smokers and current smokers were 16.42(95%CI: 11.89, 20.96), 16.81(95%CI: 12.08, 21.54), and 10.52 (95%CI: 6.63, 14.42)(Figure 1).

The mean improvement of SF-12 PCS was 7.78 (95%CI: 6.27, 7.30, $p<0.001$,), and improvement of SF-12 MCS, 4.41 (95%CI: 2.22, 6.60, $p<0.001$,). There was no significant difference among non-smokers, former smokers and current smokers in the average improvement (PCS: $p=0.552$ and MCS: $p=0.303$), however smokers had lower pre- and post-operative

PCS (p=0.002, one-way ANOVA). Interestingly, stopping smoking did not affect the PCS, as there was no difference between pre- or post-operative PCS among smokers and former smokers (p=0.20 and 0.78).

A significant difference in baseline VAS neck pain was identified between non-smokers, former smokers and current smokers [5.2(95%CI:4.7,5.7) ,6.2(95%CI:5.5,6.8), 6.4(95%CI :5.6,7.2) p=0.049) as well as VAS arm pain [4.6(95%CI:4.1,5.2) 5.9(95%CI :5.3,6.6), 5.6(95%CI:4.7,6.5) p=0.032] (Figure 2). Overall the neck pain after ACDF was improved by 2.18 (95%CI: 2.68, 1.68, p<0.001), and arm pain by 2.03(95%CI: 2.61, -.45, p<0.001), and the overall improvement was not affected by smoking status for neck pain (p=0.30) or arm pain (p =0.13).

Conclusion: Smokers reported more severe symptoms both preoperatively and postoperatively. The affect of quitting smoking on HRQOL varies based on the metric, but for the NDI smokers reported less improvement than former smokers. This is an important finding, because it indicates stopping smoking may not only improve fusion rates, but also clinical outcomes.

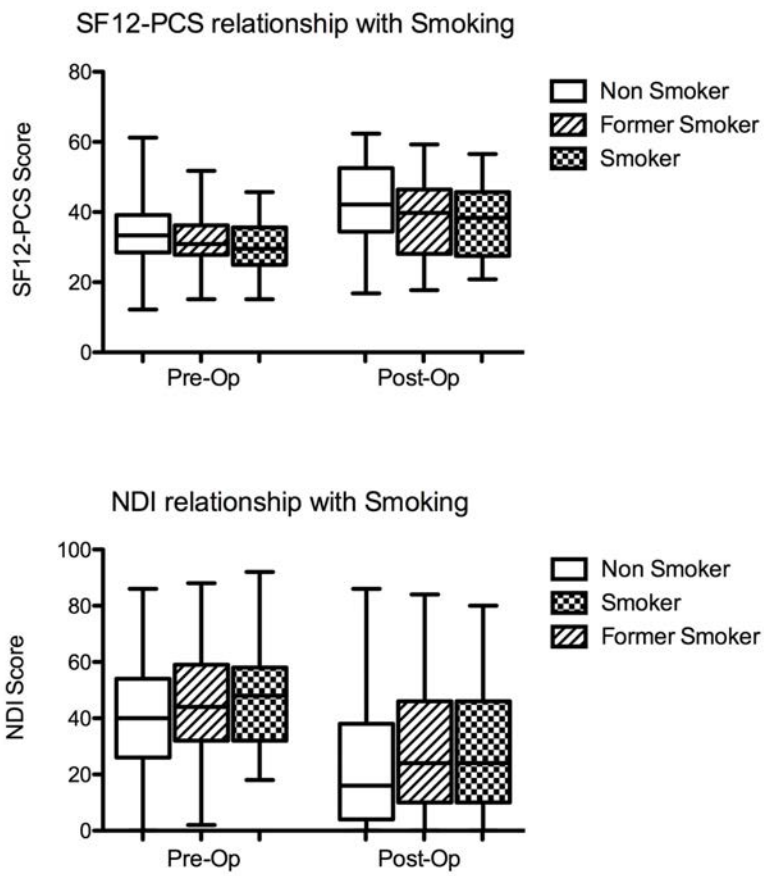
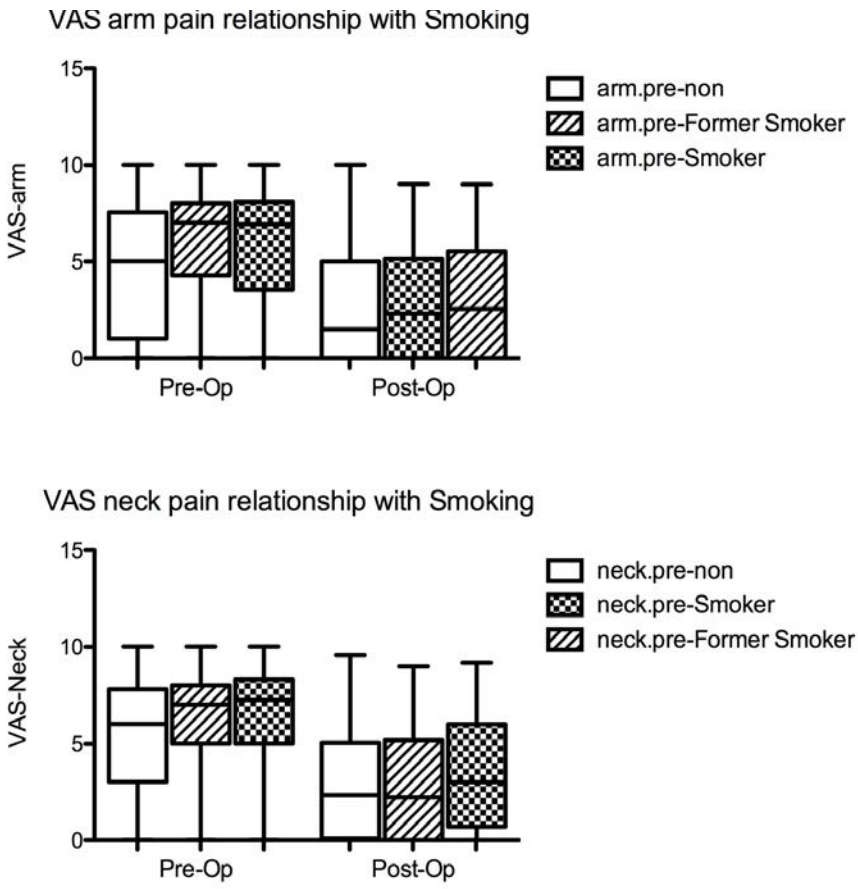


Figure 1


VAS arm pain relationship with Smoking
VAS-arm
15
10
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Pre-Op
Post-Op
arm.pre-non
arm.pre-Former Smoker
arm.pre-Smoker
VAS neck pain relationship with Smoking
VAS-Neck
15
10
5
0
Pre-Op
Post-Op
neck.pre-non
neck.pre-Smoker
neck.pre-Former Smoker

Figure 2

The Association of Preoperative Disc Height with Radiographic and Clinical Outcomes Following ACDF

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Introduction: Disc space collapse often occurs later in the natural course of cervical degenerative disc disease, and during anterior cervical discectomy and fusion (ACDF), restoration of disc space height and lordosis can assist with decompression and restoration of alignment. However, it is unclear if the amount of preoperative cervical disc space collapse correlates with outcomes following ACDF. The aim of the present study was therefore to characterize preoperative disc space height in a sample of ACDF patients and to determine the association with postoperative clinical and radiographic outcomes following ACDF.

Methods: A retrospective cohort analysis was performed on patients who underwent a single-level ACDF by one of two senior spine surgeons between 2008-2015 with minimum 6 months follow-up. Preoperative disc height was measured in terms of preoperative anterior vertebral distance (pAVD), mid-vertebral distance (pMVD), and posterior vertebral distance (pPVD). Sagittal parameters were also measured, and included change in C2-C7 lordosis, T1 angle, sagittal vertical axis (SVA), fusion mass lordosis, proximal and distal adjacent segment lordosis. Visual Analogue Scale (VAS) neck, VAS arm, and Neck Disability Index (NDI) scores were collected. The rates of adjacent segment disease (ASD), reoperation, successful fusion, and subsidence (postoperative disc space collapse ^{3}2mm) were determined. Multivariate regressions were used to control for baseline patient characteristics.

Results: A total of 120 patients who underwent a one-level ACDF during the study period were included. Mean follow-up length was 29 months. Mean age was 46.9 years, mean BMI was 28.4, and 45.4% of patients were female. As expected, increased pAVD was associated with increased preoperative lordosis (p=0.010), SVA (p=0.022), fusion segment lordosis (p=0.005), and proximal lordosis (p=0.007). Increased pAVD was also associated with increased postoperative SVA (p=0.005), T1 angle (p=0.031), and proximal segment lordosis (p=0.035). At final follow-up, pAVD was associated with increased lordosis (p=-0.026), SVA (p=0.010), and proximal lordosis (p = 0.020). Additionally, pMVD was associated with increased postoperative SVA (p=0.025), and final SVA (p=0.011). Preoperative PVD was associated with decreased postoperative distal lordosis (p=0.037) and increased final SVA (p=0.032) [Table 1].

Notably, greater pAVD was associated with greater final VAS arm scores (p=0.022), greater pMVD was associated with increased final VAS neck (p=0.037) and final VAS arm scores (p=0.040), and greater pPVD was associated with greater final VAS neck (p=0.031) and arm (p=0.023) scores. Greater AVD, MVD, and PVD were all associated with a decreased

preoperative to postoperative difference in VAS neck (p-value range 0.034-0.04) [Table 2]. No associations were found between preoperative disc height and NDI scores, or rates of ASD, reoperations, fusion, or subsidence.

Conclusions: In this study of 120 single level ACDF procedures, preoperative disc height was found to be associated with radiographic and clinical outcomes on multivariate analysis. Notably, increased anterior, middle, and posterior preoperative disc height were all associated with increased final SVA, among other parameters. Patients with well-maintained preoperative disc heights had greater final VAS neck scores, VAS arm scores, and had less postoperative improvement in VAS neck scores compared to patients with preoperative collapsed discs.

Table 1. Multivariate analysis for differences in sagittal parameters preoperatively and postoperatively

		AVD Multivariate		MVD Multivariate		PVD Multivariate	
	All patients	Beta	p-value	Beta	p-value	Beta	p-value
Preoperative							
Lordosis	5.8 + 12.5	**0.93**	**0.010**	0.68	0.081	0.03	0.929
SVA	28.4 + 10.3	**0.72**	**0.022**	0.6	0.076	0.47	0.157
Fusion segment lordosis	-0.6 + 5.6	**0.49**	**0.005**	0.23	0.181	-0.03	0.858
T1 angle	27.3 + 8.5	0.49	0.116	0.29	0.380	-0.11	0.973
Proximal lordosis	1.7 + 7.6	0.54	**0.007**	0.25	0.252	0.05	0.820
Distal lordosis	3.7 + 4.8	-0.14	0.411	0.12	0.951	-0.22	0.224
Immediate postoperative							
Lordosis	7.2 + 11.3	0.53	0.118	0.50	0.168	-0.15	0.668
SVA	30.1 + 10.8	**0.92**	**0.005**	**0.80**	**0.025**	0.61	0.084
Fusion segment lordosis	3.7 + 4.5	0.24	0.084	0.08	0.573	-0.14	0.360
T1 angle	27.4 + 8.2	**0.61**	**0.031**	0.36	0.245	0.06	0.842
Proximal lordosis	1.5 + 8.0	**0.44**	**0.035**	0.25	0.264	0.04	0.862
Distal lordosis	2.4 + 4.9	-0.33	0.072	-0.23	0.266	**-0.40**	**0.037**
Final							
Lordosis	9.8 + 11.4	**0.79**	**0.026**	0.69	0.075	0.02	0.958
SVA	28.2 + 11.3	**0.86**	**0.010**	**0.91**	**0.011**	**0.77**	**0.032**
Fusion segment lordosis	3.5 + 4.9	0.30	0.051	0.14	0.403	-0.16	0.338
T1 angle	29.0 + 8.4	0.34	0.278	0.10	0.769	-0.16	0.622
Proximal lordosis	1.9 + 7.8	**0.49**	**0.020**	0.31	0.168	0.21	0.350
Distal lordosis	4.0 + 4.6	-0.83	0.619	-0.12	0.525	-0.19	0.289

AVD = anterior vertebral distance, MVD = mid-vertebral distance, PVD = posterior vertebral distance, VAS = visual analog scale, NDI = neck disability index.

Table 2. Comparing clinical outcomes

		AVD Multivariate		MVD Multivariate		PVD Multivariate	
	All patients	Beta	p-value	Beta	p-value	Beta	p-value
Preoperative							
VAS neck	7.2 + 2.7	-0.3	0.146	-0.27	0.171	-0.24	0.206
VAS arm	4.9 + 3.6	0.2	0.54	0.41	0.193	0.325	0.294
NDI	43.2 + 19.7	-0.55	0.708	0.11	0.944	-0.174	0.904
Final							
VAS neck	2.2 + 2.3	0.32	0.056	**0.37**	**0.040**	**0.35**	**0.031**
VAS arm	1.1 + 2.0	**0.31**	**0.022**	**0.32**	**0.035**	**0.31**	**0.023**
NDI	21.7 + 21.7	1.36	0.284	1.6	0.259	1.96	0.147
Change preoperative to final							
VAS neck	5.1 + 3.8	**-0.63**	**0.04**	**-0.62**	**0.034**	**-0.58**	**0.037**
VAS arm	4.1 + 3.7	0.14	0.656	0.36	0.215	0.24	0.395
NDI	24.6 + 29.2	-1.1	0.608	-1.01	0.661	-1.75	0.406

AVD = anterior vertebral distance, MVD = mid-vertebral distance, PVD = posterior vertebral distance, VAS = visual analog scale, NDI = neck disability index.

Efficacy of Posterior Decompression with Instrumented Fusion for K-line (-)-type Cervical OPLL: Minimum 5-Year Follow-Up

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Introduction: We have reported a concept of K-line for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament (OPLL). K-line is the line that connects the midpoints of the spinal canal at C2-7 at the lateral view of the cervical radiograph in the neutral position. By using the K-line, we can evaluate the alignment of the cervical spine and the size of OPLL in one parameter. When the OPLL exceeds the K-line, the OPLL is classified into a K-line (-)-type. We previously reported poor surgical outcome of laminoplasty alone for K-line (-)-type cervical OPLL. We also reported an advantage of additional instrumented fixation for K-line (-)-type cervical OPLL. The addition of posterior instrumented fusion might eliminate the dynamic factor and prevent progression of postoperative kyphosis and off-balance. The purpose of this study was to assess midterm outcomes after posterior decompression with instrumented fusion (PDF) in patients with K-line (-)-type cervical OPLL.

Methods: Since 2000, a total of 36 cervical OPLL patients of K-line (-)-type underwent surgical treatment by posterior methods in our institutes with 5 years or longer follow-up. First surgical choice for K-line (-)-type cervical OPLL in our institutes is an anterior approach, because we believe that complete excision of the ossified mass using an anterior approach is theoretically the best procedure. However, some patients cannot choose anterior surgery in some clinical reasons. We used to choose laminoplasty for such patients in the past time, however, the addition of posterior instrumented fusion has been chosen recently. In this study, we divided those patients into laminoplasty (LMP) and PDF group. We evaluated their neurological status and radiographic findings retrospectively.

Results: There were 7 laminoplasty (LMP) and 29 PDF cases. No statistical difference was seen between the two groups for preoperative clinical data including age, gender, duration of symptoms, occupation ratio of OPLL, and preoperative C2-7 angle and CGH-C7 SVA (center of the gravity of the head to C7 sagittal vertical axis). The average recovery rate was 15.5% in the LMP group and 39.5% in the PDF group at final follow-up ($P<0.05$). The data of the C2-7 angle and CGH-C7 SVA showed 8 degrees (ranged 2 to 18 degrees) increase of kyphosis and 13.7mm (ranged -30 to 60mm) off-balance were seen postoperatively in the LMP group, whereas 7 degrees (ranged -6 to 16 degrees) increase of kyphosis and 10mm (-5 to 35mm) off-balance were seen postoperatively in the PDF group.

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Discussion: The PDF group showed better surgical outcome compared with LMP group. The addition of posterior instrumented fusion can eliminate the dynamic factor. However, contrary to expectations, the instrumentation cannot prevent progression of off-balance. The reason may come from wide exposure of the surgical site and muscle damage when we add instrumentation. Those data suggest that the benefit of instrumentation is mainly control of the local dynamic factor, nor sagittal alignment and balance.

Conclusion: Better surgical outcome can be obtained by posterior decompression with instrumented fusion when compared with laminoplasty alone for K-line (-)-type cervical OPLL.

Safety and Efficacy of an Early Home Exercise Program after Anterior Cervical Discectomy and Fusion: A Pilot Randomized Controlled Trial

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Introduction: Anterior cervical discectomy and fusion (ACDF) is the most common surgery for cervical spine conditions. Poor outcomes after ACDF have been linked to impaired muscle functioning from postsurgical disuse and deconditioning. Postoperative exercise can counteract the effects of deconditioning and promote early participation in health-promoting behaviors. To date, no study has determined whether performance of an early home exercise program (HEP) is safe and efficacious for improving ACDF outcomes. The purpose of this pilot randomized controlled trial was to examine the safety and preliminary efficacy of an early HEP performed within the first six weeks after ACDF surgery.

Materials/Methods: Thirty patients (mean ± SD age = 50.6 ± 11.0 years, 16 females) who underwent ACDF were randomized to either 1) 6-week HEP immediately after surgery or 2) usual postoperative care. The HEP intervention included daily walking, deep breathing, distraction techniques, cervical (limited to 30 degrees) and upper body range of motion, cervical and shoulder isometrics, abdominal strengthening, and theraband resistance exercises for the shoulder. Patient-reported outcomes for disability (Neck Disability Index), pain intensity (0-10 Numeric Rating Scale for neck and arm pain), quality of life (EQ-5D), and physical and mental health (SF-12) were assessed preoperatively, after completing the HEP (6 weeks after surgery) and at 6-month follow-up by study personnel blinded to group assignment. Postoperative opioid medication use was also assessed at 6 weeks and 6 months. Safety was assessed with radiographic imaging for fusion rate. Randomized group effects for 6-week and 6-month outcome were examined with separate multivariable regression models controlling for baseline outcome score and number of comorbidities (Functional Comorbidity Index). Significance level was set at $p < 0.05$.

Results: At baseline, there were no significant group differences in patient demographics (e.g., age, sex, race/ethnicity), surgical characteristics (e.g., primary diagnoses, number of fusion levels, use of postoperative cervical collar), or baseline outcome scores ($p > 0.05$). Participants in the HEP group had significantly more comorbidities (mean ± SD comorbidities = 4.3 ± 1.6) than the usual care group (mean ± SD comorbidities = 2.7 ± 1.5, $p = 0.01$). After accounting for baseline outcome and comorbidities, the HEP group reported lower 6-week neck pain than the usual care group ($F_{3, 26} = 3.3$, $p = 0.04$, $r^2 = 0.3$, mean difference = -1.7 [-3.4; -0.05]). The difference in neck pain was not maintained at 6 months ($p > 0.05$). Radiographs were obtained at a mean ± SD time point of 141.3 ± 78.9 days after surgery. No difference in fusion rate was observed between groups ($p > 0.05$).

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Conclusion: An early HEP program can be safely administered to patients immediately after ACDF with short-term benefits noted in self-reported neck pain. Larger trials are needed to inform the dissemination of early exercise programs into clinical practice.

The Incidence of Adjacent Segment Disease Following Cervical Fusion for Trauma

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Background: Adjacent Segment Disease (ASD) in the cervical spine following fusion is a significant concern for patients and surgeons treating degenerative cervical conditions. The topic has been widely researched as it pertains to treatment of spondylotic disease, however no studies have evaluated the incidence of ASD following fusion for trauma.

Introduction: Cervical fusion and/or decompression is a well-established surgical modality for treatment of traumatic injuries resulting in mechanical or neurological instability. Despite its proven long-term clinical success, the potential for accelerated ASD following fusion remains an active area of clinical concern. Several studies demonstrate increased rates of ASD and re-operation in cervical fusion performed for spondylotic disease. However, no studies have determined the incidence of ASD following cervical fusion for trauma. The purpose of the current study is to evaluate the incidence of ASD, and report the longterm radiographic and clinical outcome in patients undergoing fusion for cervical trauma. As a secondary objective, we aim to help answer the question of whether ASD is a consequence of iatrogenic factors following cervical fusion procedures or simply part of the natural history of spondylotic disease.

Methods: Radiographic and electronic medical record review was conducted on all patients undergoing cervical fusion for trauma by one of 2 spine fellowship trained surgeons at a level-one academic trauma center from 2005-2017. Overall, 196 patients were included in the initial chart and radiographic review. Of those, 61 patients had >12 month radiographic follow-up and were included in the study. Radiographic assessment of ASD was performed by 2 surgeons utilizing the grading system proposed by Hilibrand and Bohlman. Pre-existing disease, if present, was graded accordingly and if no progression of pre-existing disease was demonstrated, the patient was graded as a 1 (no disease).

Results: Of the 196 patients initially reviewed, 61 met inclusion criteria (>12 month radiographic follow up) for a follow up rate of 31.1%. There were 50 men and 11 women. The average age of the patients was 42 years (19-71). The average length of follow-up was 28 months (12-130). The mechanism of injury was: motor vehicle accident (MVA) 26, fall 22, motor cycle crash (MCC) 7, other 6. ASD was found in only one patient for a per-level overall rate of 0.82%. The annual incidence of ASD was determined to be 0.35% per level- and 0.7% per patient-per year. There were 2 incidences of pseudarthrosis (4%) and 2 patients that developed severe dysphagia (4%). Reoperation was necessary for 1 patient that developed kyphosis at the cervicothoracic junction after a C3-6 posterior fusion requiring extension to T2, and 1 patient suffered a subsequent injury requiring C7-T1 stabilization following a C6-7 ACDF. Results are summarized in Table 1.

Conclusion: The incidence of ASD following cervical fusion for trauma is lower than reported historical data for the treatment of spondylotic/disc disease. This data suggests that ASD

may be more of a consequence of the natural history of disease rather than a product of iatrogenic factors following cervical fusion procedures.

Number of patients	196
Gender	61
Male N(%)	147 (76%)
Female, N(%)	49 (24%)
Surgical Case Mix	
Anterior/Anterior & Posterior	250 (88%)
Posterior only	32 (12%)
Postoperative Follow up	Minimum 12 months
N (%)	61 (31.1%)
Average f/u (Range)	28 months (12-130)
Male	50
Female	11
Mechanism of Injury	
Motor Vehicle Accident (MVA)	26
Fall	22
Motor cycle crash	7
Other	6
ASIA Classification	
ASIA A	2
ASIA B	2
ASIA C	4
ASIA D	14
ASIA E	39
Adjacent Segment Disease N (%)	1 level (0.82%)
Complication	
Pseudoarthrosis (%)	2 (3%)
Dysphagia (%)	2 (3%)
Reoperation (%)	2 (3%)

Table 1. Summary of Cervical Injury patient characteristics. ACDF = Anterior cervical disektomy and fusion

The Role of Glycemia in Survival and Neurological Recovery after Traumatic Spinal Cord Injury

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Introduction: While experimental and clinical evidence indicates that hyperglycemia worsens neurological outcome after traumatic brain injury, the impact of hyperglicemia in secondary mechanisms of neuronal damage after acute spinal cord injury (SCI) has been little investigated. This study examined the potential association of glycemia in the hyperacute stage after SCI and outcomes after acute traumatic SCI.

Methods: This retrospective cohort study includes all patients who were enrolled into the Third National Spinal Cord Injury Study (NASCIS 3). Data on the glycemia within 24 hours, at 48 hours and at day 7 after acute SCI were examined as potentially associated with survival within the first year after SCI as well as neurological recovery at 6 weeks, at 6 months and at 1 year following SCI. Neurological recovery included the NASCIS motor, sensory and pain scores. Analyses of the dependent continuous variables (i.e. NASCIS motor, sensory, and pain scores) were carried out using linear regression analyses adjusted for the major potential confounders. Survival analysis was carried out using Kaplan-Meier curve and log-rank test.

Results: There were 76 women and 423 men with mean age of 35.7 years (range from 14 to 92 years) who mostly sustained cervical SCI due to motor vehicle accident followed by falls. On admission, 96.6% of the individuals had hyperglycemia. Glycemia varied from 125 to 533 mg/L among the individuals with hyperglycemia. There was a significant decline in the initial glycemia within 24 hours (188.20±2.29 mg/L) when compared to glycemia at 48 hours (164.44±2.08 mg/L) and at day 7 after SCI (125.02±2.25 mg/L; $p<0.0001$).

The results of the regression analyses revealed that higher glycemia within 24 hours post-injury was associated with lower motor, sensory and pain scores at 6 weeks and at 6 months, but not at 1 year following SCI (**Table 1**). Glycemia at 48 hours and at day 7 post-injury was not associated with motor, sensory and pain scores at 6 weeks, at 6 months or at 1 year following SCI, except for a poorer motor recovery and a greater pain score at 1 year after SCI related to higher glycemia at 48 hours post-injury (**Table 1**).
Survival analysis revealed that hyperglycemia within 24 hours and at 48 hours post-injury was not associated mortality within the first year after SCI ($p=0.3254$ and $p=0.0696$, respectively). However, hyperglycemia at day 7 post-injury was associated with greater mortality after SCI (**Fig. 1**).

Conclusion: The results of this study suggest that hyperglycemia at day 7 post-injury may be associated with greater mortality within the first year following SCI. Among the survivors, glycemia at 24 hours post-injury was associated with poorer motor and sensory recovery as well as greater pain scores within the first 6 months after SCI. However, glycemia within 24 hours, at 48 hours, and at day 7 post-injury did not adversely affect the individuals' neurological recovery at 1 year following SCI. Further investigations are needed to clarify the reasons why hyperglycemia may be associated with greater mortality at 1 year after SCI, which could have clinical implications.

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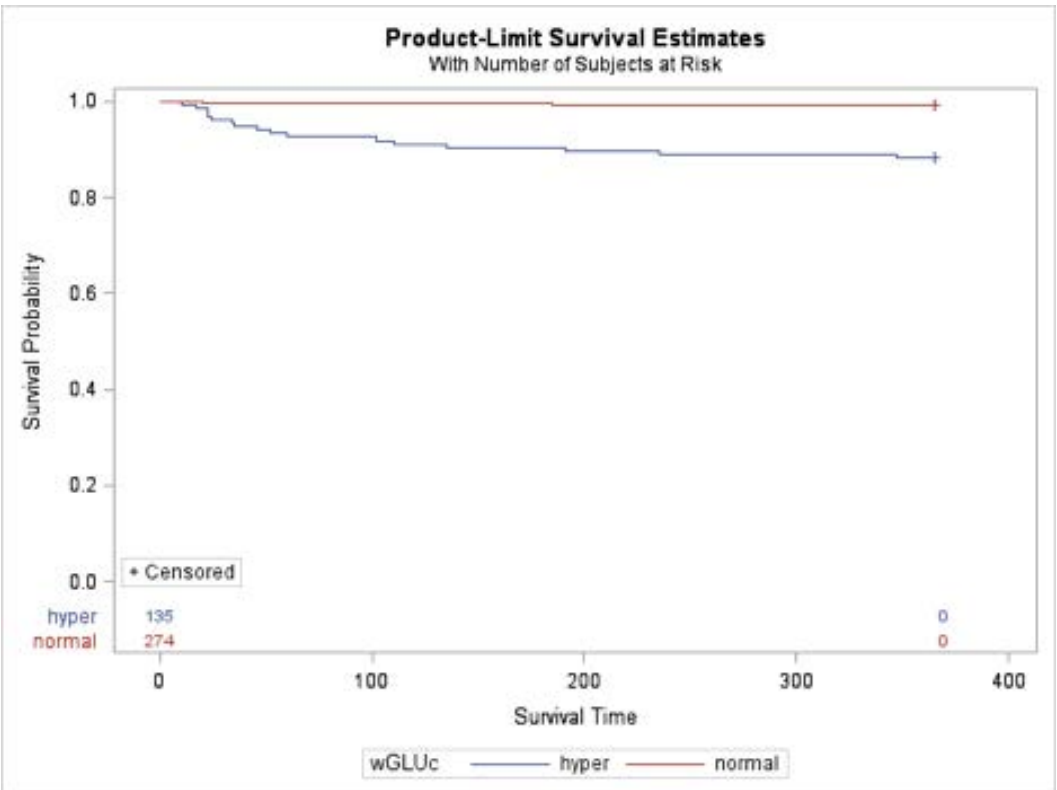
Table 1. Results of the regression analyses adjusted for neurological scores at admission, age, sex, trial drug protocol, level of SCI, Glasgow Coma Score, and serum creatinine concentration.

Dependent variable		R-square	F value	P value
Motor at 6 weeks	Model	0.603	56.10	<0.0001
	Glycemia at 24 hrs		6.95	0.0088
Sensory at 6 weeks	Model	0.597	53.95	<0.0001
	Glycemia at 24 hrs		4.00	0.0464
Pain score at 6 weeks	Model	0.554	47.24	<0.0001
	Glycemia at 24 hrs		7.82	0.0055
Motor at 6 months	Model	0.524	39.70	<0.0001
	Glycemia at 24 hrs		4.03	0.0455
Sensory at 6 months	Model	0.563	46.24	<0.0001
	Glycemia at 24 hrs		3.01	0.0836
Pain score at 6 months	Model	0.497	36.47	<0.0001
	Glycemia at 24 hrs		5.39	0.0209
Motor 1 year	Model	0.476	31.82	<0.0001
	Glycemia at 24 hrs		2.98	0.0854
Sensory at 1 year	Model	0.525	38.55	<0.0001
	Glycemia at 24 hrs		1.72	0.1910
Pain score at 1 year	Model	0.493	34.6	<0.0001
	Glycemia at 24 hrs		2.39	0.1227
Motor at 6 weeks	Model	0.598	54.75	<0.0001
	Glycemia at 48 hrs		2.33	0.1282
Sensory at 6 weeks	Model	0.592	52.73	<0.0001
	Glycemia at 48 hrs		0.03	0.8731
Pain score at 6 weeks	Model	0.548	45.71	<0.0001
	Glycemia at 48 hrs		2.96	0.0863
Motor at 6 months	Model	0.520	39.17	<0.0001
	Glycemia at 48 hrs		1.79	0.1822
Sensory at 6 months	Model	0.559	45.56	<0.0001
	Glycemia at 48 hrs		0.01	0.9171
Pain score at 6 month	Model	0.494	35.89	<0.0001
	Glycemia at 48 hrs		1.70	0.1929
Motor at 1 year	Model	0.487	33.08	<0.0001
	Glycemia at 48 hrs		4.10	0.0437
Sensory at 1 year	Model	0.556	43.53	<0.0001
	Glycemia at 48 hrs		0.14	0.7092
Pain score at 1 year	Model	0.492	34.45	<0.0001
	Glycemia at 48 hrs		4.27	0.0396
Motor at 6 weeks	Model	0.638	58.83	<0.0001
	Glycemia at day 7		2.91	0.0892
Sensory at 6 weeks	Model	0.638	58.10	<0.0001

	Glycemia at day 7		0.01	0.9046
Pain score at 6 weeks	Model	0.583	48.10	<0.0001
	Glycemia at day 7		0.02	0.8928
Motor at 6 months	Model	0.517	34.97	<0.0001
	Glycemia at day 7		2.13	0.1458
Sensory at 6 months	Model	0.566	42.38	<0.0001
	Glycemia at day 7		0.28	0.5962
Pain score at 6 month	Model	0.498	35.20	<0.0001
	Glycemia at day 7		0.43	0.5128
Motor at 1 year	Model	0.468	28.05	<0.0001
	Glycemia at day 7		1.25	0.2647
Sensory at 1 year	Model	0.524	35.05	<0.0001
	Glycemia at day 7		0.07	0.7867
Pain score at 1 year	Model	0.492	31.59	<0.0001
	Glycemia at day 7		0	0.9824

Figure 1. Survival analysis using Kaplan-Meier curve with log-rank test (p<0.0001)



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Is Conservative Treatment Effective for Unilateral Sagitally Split Fractures of C1 Lateral Mass?

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Introduction: Unilateral sagitally split fracture (USSF) of C1 lateral mass (LM) is a rare variant type of C1 atlas fracture. The integrity of transverse atlantal ligament (TAL) is a key factor to determine the stability in the case of C1 atlas fracture. To date, definite treatment guideline of USSF of C1 LM has not been established. Moreover, the effect of TAL injury on surgical outcomes is still controversial in USSF of C1 LM. Therefore, we performed the current study to investigate clinical and radiologic outcomes of USSF of C1 LM that have been treated conservatively and suggest appropriate treatment guideline.

Materials/Methods: 26 consecutive cases of USSF of C1 LM were included from 5 trauma centers of tertiary university hospitals. The fractures associated with other cervical spines, such as C2 and occiput, were excluded from the study. The mean age was 52 years old. 16 were male and 10 were female. 16 were TAL injury group (9 type I and 7 type II by Dickman's classification) and 10 were TAL intact group. All cases were treated by conservative measures including skull traction followed by rigid brace for TAL intact group and halovest for TAL injury group for 12 weeks. The mean follow-up was 16 months (range, 12 - 47 months). Three spine surgeons measured radiologic parameters on lateral radiograph and open mouth view of cervical spine, 2-dimensional reconstructed CT scans and MRI of initial and last follow-up: Total LM displacement (LMD), unilateral LMD at fracture side, atlanto-dental interval (ADI), clivus canal angle (CCA), atlanto-occipital joint axis angle (AOJAA), and basion-dens interval (BDI). The averages of three measurements were used as final results. The radiologic outcomes were evaluated by comparing initial presentation and last follow-up in two groups. Clinical outcomes were evaluated by visual analog scale (VAS) and Odom's criteria.

Results: At last follow-up, for TAL intact group, total LMD, unilateral LMD at fracture side, ADI, CCA, AOJAA, and BDI were maintained well compared to initial presentation (1.2 mm vs 1.2 mm, $p = 0.973$) (1.0 mm vs 1.1 mm, $p = 0.828$) (1.5 mm vs 1.3 mm, $p = 0.162$) (154.8 degrees vs 151.5 degrees, $p = 0.105$) (105.9 degrees vs 105.3 degrees, $p = 0.800$) (4.2 mm vs 3.7 mm, $p = 0.079$). However, for TAL injury group, total LMD, unilateral LMD at fracture side, ADI, CCA, AOJAA, and BDI were worsened compared to initial presentation (5.9 mm vs 6.7 mm, $p < 0.05$) (4.3 mm vs 4.7 mm, $p < 0.001$) (2.0 mm vs 3.0 mm, $p < 0.001$) (155.6 degrees vs 145.2 degrees, $p < 0.001$) (107.8 degrees vs 98.3 degrees, $p < 0.001$) (4.4 mm vs 2.6 mm, $p < 0.001$). The worsening of total LMD, unilateral LMD at fracture side, ADI, CCA, and AOJAA were more severe in type I TAL injury than type II TAL injury (8.0 mm vs 5.1 mm, $p < 0.05$) (6.2 mm vs 4.4 mm, $p < 0.01$) (3.4 mm vs 2.5 mm, $p < 0.05$) (142.2 degrees vs 149.0 degrees, $p< 0.05$) (94.1 vs 103.8 degrees, $p < 0.05$). The worsening of BDI was severe in type I TAL injury but statistically not significant (2.3 mm vs 2.9 mm, $p = 0.486$). VAS significantly decreased in TAL intact group (4.7 points vs 2.1 points, $p < 0.001$) but not in TAL injury group (6.8 points vs 4.7 points, $p = 0.435$). According to Odom's criteria, satisfactory outcomes were higher in TAL intact group compared to TAL injury group (80% vs 37.5%, $p < 0.05$).

Conclusion: Conservative treatment for USSF of C1 LM with TAL injury allows subsidence of occiput into C2 with aggravation of LMD of C1. This causes coronal and sagittal malalignment of occipitocervical junction, resulting in unsatisfactory clinical outcomes. Our results suggest that early surgical stabilization should be considered as choice of treatment for USSF of C1 LM with TAL injury.

Risk Factors of Poor Functional Prognosis for Patients with Traumatic Cervical Spinal Cord Injury with Motor Complete Loss

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Introduction: Physical assessment such as American Spinal Injury Association impairment scale (AIS) grade could predict a tendency of functional prognosis following traumatic cervical spinal cord injury (CSCI). In actually, about 80% patients of those with AIS grade A at initial examination have few chances of neurological recovery, however about 10% converting to AIS C or D. In contrast, at least some of the AIS grade B patients show motor recovery and about 50-60% of them can convert to AIS C or D. The underlying mechanism and risk factors between motor functional recovery and no-recovery remains unclear. The purpose of this study is to elucidate risk factors associated with poor functional prognosis following traumatic CSCI.

Materials/Methods: Consecutive 447 traumatic acute CSCI patients, who were evaluated for neurological impairment within 5 days after injury at our institute, were eligible for this study. Patients with complete loss of motor (AIS grade A or B) at admission were selected and divided into two groups according to the functional outcomes at discharge, retrospectively. Patients with AIS grade B or lower at discharge were categorized as poor outcome group (group P) and patients with AIS grade C or higher as good outcome group (group G). MRI and CT characteristics and other factors that affected clinical outcomes were assessed by single and multiple regression analyses. In MRI, the presence of confined low intensity changes in diffuse high intensity area (Low in High), loss of subdural space and increase in cord caliber in adjacent to lesion epicenter no less than single vertebral height (Cord Swelling) and no less than 50% of vertebral displacement or cord compression of lesion epicenter (Cord Compression) on T2-weiighted sagittal images were assessed.

Results: Of the 87 patients with complete loss of motor function at initial examination, 33 were categorized as good outcome group with a mean ASIA motor score (MS) of 9.7 at admission and of 46.8 at discharge. 54 were categorized as poor outcome group with a mean ASIA-MS of 12.8 at admission and of 17.4 at discharge, respectively. As shown in Table 1, a multivariate regression analysis revealed that the intramedullary low in high intensity area and cord compression on MR images were significantly risk factors for poor functional prognosis following CSCI ($p<0.05$). In contrast, the variables about the presence of diabetic mellitus, ankylosing spinal hyperostosis (ASH) and complete loss of motor and sensory function (AIS grade A) at initial examination did not exhibit significant. Furthermore, CSCI without bone injury and remaining of touch sensation in lower extremity also did not affect positively in clinical outcomes from the statistical standpoint.

Conclusion: In this study, our results show that MRI features such as an intramedullary low in high intensity change and severe cord compression are highly indicative of poor prognosis for the CSCI patients with severe paresis at injury. When we find such a negative characteristics on initial MRI, we should take a consideration of possibility of poor prognosis.

Table 1. Overview of univariate and multivariate regression analysis

	Univariate		Multivariate*	
	OR (95%CI)	*P*	OR (95%CI)	*P*
MRI & CT				
Cord Compression	6.3 (2.4-16.6)	***< 0.001***	4.8 (1.4-17.1)	***< 0.05***
Cord Swelling	17.4 (2.2-137.4)	***< 0.001***	4.6 (0.5-43.6)	*0.19*
T2WI Intramedullary Low in High	5.6 (1.9-16.7)	***< 0.01***	6.2 (1.5-26.4)	***< 0.05***
ASH	8.2 (1.0-66.7)	***< 0.05***	2.3 (0.2-25.8)	*0.49*
CSCIWORA	0.3 (0.1-0.9)	*0.05*	0.4 (0.1-1.7)	*0.21*
Others				
DM	3.9 (1.0-14.5)	*0.06*	3.0 (0.5-17.3)	*0.18*
Complete Loss of Motor & Sensory	2.5 (0.9-6.8)	*0.08*	0.5 (0.1-2.4)	*0.42*
Touch Sensation remains in L/E	0.3 (0.1-1.1)	*0.09*	0.3 (0.0-2.1)	*0.23*

* The multivariate model included age, sex, and all the variables listed in the table.

1st Place Basic Science Research Award Winner

Transplantation of Neural Stem/Progenitor Cell Derived from Human iPS Cells with Gamma-Secretase Inhibitor Treatment Promotes Motor Functional Recovery and Axonal Regrowth After Chronic Spinal Cord Injury

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Introduction: We have previously reported that treatment with a clinically relevant drug gamma-secretase inhibitor (GSI) promotes the growth of more mature neurons in human iPSC-derived transplantation for subacute spinal cord injury (SCI). The treatment of chronic SCI, however, is very different to that of acute or subacute SCI due to phase-dependent changes in the intraspinal environment variation such as glial scar and cavity formation. Reports showing favorable outcomes in chronic SCI have been extremely limited in the past. The purpose of this study is to evaluate the merits of treating neural stem/progenitor cells derived from human iPS cells (hiPSC-NS/PCs) with GSI prior to transplantation in chronic SCI.

Materials/Methods: Non-tumorigenic hiPSC-NS/PCs were cultured with or without GSI for 1 day before transplantation. Contusive SCI was induced at T10 level in immunodeficient NOD/SCID mouse. hiPSC-NS/PCs with GSI treatment (GSI group), hiPSC-NS/PCs without GSI treatment (Control group) or PBS (PBS group) were transplanted at 42 days after injury. The growth/survival and histological analyses of the transplanted cells were monitored with bioluminescence imaging and immunohistochemistry. Behavioral analyses were performed using BMS scoring, rota-rod testing and treadmill gait analyses.

Results: Both GSI treated and untreated hiPSC-NS/PCs survived following transplantation in the chronic phase without any obvious tumorigenicity. In the GSI group, the proportion of mature neurons increased significantly compared with the control group, and they integrated with the host neural circuitry. Quantitative analyses revealed that the transverse area of the spinal cord at the lesion epi-center and +4mm caudal area were significantly larger in the GSI group compared with the other groups. Luxol fast blue (LFB) staining also showed that the GSI group was significantly larger compared with the other groups in LFB-positive myelinated areas at all sites examined. There were significantly more neuronal and serotonergic fibers in the GSI group. Moreover, immuno-electron microscope analysis revealed that there was a lot of transplanted cells derived regenerative axons and pre-/post-synaptic formation, in which myelinated by host cells and localized in the active remyalination site in host injured spinal cord (Fig 1). We observed significant improvements in functional recovery at 56 days after transplantation of hiPSC-NS/PCs with GSI treatment (Fig 2). At 84 days after transplantation, in the GSI group, the mice remained on the rotating rod for a significantly longer time compared with the other group. The treadmill gait analyses also revealed a significantly longer stride length and smaller stance angle in the GSI group than in the other groups.

Conclusion: This study indicates that treating hiPSC-NS/PCs with GSI before transplantation resulted in a significantly greater tendency for the axons to regrow in the injured spinal cord,

which helps to improve motor function in chronic SCI. We believe that, by treating the cells for transplantation with GSI, they gain the ability to extend their regenerative axons despite the environment being disadvantageous in the chronic phase following a SCI.

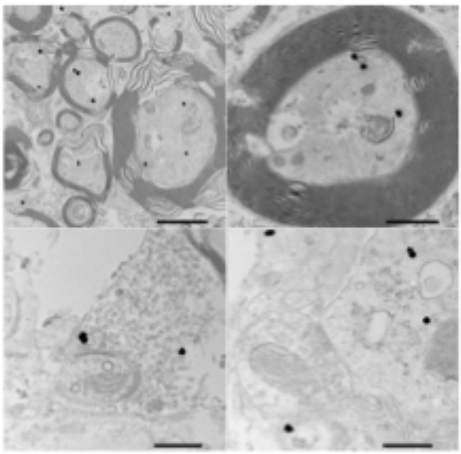

Figure 1. Representative images of immune-electron microscopy. Transplanted cells were detectable by the black dots observed upon anti-human specific cytoplasm (STEM121) antibody staining. Anti-STEM121 antibody labeling cells were localized in the active remyalination site in host injured spinal cord. At a high magnification, human regenerative axons myelinated by host cells. Both pre- and post-synapses labeled with STEM121-positive dots with almost equal frequency. Scale bar, 2 **µ**m (upper left), 1 **µ**m (upper right), 500 nm (lower).

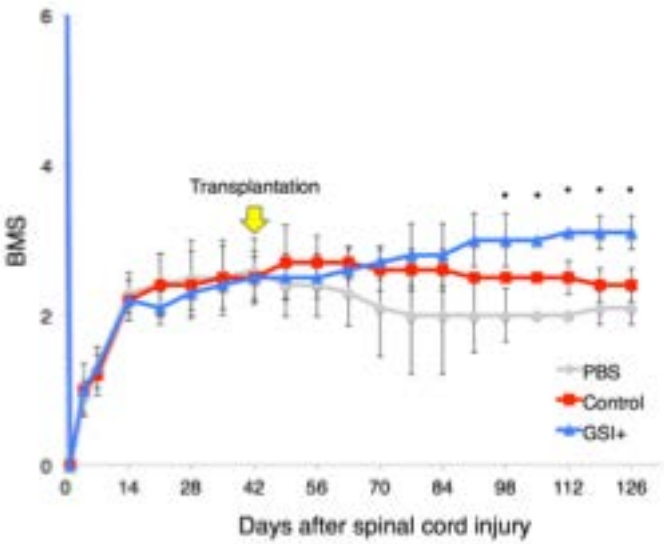

Figure 2. Comparison of the BMS scores among the PBS, control, and GSI groups. Motor function in the hind limbs was assessed weekly for up to 84 days after transplantation using the BMS score (PBS group, n = 10; control group, n = 10; GSI group, n = 10 mice). *p <

Traumatic Cervical Spinal Cord Injuries with Fracture: An Investigation of Early vs. Delayed Surgery among 6,636 Propensity-Matched Patients

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Introduction: Currently, optimal timing of surgical intervention for traumatic spinal cord injuries (SCIs), a life-altering event and enormous economic burden, is unclear. Our goal was to investigate the perioperative and postoperative outcomes in patients with traumatic SCIs.

Methods: The NIS was queried for ICD-9 codes pertaining to SCI w/ fracture (806-806.19). Patients without traumatic etiology, neuromuscular conditions (e.g. downsyndrome), with SCIWORA, and without complete time to procedure(TTP) data were excluded. Patients were stratified into 7 groups by TTP: Same-day as admission (SD), 1-day delay (1D), 2-day delay (2D), 3-day delay (3D), 4-7 days delay (4-7D), 8-14 days delay (8-14D), >14 days delay (>14D). In an attempt to reduce covariate bias, groups were propensity score matched(PSM) by age, comorbidity index(CCI), mechanism of injury (MOI)(fall, MVA, pedestrian), trauma status at admission (hypotension, shock, hemorrhage, intubation), and concurrent injuries(-none, major[skull,pelvis,rib,femur,humerus fxs], minor[radius,ulna,carpals,tarsals,phalanges,tibua,fibula fxs]). Surgical details, perioperative complications, length of stay(LOS), total charges, and discharge disposition was compared. Binary logistic regressions determined independent predictors of varying complications (reference: same-day).

Results: 28,414 patients were included. After PSM, 6,636 patients remained (948 per group). Overall age 49.3, gender: 25.4%F, 67.4% white, 15.1% black, 11.4% hispanic, CCI: 1.2. Most common MOIs were 38.2% MVAs, 32% falls, 19.9% pedestrian accidents, 5.7% assaults, 4.2% sports. Procedure rates were 64.2% spinal fusion (36.8% 2-3 lvls, 16.1% 4-8 lvls, 1.4% >8 lvls), 32.5% decompressions, 14.7% halo/traction. SD was associated with the highest mortality (28.8% vs. 6.1-11.6%), lowest LOS (15.14 vs 15.24-54.2days) and total hospital charges ($172,086.93 vs $204,931.12-$545,797.14), all p<0.001. Relative to SD, all delay groups had significantly increased odds of postoperative respiratory complications (1D-OR: 2.8[1.5-5.1] à 8-14D-OR: 5.9[3.4-10.3]), infection (1D-OR: 1.2[0.3-4.1] à >14D-OR: 10.2[3.9-26.7]), discharging to another care facility (1D-OR: 3.0[2.1-4.3] à 8-14D-OR: 3.1[2.2-4.3]), or discharging with quadriplegia (1D-OR: 1.1[0.8-1.4] à >14D-OR: 1.5[1.2-1.9], exception 3D-OR: 0.9[0.6-1.1]). 2D and 3D were significantly less likely to develop ARDS

(OR: 0.8[0.6-1.0], OR: 0.9[0.7-1.1]) and any complication (OR: 0.9[0.8-1.1], OR: 0.7[0.6-0.9]), while all delay groups were less likely to develop sepsis (ORs: 0.6-0.9, exception >14D OR: 2.3[1.7-3.1]) and paraplegia (ORs 0.0-0.8) compared to SD.

Conclusion: Patients operated on the same day as admission were significantly less likely to develop infection, respiratory complications, or discharge to another care facility. Same-day operative patients were also less likely to discharge with quadriplegia, and more likely to discharge with paraplegia, indicating early intervention may significantly benefit discharge neurologic status. 2-Day and 3-Day operative patients exhibited significantly less risk of developing ARDS, and complication, or sepsis. While immediate and 2-3 day delayed operations appear to have unique advantages, patients who underwent procedures >14 days after admission were associated with poor outcomes and discharge disposition.

Prospective 20-Year Follow-Up Study of Patients with Whiplash Associated Disorders Compared with Healthy Volunteers Using Magnetic Resonance Imaging

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Introduction: Very few studies illustrated long-term degenerative changes of cervical spine in patients with whiplash associated disorder (WAD). The purpose of this study was to evaluate the degenerative changes of the cervical spine that developed over 20 years in patients after whiplash injury using MRI, comparing with that developed in healthy volunteers.

Materials/Methods: In 1990s, 497 asymptomatic volunteers and 506 patients who suffered from acute whiplash injury were evaluated for the prevalence of degenerative changes in the cervical spine using MRI. 193 subjects (control group) and 81 patients (WAD group) from the original cohort were recruited for this study. There were no statistically significant differences between the two groups in the male to female ratio, the mean age, and the mean follow-up duration, at the follow-up time. Degenerative changes of the cervical spine were assessed on MRI using the original numerical grading systems for all intervertebral levels between C2 and T1. The evaluated findings were “Decrease in signal intensity of the intervertebral disc (DSI)”, “Anterior compression of the dura and spinal cord (AC)”, “Posterior disc protrusion (PDP)”, “Disc space narrowing (DSN)”, and “Foraminal stenosis (FS)”. The progression of degeneration was defined as progression of at least one grade at one vertebral disc or more. They were also asked about cervical spine-related symptoms. The prevalence of the clinical symptoms and the incidence of progression for each degenerative finding between the two groups were compared. The relationships between progression of degeneration on MRI and the change in the severity of the cervical spine related symptoms were also evaluated.

Results: The cervical disc degeneration on MRI progressed in 95.1% in the WAD group and 95.3% in the control group (N.S.). The progression rates of DSI was 84.0%, AC 77.8%, PDP 85.2%, DSN 9.9%, FS 12.4% in WAD group. The rates in control group were 81.4%, 86.0%, 82.9%, 15.0%, 19.2%, respectively (N.S).

WAD patients complained neck pain in 87.7%, stiff shoulders in 65.4%, headache in 37.0%, arm pain in 14.8%, and arm numbness in 9.9% at the time of the original study and 24.7%, 70.4%, 22.2%, 12.4%, and 7.4%, at the present study, respectively. While in the control

group, the frequencies of each symptom were 18.1%, 45.1%, 13.0%, 4.7%, and 8.8%, respectively. At follow-up, neck pain deteriorated or remained unchanged in 23% and stiff shoulders in 57%. The progression of degenerative changes on MRI was not significantly related with the unfavorable outcomes (unchanged or deteriorated) of neck pain and stiff shoulders in WAD patients.

Conclusion: Neck related clinical symptoms were more frequently observed in the WAD group, although neck pain significantly improved in WAD patients at follow-up. However, the progressions of the degenerative changes on MRI over 20 years were similar between the two groups. And, the progressions of the degenerative changes were not related with the unfavorable outcomes of the patients in the WAD group. These results suggest that whiplash injury may not accelerate degeneration of the cervical spine over 20 years and may not result in unfavorable long-term clinical outcomes.

Opioids Delay Healing of Spinal Fusion: A Rabbit Posterolateral Spinal Fusion Model

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Introduction: Opioid use is prevalent for management of pre- and post-operative pain in patients undergoing spinal fusion. In-vitro and pre-clinical studies suggest a negative effect of opioids on bone healing and turnover. However, the effect of opioids on healing of spinal fusion has not been investigated before. Failure of fusion healing remains a concern after spinal fusion as it can result in poor clinical outcome, need for revision surgery, and additional healthcare costs. The objective of our study was to study the effect of systemic opioids on the healing of spinal fusion using a rabbit posterolateral spinal fusion model.

Methods: 24 adult, New Zealand white rabbits were studied in two groups. The opioid group (n=12) received four-weeks pre-operative and six-weeks post-operative transdermal fentanyl. The control group (n=12) received only peri-operative pain control as necessary. All animals received a bilateral L5-L6 posterolateral spinal fusion using iliac crest autograft. Animals were euthanized at the six-week post-operative time point, and assessment of fusion was done by manual palpation, plain radiographs, micro-computed tomography (microCT) using previously reported scoring systems, and histological analysis.

Results: 12 animals in control group and 11 animals in the opioid group were available for analysis at the end of six weeks. The mean serum fentanyl level in the opioid group at pre-operative assessment (before skin incision) was 2.73± 0.24 ng/ml, and 1.58± 0.71 ng/ml four-weeks post-operatively. The fusion scores on manual palpation, radiographs, and microCT were not statistically different. Three-dimensional microCT morphometry found that the fusion mass in the opioid group had a lower bone volume (p=0.09), lower trabecular number **(p=0.02)** and higher trabecular separation **(p=0.02)** as compared to control. On low power (10x) histological analysis, most of the sections showed 75-100% of the fusion mass composed of new bone, and some sections showed up to 20% of cartilage and fibrous tissue. On high power (79x) analysis in the control group, there was remodeling of woven bone to lamellar organization with incorporation of osteocytes, and formation of mature marrow **(Fig 1)**. In the opioid group, there was presence of hypertrophied osteoblasts and woven new bone formation. There was no lamellar organization or development of mature marrow elements **(Fig 2)**. Less dense trabeculae on microCT correlated with histological findings of relatively immature fusion mass in the opioid group.

Conclusion: Optimization of modifiable patient factors before spinal fusion represents a cost-effective way to improve chance of fusion success. A biologically plausible and modifiable exposure that has not been studied in spinal fusion is opioid use. We found that presence of systemic opioids in the pre- and post-operative period negatively affects the process of spinal fusion healing. Fusion mass in animals with opioid exposure had fewer, and widely spaced trabeculae on microCT analysis. Additionally, there was a delay in the maturation of woven bone on histological analysis in the opioid group. These findings indicate a less mature and inferior quality fusion mass because of opioids, warrant concern, and lay foundation for further research.

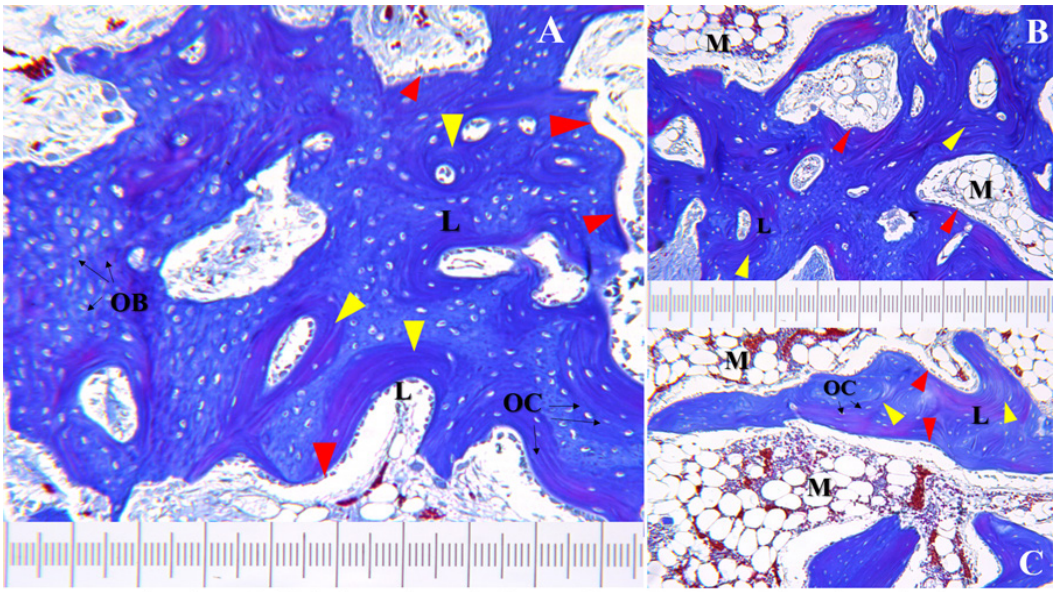

Fig. 1 Representative micrograph of fusion in control group showing woven bone undergoing remodeling and maturation of intramembranous woven bone. ***A-C*** -Lamellar (L) organization of matrix (yellow arrow) with incorporated osteocytes (OC). Small and less dense osteoblasts seen lining new bone **(red arrow).** Developing mature marrow elements (M). ***A*** – Area of woven bone with haphazard arrangement of incorporated osteoblasts (OB) and unorganized matrix can be seen. Compare to smaller and tapered osteocytes (OC) in organized lamellar (L) matrix. **(Mallory aniline blue connective tissue stain, 79x magnification)**

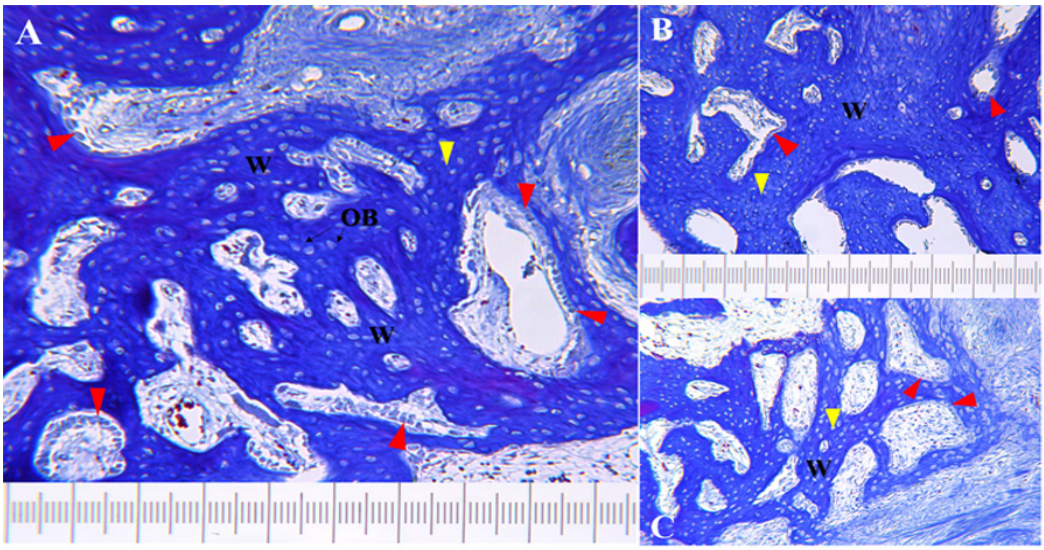

Fig. 2 Representative micrograph of fusion in opioid group showing intramembranous woven bone. ***A-C*** – Woven (W) bone **(yellow arrow)** with haphazard arrangement of incorporated osteoblasts (OB) and unorganized matrix can be seen. Hypertrophied and dense osteoblasts seen lining new bone **(red arrow). (Mallory aniline blue connective tissue stain, 79x magnification).**

Improvements in Pain and Physical Function After Cervical Spine Surgery Predict Betterment in Other Areas of Health and Wellness

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Introduction: The primary goal of surgery for cervical degenerative disease is to reduce pain and improve physical function. However, patients often experience problems in other areas of health and wellness. In setting expectations for outcomes of cervical spine surgery, it would be beneficial to understand how improvements in pain and physical function may influence these other health domains. PROMIS is a multi-dimensional assessment that measures spine patients' pain, physical function, fatigue, anxiety, depression, sleep disturbance, and social participation with a population mean of 50 (SD 10).

Methods: Patients undergoing surgery for degenerative cervical disease completed PROMIS surveys preoperatively and 6 weeks and 3, 6 and 12 months postoperatively. Between December 2014 and January 2018, PROMIS data was collected for 561 visits of 220 unique patients. Repeated measures logistic regression was used to calculate the odds of a meaningful improvement (MCID) in PROMIS domains given a 5-point improvement in either pain or physical function.

Results: A 5-point decrease in pain was associated with 76% increased odds of MCID in fatigue (95% CI 1.18, 2.62 p=.006), 57% increased odds for anxiety (CI 1.02, 2.42, p=.039), 76% increased odds for sleep disturbance (CI 1.33-2.33, p<.001), and 197% increased odds for social participation (CI 1.38, 3.48, p=.001). Similarly, a 5-point gain in physical function predicted 83% increased odds of MCID in social participation (CI 1.06-3.15, p=.030).

Conclusions: Decreases in pain yield meaningful improvements in fatigue, anxiety, sleep disturbance, and social participation. Additionally, gains in physical function result in meaningful improvements in social role participation. Although patients present for cervical spine surgery primarily due to pain and limitations in physical function, our results suggest that improvement in these domains will lead to improvements in other areas of health and wellness.

Efficacy of Posterior Decompression with Instrumented Fusion for K-line (-)-type Cervical OPLL - Comparison between Long Fusion and Short Fusion

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Introduction: We have reported a concept of K-line for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament (OPLL). K-line is the line that connects the midpoints of the spinal canal at C2-7 at the lateral view of the cervical radiograph in the neutral position. By using the K-line, we can evaluate the alignment of the cervical spine and the size of OPLL in one parameter. When the OPLL exceeds the K-line, the OPLL is classified into a K-line (-)-type. We previously reported poor surgical outcome of laminoplasty alone for K-line (-)-type cervical OPLL. We also reported an advantage of additional instrumented fixation for K-line (-)-type cervical OPLL. The addition of posterior instrumented fusion might eliminate the dynamic factor and prevent progression of postoperative kyphosis and off-balance. The purpose of this study was to assess the adequate range of instrumented fixation for posterior decompression with instrumented fusion (PDF) in patients with K-line (-)-type cervical OPLL.

Methods: Seventeen cervical OPLL patients of K-line (-)-type who underwent PDF between 2004 and 2011 in our institute were retrospectively reviewed. Follow-up durations at postoperative period was 106 months (minimum 60 months) on average. We divided those 17 patients into two groups whether the fixation is focal or long fusion. We evaluated their neurological status and radiographic findings retrospectively.

Results: There were nine cases whose range of fixation was focal to the most stenotic level (S group) and eight cases whose range of fixation was from C2 to C7 (Th1) (L group). No statistical difference was seen between the two groups for preoperative clinical data including age, gender, duration of symptoms, occupation ratio of OPLL, and C2-7 angle. The average JOA score was 10.9 in S group and 12.3 in L group at a year follow-up. The average JOA score was 10.5 in S group and 10.9 in L group at final follow-up. The average recovery rate was 40% in both group at a year follow-up. The recovery rate was 36% in S group and 24% in L group at final. The data of the C2-7 angle and CGH-C7 SVA (center of the gravity of the head to C7 sagittal vertical axis) showed 10 degrees increase of kyphosis and 16mm off-balance in the S group, whereas 4 degrees increase of kyphosis and 5mm off-balance were seen in the L group. The range of motion at the maximal spinal cord compression level controlled during the follow-up period in both groups.

Conclusion: Relatively good surgical outcome could be obtained by posterior decompression with instrumented fusion for patients with K-line (-)-type cervical OPLL in both short fusion

and long fusion group. The addition of posterior instrumented fusion eliminated the dynamic factor and preserved local stabilization in both two groups. Slight progression of cervical kyphosis and off-balance was observed in S group. But the change of alignment and sagittal balance is limited. The ratio of change might not have impact clinically so much.

Evaluation of PROMIS Physical Function in Anterior Cervical Discectomy and Fusion

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Introduction: The Patient-Reported Outcomes Measurement Information System (PROMIS) was developed to enhance collection of patient reported outcomes (PROs) that is easy to administer and applicable across a wide range of patient populations. As PROMIS becomes increasingly utilized, it is important to assess its validity among procedure-specific populations. In this context, the purpose of this study is to evaluate the utility of PROMIS physical function (PF) domain as compared to legacy measures of PROs among patients undergoing an anterior cervical discectomy and fusion (ACDF).

Materials/Methods: Patients undergoing a primary, 1-3 level ACDF were retrospectively identified from a prospectively-maintained surgical registry. PROMIS PF and legacy PRO scores were obtained at preoperative and 6-week, 12-week, and 6-month postoperative visits. PROMIS PF was administered using the computer adaptive testing format. Legacy PROs included Neck Disability Index (NDI), Short Form-12 (SF-12) physical composite, Visual Analog Scale (VAS) neck pain, and VAS arm pain. Postoperative improvements in PROs were assessed using paired t-tests. Correlations between PROMIS and legacy PROs were tested using Pearson correlation coefficient with strength of association interpreted as follows: $|r|=0.1$-0.3, weak; $|r|=0.3$-0.5, moderate; $|r|=0.5$-1.0, strong. Statistical significance was set at $p<0.05$.

Results: A total of 57 ACDF patients (31 males) were included in this analysis. The average age of the sample was 50.1 years. The majority of patients underwent a single level fusion (61.4%). The mean preoperative PROMIS PF score was 40.0 ± 6.4. PROMIS PF scores significantly improved at 12 weeks ($p<0.001$) and 6 months ($p<0.001$) postoperatively, but not at 6 weeks ($p=0.058$). NDI, VAS neck pain, and VAS arm pain scores demonstrated significant improvement at all postoperative timepoints ($p<0.001$). SF-12 scores only exhibited significant improvement at the 6-month follow up visit. Improvements in PROs are presented in **Table 1.** Significant correlations between PROMIS PF and NDI and SF-12 were identified at all preoperative and postoperative timepoints ($|r|>0.5$, $p<0.001$; **Table 2**). PROMIS PF also exhibited strong correlations with VAS neck pain at postoperative timepoints ($|r|>0.5$, $p<0.001$; **Table 2**), and a moderate correlation preoperatively ($r= -0.405$, $p=0.018$; **Table 2**). Strong correlations between PROMIS PF and VAS arm pain were not identified (**Table 2**).

Conclusions: Patients undergoing a primary 1-3 level ACDF experience significant improvements in PROMIS PF scores at 12-week and 6-month postoperative visits, but not at 6-weeks. Furthermore, PROMIS PF exhibits strong correlations to NDI and SF-12 at all preoperative and postoperative timepoints. These results suggest that PROMIS PF accurately measures physical function and may be used in lieu of legacy physical function instruments for patients undergoing ACDF.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Table 1. Changes in Patient Reported Outcomes Following ACDF

	Mean ± SD	Change ± SD	†p-value*
PROMIS			
Preoperative	40.0 ± 6.4	-	-
6-week	42.0 ± 7.3	2.1 ± 7.4	0.058
12-week	**46.3 ± 9.6**	**5.5 ± 8.4**	**<0.001**
6-month	**47.1 ± 8.8**	**7.1 ± 7.0**	**<0.001**
NDI			
Preoperative	35.9 ± 18.0	--	-
6-week	**27.8 ± 19.0**	**-7.5 ± 15.3**	**<0.001**
12-week	**22.5 ± 18.7**	**-13.8 ± 16.7**	**<0.001**
6-month	**20.2 ± 17.4**	**-14.1 ± 18.7**	**<0.001**
VAS Neck			
Preoperative	5.9 ± 2.2	**--**	**-**
6-week	**3.3 ± 2.7**	**-2.5 ± 2.7**	**<0.001**
12-week	**2.6 ± 2.5**	**-3.3 ± 2.8**	**<0.001**
6-month	**2.8 ± 2.7**	**-3.0 ± 3.1**	**<0.001**
VAS Arm			
Preoperative	5.6 ± 2.4	--	-
6-week	**2.4 ± 2.5**	**-3.2 ± 2.9**	**<0.001**
12-week	**2.9 ± 3.1**	**-2.8 ± 3.4**	**<0.001**
6-month	**3.1 ± 3.2**	**-2.4 ± 3.4**	**<0.001**
SF-12			
Preoperative	36.0 ± 8.3	**-**	**-**
6-week	35.3 ± 8.4	-0.3 ± 8.9	0.840
12-week	40.1 ± 9.4	2.7 ± 9.1	0.060
6-month	**41.5 ± 9.8**	**4.6 ± 8.6**	**<0.001**

SD = Standard Deviation; VAS = Visual Analog Scale; NDI = Neck Disability Index; SF-12 = Short Form-12 Physical Composite Score

***Boldface** indicates statistical significance.

†P-value is calculated using paired Student's t-test comparing scores at each time point to preoperative values

Table 2. PROMIS Association with Postoperative Outcomes

	r*	p-value
NDI		
Preoperative	**-0.600**	**<0.001**
6-week	**-0.617**	**<0.001**
12-week	**-0.605**	**<0.001**
6-month	**-0.723**	**<0.001**
VAS Neck		
Preoperative	-0.405	0.018
6-week	**-0.509**	**<0.001**
12-week	**-0.584**	**<0.001**
6-month	**-0.595**	**<0.001**
VAS Arm		
Preoperative	-0.458	<0.001
6-week	-0.493	<0.001
12-week	-0.201	0.190
6-month	-0.492	<0.001
SF-12		
Preoperative	**0.703**	**<0.001**
6-week	**0.621**	**<0.001**
12-week	**0.761**	**<0.001**
6-month	**0.760**	**<0.001**

SD = Standard Deviation; VAS = Visual Analog Scale; NDI = Neck Disability Index; SF-12 = Short Form-12 Physical Composite Score
*__Boldface__ indicates strong correlation with PROMIS score at the corresponding timepoint as identified by Pearson correlation coefficient ($|r| \geq 0.5$, $p<0.05$)

Predicting the Combined Occurrence of Poor Clinical and Radiographic Outcomes Following Cervical Deformity Corrective Surgery

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Introduction: Cervical deformity (CD) correction increasingly becomes more challenging and complex. The aim of this study was to use baseline demographic, clinical, and surgical factors to predict a poor outcome following CD surgery.

Methods: Retrospective review of a multicenter prospective cervical deformity database. CD was defined as at least one of the following:C2-C7 Cobb>10°, CL>10°, cSVA>4cm, CBVA>25°. Patients were categorized based on having an overall poor outcome or not. Outcome Measures: Cervical alignment parameters: cervical sagittal vertical axis (cSVA), C2-7 cervical lordosis(CL), T1 Slope minus CL(TS-CL). Upper cervical/cranial parameters: Slopes from C0, C1, and C2, and C0-2 angle. Surgical outcomes: complications, operative time, blood loss. Health-related quality of life measures: NDI, EQ5D, mJOA. A 'poor outcome' was defined as having all three of the following categories met: radiographic poor outcome: deterioration or severe radiographic malalignment 1-year post-operatively for cSVA or TS-CL, clinical poor outcome: failing to meet MCID for NDI or having severe mJOA Ames modifier, complications/reop poor outcome: major complication, mortality, or reoperation for a complication other than infection. Univariate logistic regression followed by multivariate regression models were performed and internal validation performed by calculating the AUC.

Results: 89 cervical deformity patients were included (61.9 years, 65.2% female, BMI 29.2kg/m^2). By 1-year post-op, 18 patients were characterized as having an overall poor outcome. For radiographic poor outcomes, 73% of patients either deteriorated or remained severe for TS-CL, 8% for cSVA, 34% for horizontal gaze, and 28% for global SVA. In looking at clinical poor outcomes: 80% of patients did not reach MCID for EQ5D, 60% for NDI, and 24% of patients had a severe mJOA score(<12). For the complications/mortality poor outcome, 28 patients experienced a major complication, 11 had a reoperation, and one complication-related death. 75% of patients with a poor clinical outcome had a poor radiographic outcome. 35% of poor radiographic and 37% of poor clinical outcome patients had a major complication. A poor outcome was predicted by the following combination of factors: osteoporosis, baseline neurologic status, use of transition rod, number of posterior decompressions, baseline

pelvic tilt, T2-T12 kyphosis, T1S, C2-T3 SVA, CTPA, global SVA, and number of levels in maximum thoracic kyphosis. The final model predicting a poor outcome(AUC=86%) included the following: osteoporosis(OR:5.9, CI:0.9-39), worse baseline neurologic status(OR: 11.4, CI: 1.8-70.8), baseline pelvic tilt >20°(OR:0.92, CI:0.85-0.98), >9 levels in maximum thoracic kyphosis(OR:2.01, CI:1.1-4.1), preop C2-T3 SVA>5.4cm(OR:1.01, CI:0.9-1.1), and global SVA>4cm(OR:3.2, CI:.09-10.3).

Conclusions: 20.2% of CD patients in this study had a poor overall outcome, defined by deterioration in radiographic and clinical outcomes, and a major complication, with 75% of patients with a poor clinical outcome had a poor radiographic outcome. A poor outcome was most strongly predicted by severe baseline neurological deficit, SVA>4, and including more of the thoracic maximal kyphosis in the construct.

Foraminal Re-Stenosis After Posterior Cervical Foraminotomy with Laminoplasty

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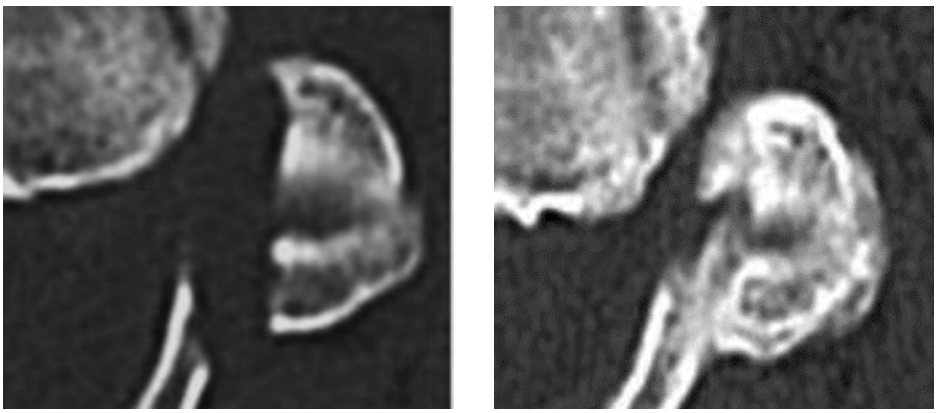
Objective: Studies evaluating recurrent foraminal stenosis after posterior cervical foraminotomy (PCF) and investigating risk factors of foraminal re-stenosis are limited. The purpose of this study was to investigate the radiographic recurrence of foraminal stenosis after PCF.

Methods: Seventy-eight consecutive patients (50 males and 28 females, mean age of 62 years at surgery) with cervical spondylotic radiculomyelopathy who underwent PCF concomitant with open-door laminoplasty were included. This retrospective case-control study has a minimum follow-up of 2 years. In total, 133 foramina (C5/6: 79 foramina, C6/7: 54 foramina) undergoing PCF were radiographically evaluated using the following parameters: disc height, focal range of motion at the corresponding disc level, foraminal diameter (FD) and facet joint width (FW) in the axial view, and re-stenosis rate (RR) of foramina. RR was calculated in the axial view as follows: (foraminal regrowth at 2 years after surgery) / (foraminal enlargement immediate postoperatively) × 100%.

Results: FDs preoperatively, postoperatively, and at 2-year follow-up were 2.2, 6.6, and 4.6 mm, respectively, and FWs were 14.5, 8.6, and 10.6 mm, respectively (Fig.1). Both parameters significantly increased at 2-year follow-up ($p<0.01$). The mean RR was 42% (range, 22-66%). In the analysis of the risk factors of higher RR (>50%), logistic regression demonstrated preoperative posterior disc height (PDH) (OR=0.33; 95% CI=0.193-0.563; $P<0.001$) as a risk factor. Receiver operating characteristic curve showed that the cut-off value of RR 50% was PDH of 1 mm (AUC 0.73, sensitivity 52%, specificity 86%, p value 0.001).

Conclusion: After posterior foraminotomy following laminoplasty, enlarged foraminal space gradually decreased during the 2-year follow-up period. The main reason of foraminal re-stenosis was bone regrowth of the medial aspect of the resected facet joint, which is caused by disc degeneration with loss of PDH.

Foraminal re-stenosis 2-years after surgery



PO1W **PO2Y**

Figure 1

Preoperative Chronic Opioid Therapy: A Risk Factor for Reoperations, Complications, and Postoperative Opioid Use Following Cervical Fusion Surgery

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Introduction: Opioid therapy is one of the most effective and commonly practiced methods to control acute post-operative pain. However, concerns relating to overwhelming use of prescription narcotics including inherent risk of abuse, tolerance, and inferior outcomes following major surgery has been a contentious issue. The purpose of this study is to elucidate the impact of preoperative chronic opioid therapy (COT) on outcomes following cervical spine fusions.

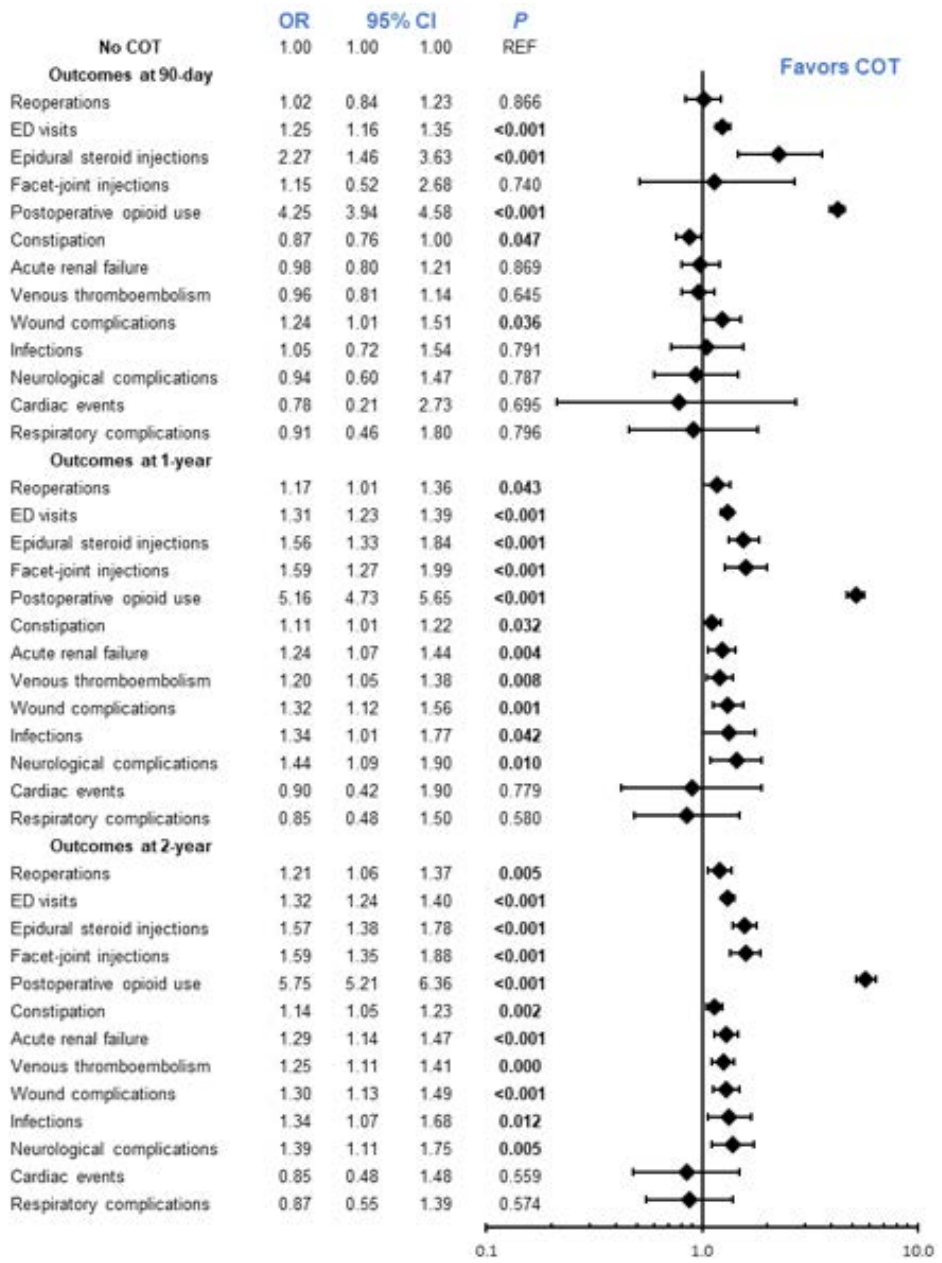
Materials/Methods: The Humana Inc. dataset was queried from 2007-2015 for patients undergoing primary cervical spine arthrodesis [ICD-9 codes 81.01-81.03] Primary outcome measures were 1-year and 2-year reoperation rates, emergency department (ED) visits, epidural steroid and facet-joint injections, adverse events and prolonged postoperative opioid use. Secondary outcomes included short-term outcomes including 90-day complications (new constipation, acute renal failure, venous thromboembolic events, infections, post-operative wound, neurologic, respiratory and cardiac complications). COT was defined as a history of opioid prescription filling within 3-months prior to surgery and was the primary exposure variable of interest. Generalized linear models investigated the association of preoperative COT on primary and secondary endpoints following risk-adjustment.

Results: A total of 20730 patients [51.3% female; 85.9% elderly >50 years] underwent primary cervical spine arthrodesis. Of these, 10539 [n=50.8%] were on preoperative COT. Postoperatively, 75.3% were on narcotics at 3-month and 29.8% remained on opioids at 1-year. Multivariable regression models following risk adjustment noted COT to be associated with increased odds of 90-day ED visit (OR:1.25; p<0.001), epidural steroid injections (OR:2.27; p<0.001), wound complications (OR: 1.24; p=0.036). At 1-year, risk-adjusted analysis demonstrated COT to be strongly associated with reoperations (OR: 1.17;p=0.043), ED visits (OR:1.31; p<0.001), epidural steroid (1.56; p<0.001) and facet joint (OR:1.59; p<0.001) injections, and adverse events including wound complications (OR:1.32 ;p<0.001), infections (OR:1.34 p=0.042), constipation (OR: 1.11 p=0.032), neurological complications (OR:1.44; p=0.01), acute renal failure (OR: 1.24; p=0.004) and venous thromboembolism (OR:1.20; p=0.008). COT continued to be a significant risk-factor for 2-year reoperations including adjacent segment disc disease (OR: 1.21; p=0.005), ED visits (OR:1.32; p<0.001), epidural steroid (OR:1.57; p<0.001) and facet-joint injections (OR:1.59; p<0.001), adverse events including constipation (OR:1.14; p=0.002), venous thromboembolism (OR:1.25; p<0.001), acute renal failure (OR:1.30; p<0.001), wound complications (OR:1.57; p=0.003) and infections (OR:1.34; p=0.012), neurological complications (OR:1.39; p=0.005) Preoperative COT was associated with prolonged postoperative narcotic use at 3-month (OR:1.30; p<0.001), 1-year (OR:5.17; p<0.001) and at 2-year (OR:5.75; p<0.001) after cervical arthrodesis [Fig.1]

Conclusion: Preoperative COT is a modifiable risk factor and is strongly associated with prolonged postoperative opioid use. Additionally, COT was associated with inferior short-

term and long-term outcomes after cervical spine arthrodesis. Our study findings recommend development of a multi-disciplinary preoperative opioid weaning protocol prior to spine surgery to optimize post-operative outcomes, improve patient safety and minimize narcotic consumption.

Figure 1. Generalized linear model demonstrating the risk-adjusted association of preoperative chronic opioid therapy (COT) with outcomes assessed at 90-day, 1-year and 2-year following cervical spine arthrodesis



	OR	95% CI		P
No COT	1.00	1.00	1.00	REF
Outcomes at 90-day				
Reoperations	1.02	0.84	1.23	0.866
ED visits	1.25	1.16	1.35	**<0.001**
Epidural steroid injections	2.27	1.46	3.63	**<0.001**
Facet-joint injections	1.15	0.52	2.68	0.740
Postoperative opioid use	4.25	3.94	4.58	**<0.001**
Constipation	0.87	0.76	1.00	**0.047**
Acute renal failure	0.98	0.80	1.21	0.869
Venous thromboembolism	0.96	0.81	1.14	0.645
Wound complications	1.24	1.01	1.51	**0.036**
Infections	1.05	0.72	1.54	0.791
Neurological complications	0.94	0.60	1.47	0.787
Cardiac events	0.78	0.21	2.73	0.695
Respiratory complications	0.91	0.46	1.80	0.796
Outcomes at 1-year				
Reoperations	1.17	1.01	1.36	**0.043**
ED visits	1.31	1.23	1.39	**<0.001**
Epidural steroid injections	1.56	1.33	1.84	**<0.001**
Facet-joint injections	1.59	1.27	1.99	**<0.001**
Postoperative opioid use	5.16	4.73	5.65	**<0.001**
Constipation	1.11	1.01	1.22	**0.032**
Acute renal failure	1.24	1.07	1.44	**0.004**
Venous thromboembolism	1.20	1.05	1.38	**0.008**
Wound complications	1.32	1.12	1.56	**0.001**
Infections	1.34	1.01	1.77	**0.042**
Neurological complications	1.44	1.09	1.90	**0.010**
Cardiac events	0.90	0.42	1.90	0.779
Respiratory complications	0.85	0.48	1.50	0.580
Outcomes at 2-year				
Reoperations	1.21	1.06	1.37	**0.005**
ED visits	1.32	1.24	1.40	**<0.001**
Epidural steroid injections	1.57	1.38	1.78	**<0.001**
Facet-joint injections	1.59	1.35	1.88	**<0.001**
Postoperative opioid use	5.75	5.21	6.36	**<0.001**
Constipation	1.14	1.05	1.23	**0.002**
Acute renal failure	1.29	1.14	1.47	**<0.001**
Venous thromboembolism	1.25	1.11	1.41	**0.000**
Wound complications	1.30	1.13	1.49	**<0.001**
Infections	1.34	1.07	1.68	**0.012**
Neurological complications	1.39	1.11	1.75	**0.005**
Cardiac events	0.85	0.48	1.48	0.559
Respiratory complications	0.87	0.55	1.39	0.574

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Swallowing Function Following Anterior Cervical Discectomy and Fusion with and without Anterior Plating

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Introduction: The use of anterior cervical plating in anterior cervical discectomy and fusion (ACDF) procedures has been associated with improved postoperative outcomes compared to stand alone cages. However, concerns exist regarding increased rates of postoperative dysphagia following an ACDF with use of anterior plating. Previous studies have reported on the relationship between ACDF instrumentation and postoperative dysphagia. However, little is known regarding the association between anterior plating and swallowing function using a validated questionnaire, such as the SWAL-QOL. As such, the purpose of this study is to quantify the effect of anterior plating on swallowing function as defined by the SWAL-QOL questionnaire following a primary, single level ACDF.

Materials/Methods: A prospectively-maintained database of patients that underwent a primary, single level ACDF from 2014-2017 was reviewed. Patients were grouped into those receiving a stand-alone cage (Cage) or a cage with anterior plating (Plate). SWAL-QOL scores were recorded at preoperative and 6-week and 12-week postoperative time points. Lateral radiographs were used to create a swelling index by obtaining a ratio of the prevertebral swelling distance to the anterior posterior diameter of each vertebral body at the involved levels ± 1 level. An air index was created using the same methodology, using tracheal air window diameter in place of prevertebral swelling distance. Statistical analysis was performed using chi-square analysis and independent t-tests for categorical and continuous variables, respectively. Statistical significance was set at $p<0.05$.

Results: A total of 68 primary, single-level ACDF patients were included in this analysis. Of these, 41 (60.3%) received a stand-alone cage and 27 (39.7%) received a cage with anterior plating. No differences in demographics or comorbidities were observed between groups ($p>0.05$ each). Additionally, no differences in operative time, estimated blood loss, or length of hospital stay were identified between Cage and Plate cohorts. Finally, no differences were observed in postoperative changes in SWAL-QOL scores (Table 1) or swelling and air indices (Table 2) from preoperative values between groups.

Conclusions: The results of this study demonstrate that patients undergoing a primary, single level ACDF with or without anterior plating experience similar operative times and lengths of stay. Furthermore, patients that receive a cage with anterior plating did not experience significant increases in dysphagia as measured by the SWAL-QOL questionnaire compared to patients that received a stand-alone cage. Furthermore, radiographic assessments of swelling are comparable in patients receiving a cage with anterior plating or a stand-alone

cage. Patients should be counselled to expect similar postoperative swallowing function following a primary, single level ACDF regardless of instrumentation used.

Table 1. Outcomes.*

	Cage (N=41)	Plate (N=27)	†p-value
SWAL-QOL (Mean ± SD)			
Preoperative	93.3 ± 8.1	95.6 ± 7.5	0.245
6-week Postoperative	89.2 ± 14.1	93.5 ± 7.1	0.149
12-week Postoperative	89.5 ± 13.0	92.4 ± 10.4	0.387
Changes in SWAL-QOL (Mean ± SD)			
Preoperative	93.3 ± 8.1	95.6 ± 7.5	
Δ 6-week Postoperative	-4.1 ± 12.4	-2.1 ± 8.0	0.457
Δ 12-week Postoperative	-3.1 ± 11.7	-3.0 ± 12.0	0.974

SD = Standard deviation
***Boldface** indicates statistical significance.
†p-value calculated using student's t-test.

Table 2. Radiographic Outcomes.*

	Cage (N=41)	Plate (N=27)	†p-value
Swelling Index Average (Mean ± SD) ∫			
Preoperative	67.9 ± 18.4	75.0 ± 13.1	0.107
6-week Postoperative	**75.4 ± 16.4**	**87.6 ± 18.3**	**0.010**
12-week Postoperative	72.0 ± 15.9	80.5 ± 19.3	0.091
Swelling Index Δ (Mean ± SD)			
Δ 6-week Postoperative	7.5 ± 11.6	12.6 ± 13.5	0.124
Δ 12-week Postoperative	5.2 ± 9.3	6.0 ± 12.7	0.785
Air Index Average (Mean ± SD) ∫			
Preoperative	107.1 ± 20.6	115.5 ± 14.2	0.088
6-week Postoperative	106.6 ± 22.4	109.9 ± 18.0	0.551
12-week Postoperative	105.3 ± 22.4	108.6 ± 17.7	0.575
Air Index Δ (Mean ± SD)			
Δ 6-week Postoperative	-0.5 ± 14.8	-5.6 ± 14.1	0.189
Δ 12-week Postoperative	-1.4 ± 14.8	-7.3 ± 17.8	0.209

SD = Standard deviation
***Boldface** indicates statistical significance.
∫ Air/Swelling Index Average = Average of Tracheal Air/Pretracheal Swelling Measurement for Index, Index ± 1-level
Δ Air/Swelling Index Difference = Postoperative Air/Swelling Index Average – Preoperative Air/Swelling Index Average
†P-value calculated using student's t-test.

A Prospective Cohort Study of Lamina Closure After Double-Door Laminoplasty without Lamina Spacer in Cervical Spondylotic Myelopathy Patients

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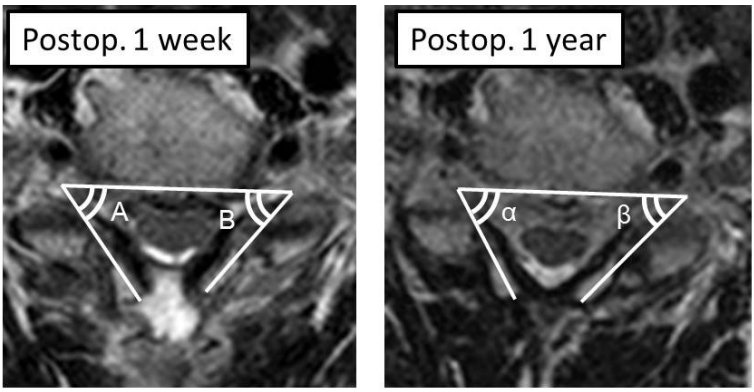
Introduction: Lamina closure (LC) is an important complication after laminoplasty (LAMP) without lamina spacer and sometimes leads to poor clinical outcomes. However, there have been no prospective studies evaluating LC after double-door LAMP. The purpose of this study was to investigate the LC after LAMP prospectively.

Materials/Methods: A total of 101 consecutive cervical spondylotic myelopathy patients with non-kyphotic alignment (63 male, 38 female; mean age 67.5 years) who underwent double-door LAMP without lamina spacer and completed a 1-year follow-up were enrolled. Lamina angles in a total of expanded 618 laminae were measured on MRI before, 1-week and 1-year after surgery. The retention rate was calculated as the ratio of the lamina angle at 1-year relative to 1-week after surgery (Figure 1). The LC was defined as < 0.8 of the retention rate. In addition, level of expanded lamina, CL (C2-7 lordotic angle) and C-JOA score were investigated.

Results: The LC was observed in 10 laminae (1.6%) of 4 patients (4.0%) at the 1-year follow-up period. We compared the LC (+) group with the LC (−) group. The preoperative CLs showed no significant differences between the two groups; however, the postoperative CL was smaller in the LC (+) group. The minimum retention rate in each patient was positively correlated with the CL at 1-year after surgery (P=0.016, R=0.238: Figure 2). In all of the LC (+) patients, postoperative kyphotic deformity (CL < 0) was confirmed and the levels of LC laminae were observed at the apex levels of cervical kyphosis. The recovery rate of the C-JOA score in the LC (+) group was significantly lower than that in the LC (−) group (16.6% vs. 45.1%: P=0.030).

Conclusion: Double-door LAMP without lamina spacer could maintain the expanded laminae in 96.0% of patients postoperatively. The LC occurred in patients with postoperative kyphotic deformity and leads to poor neurological recovery.



- Retention rate: α/A, β/B
- Lamina closure (LC): < 0.8 of the retention rate

Figure1

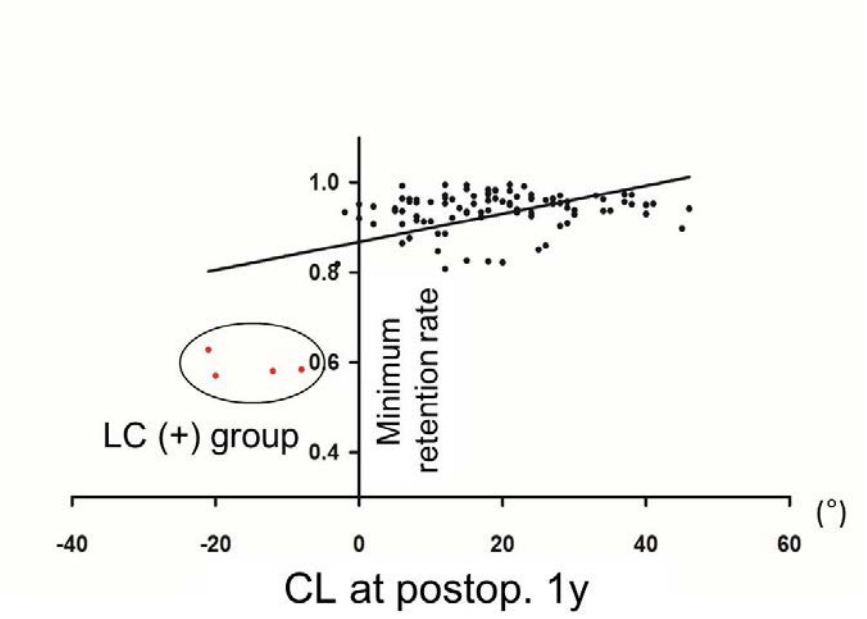


Figure 2

Is There a Role for DVT Chemoprophylaxis After Elective Spine Surgery? An Analysis of Bleeding and Clotting Complications in 81,045 Patients

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Introduction: When considering methods of postoperative care, surgeons must balance opposing bleeding and thrombotic risks. Unlike most inpatient procedures, chemical prophylaxis has typically been withheld following spine surgery due to a fear of developing serious bleeding complications such as epidural hematoma. However, this practice increases the risk of thrombotic complications such as deep vein thrombosis and subsequent pulmonary embolism. The purpose of this investigation was to determine the incidence and severity of bleeding and thrombotic complications in patients who had undergone elective spine surgery.

Methods: A retrospective review of the PearlDiver database was carried out. We analyzed two groups of patients from 2007-2016 who had undergone elective surgery on the cervical spine and either 1) had or 2) had not received chemoprophylaxis within 5 days of index procedure. We analyzed and compared severity of all thrombotic and bleeding complications including incidence of complications requiring operative washout, diagnosis of pulmonary embolism, ICU admission, and mortality associated with bleeding or thrombotic complications. Groups were compared using chi-squared analyses.

Results: A total of 81,045 unique patients were identified in the Humana Insurance subset of the PearlDiver database. The majority (>99%) were withheld chemoprophylaxis following spine surgery, and the overall rates of bleeding and thrombotic complications within this group were 2.10% and 3.01%, respectively ($p<0.01$). The incidence of surgical intervention for a wound washout procedure was 0.67% compared to 1.33% for a diagnosis of pulmonary embolism within 3 months of spine surgery ($p<0.01$). ICU admission rates related to a wound washout procedure were 0.09% compared to 0.44% for the complication of pulmonary embolism ($p<0.01$). There were no observed differences in mortality. This trend was consistent and observed for sub analyses of all three spinal procedures (Table 1). For the group receiving chemoprophylaxis post operation, in contrast, the incidence of thrombotic complications was observed to be higher than bleeding complications ($p<0.01$).

Conclusion: While there is no established standard of care, surgeons operating on the spine have traditionally withheld chemoprophylaxis for fear of increasing the risk of bleeding complications, a practice which inherently places patients at an increased risk for thrombotic complications. In this patient population with no chemoprophylaxis, the risks of a thrombotic complications were significantly greater than the incidence of bleeding complications. These data suggest that there may be an expanded role for chemoprophylaxis after elective spine surgery.

Table 1.

	Anterior Cervical Fusion		Posterior Cervical Laminectomy		Posterior Cervical Fusion	
n	34067		43334		23874	
Bleeding Complications	1.38% (469)	**p<.0001**	2.28% (989)	**p<.0001**	3.18% (759)	**p<.0001**
Thrombotic Complications	2.10% (714)		3.16% (1369)		4.77% (1139)	
Surgical Intervention	0.37% (125)	**p<.0001**	0.78% (339)	**p<.0001**	1.03% (247)	**p<.0001**
PE Incidence	0.95% (325)		1.45% (627)		2.01% (479)	
ICU Admission 7 Day Window-Wash Out	0.09% (31)	**p<.0001**	0.08% (35)	**p<.0001**	0.12% (28)	**p<.0001**
ICU Admission 7 Day Window-PE	0.37% (127)		0.43% (188)		0.72% (172)	

Multi-level Anterior Cervical Discectomy and Fusion (ACDF) in an Inpatient vs. Outpatient Setting

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Introduction: An emphasis on reducing healthcare costs has led to numerous surgeries being performed on an outpatient basis. Because of short operative times and moderate post-operative pain, single-level ACDF is one of the most common spine surgeries performed in an outpatient setting. Despite the success of single-level ACDF in the outpatient setting, concerns over increased post-operative complications, including respiratory compromise have curtailed the performance of multi-level ACDF in the same setting. The aim of this study was to evaluate differences in patient and procedural factors, and compare early outcomes and safety in mutli-level ACDF in the inpatient versus outpatient setting.

Methods:
Study Design: Retrospective review of prospectively collected data.

Population: Patients undergoing multi-level ACDF - divided based on inpatient or outpatient surgery.

Extracted Data:

- Demographics, comorbidities, operative data and complications occurring during the index hospitalization.
- Patient reported outcomes (PROs), including NDI, VAS for Neck and Arm pain and SF-12 Physical and Mental Health Scores collected pre- and post-operatively.

Statistics: Fisher's exact test for categorical variables, Independent Samples Student's t-test for continuous variables.

Results: Of the 103 patients in this study, 57 were outpatients and 46 were inpatients. Inpatients were older (56.7 vs 52.2 years, $p=0.012$) and had a higher ASA class ($p=0.002$) with no patients being ASA 1 compared to 9 outpatients, and 11 patients being ASA 3 compared to 4 outpatients. There was no difference in BMI ($p=0.12$) or smoking status ($p=0.67$).

Of the 83 two-level cases, 60.2% were outpatient surgeries compared to 35% of the 20 three-level cases ($p=0.042$). Outpatients had shorter operative times (71.26 vs 83.59 minutes, $p<0.0001$), and lengths of stay (8.51 vs 35.76 hours, $p<0.0001$). Outpatients also had a lower estimated blood-loss (EBL) (33.04 vs 45.87 ml, $p=0.003$) and fewer in-hospital complications (5.3 % vs 37.0 %, $p<0.0001$). One patient in the inpatient group required re-intubation for a post-operative hematoma. The two groups had similar POD 0 pain (4.96 in outpatients vs 4.89 in inpatients, $p=0.84$).

Pre-operatively inpatients and outpatients were similar in all PROs, except SF-12 PHS, which was worse in the inpatient group (p=0.024). Outpatients had better early outcomes in terms of 6-week NDI (27.97 vs 37.59, p=0.014), VAS neck (2.92 vs 4.02, p=0.044) and SF-12 PHS (35.66 vs 30.79, p =0.008). However, these differences did not persist at 6-months.

Conclusions: The results of our study suggest that multi-level ACDF can be performed safely in the outpatient setting without an increased risk of complications compared to the inpatient setting in an appropriately selected patient. Specifically, patients' age and ASA class, and number of levels being fused should be taken into consideration when deciding on performing a multi-level ACDF in an outpatient setting. Outpatient surgery was related to fewer levels being fused, lower EBL and shorter procedure time. Thus, these factors should be taken into account when planning surgery as they may help us better predict which patients can be treated on an outpatient basis and which factors may necessitate inpatient admission. Importantly, the setting of the surgery does not impact patient reported outcomes.

Table 1: Patient Demographics and Procedural Factors

	Outpatient	Inpatient	p-value
DEMOGRAPHICS			
• Number of cases (n)	57	46	
• Age (in years)	52.19 ± 7.47	56.72 ± 10.48	**0.012**
Gender			0.76
• Male	33 (57.9 %)	28 (60.9 %)	
• Female	24 (42.1 %)	18 (39.1 %)	
Body Mass Index (BMI) (in kg/m^2)	28.28 ± 5.63	29.99 ± 5.36	0.12
Current smoker (within 1 year)	7 (12.3 %)	7 (15.2 %)	0.67
ASA Classification			**0.002**
• Class 1	9	0	
• Class 2	33	34	
• Class 3	4	11	
PROCEDURAL FACTORS			
Number of levels operated			**0.042**
• 2 level (n=83)	50	33	
• 3 level (n=20)	7	13	
Procedure time (in minutes)	71.26 ± 12.48	83.59 ± 20.71	**<0.0001**
Total length of stay (LOS) (in hours)	8.51 ± 4.39	35.76 ± 15.41	**<0.0001**
Estimated blood loss (EBL) (in ml)	33.04 ± 13.57	45.87 ± 27.41	**0.003**
In-hospital complications	3 (5.3 %)	17 (37.0 %)	**<0.0001**
• Aspiration/ Re-intubation	0 (0.0 %)	1 (2.2 %)	0.447
• Urinary Retention requiring Catheterization	2 (3.5 %)	16 (34.8 %)	**<0.0001**
• Epidural Hematoma	0 (0.0 %)	1 (2.2 %)	0.447
• Ileus	0 (0.0 %)	1 (2.2 %)	0.447
• Dysphagia (IV fluid hydration, tube feeding, clinical swallowing evaluation)	0 (0.0 %)	2 (4.3 %)	0.197
POD 0 average pain scores	4.96 ± 2.07	4.89 ± 1.47	0.84

Table 2: Patient reported outcomes (PROs)

	Outpatient	Inpatient	p-value
NDI			
• Pre-operative	39.45 ± 18.92	46.06 ± 23.11	0.15
• 6-week	27.97 ± 17.92	37.59 ± 17.40	**0.014**
• 6-month	21.94 ± 17.49	31.00 ± 20.60	0.058
VAS Neck Pain			
• Pre-operative	6.16 ± 2.70	7.89 ± 11.32	0.3
• 6-week	2.92 ± 2.46	4.02 ± 2.51	**0.044**
• 6-month	2.99 ± 2.68	3.67 ± 2.94	0.33
VAS Arm Pain			
• Pre-operative	5.86 ± 2.57	5.78 ± 2.89	0.9
• 6-week	2.54 ± 2.57	3.52 ± 2.87	0.097
• 6-month	2.82 ± 2.58	3.21 ± 2.78	0.55
SF-12 PHS			
• Pre-operative	34.4 ± 7.92	30.11 ± 8.72	**0.024**
• 6-week	35.66 ± 7.16	30.79 ± 6.69	**0.008**
• 6-month	39.7 ± 11.38	34.73 ± 10.12	0.12
SF-12 MHS			
• Pre-operative	44.21 ± 14.52	44.76 ± 11.74	0.86
• 6-week	51.31 ± 10.60	50.11 ± 12.74	0.68
• 6-month	51.10 ± 11.05	48.52 ± 13.96	0.47

Predictors of Complications and Increased Length of Stay After Cervical Spine Osteotomy

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Introduction: Though previous studies have utilized the National Surgical Quality Improvement Program (NSQIP) dataset to identify risk factors for complications of thoracolumbar spinal deformity surgery, there has been very limited investigation of cervical spine deformity correction. We performed a retrospective analysis of the NSQIP database to identify predictors of complications after cervical spine osteotomy.

Methods: Patients undergoing cervical spine osteotomy were identified in the NSQIP dataset using all CPT codes from years 2005-2016. For each patient, data including patient and case clinical characteristics, length of stay, and diagnosis of a complication, including transfusion, wound disruption, surgical site infection, reintubation, pneumonia, urinary tract infection (UTI), sepsis, thromboembolic event, major cardiac event, stroke, reoperation, readmission, and death was abstracted. Patient and case clinical predictors of any of the reported complications and increased length of stay were identified in multivariate logistic regression analyses.

Results: In total, 979 patients were identified with mean age 56.1 (SD 12.4) and mean BMI 29.9 (SD 6.7). 173 (17.7%) were diabetic, 249 (25.4%) were smokers, and 54 (5.5%) had COPD. 490 (50.2%) were classified as ASA 1 or 2, 453 (46.4%) were classified as ASA 3, and 34 (3.5%) were classified as ASA 4. 649 (66.3%) of cases were performed by neurosurgeons, and mean operative duration was 3.1 (SD 2.2) hours. 29 (3.0%) cases were classified as emergencies (Table 1). Mean length of stay was 3.6 (SD 5.2) days. There was an overall complication rate of 16.5%. The most common complications included transfusion (79, 8.1%), readmission (47, 4.8%), reoperation (34, 3.5%), and reintubation (31, 3.2%). Multivariate analysis demonstrated that risk factors for any complication included increased age ($p=0.03$), ASA classification 3 ($p=0.005$) and 4 ($p=0.0004$), increased operative duration ($p<0.0001$), and emergency status ($p=0.0004$). Risk factors for increased length of stay were increased age ($p=0.04$), decreased functional status ($p=0.02$), disseminated cancer ($p=0.005$), ASA classification 3 ($p<0.0001$) and 4 ($p<0.0001$), increased operative duration ($p<0.0001$), emergency status ($p=0.0005$), and orthopaedic surgeon (vs. neurosurgeon) ($p=0.02$).

Conclusions: As utilization of osteotomy for cervical spine deformity increases, understanding patient and surgical risk factors is important for predicting and preventing complications. This study is the largest sample to date of cervical osteotomy patients and provides useful clinical data for patient selection and counseling.

Table 1: Patient and Case Characteristics, Complication Rate, and Length of Stay

Variable	Overall		Complications		Length of Stay	
Continuous	**Mean**	**SD**	**Mean**	**SD**		
Age	56.1	12.4	62.4	10.7	N/A	
BMI	29.9	6.7	28.4	7		

Operative Duration	3.1	2.2	5.2	2.5		
Categorical	**N**	**%**	**N**	**%**	**Mean**	**SD**
Surgical Specialty						
Neurosurgery	649	66.3	108	16.6	3.4	4.7
Orthopedics	330	33.7	53	16.1	4.1	5.9
Diabetes Status						
No	806	82.3	129	16.0	3.5	4.8
Insulin	74	7.6	17	23.0	6.0	9.0
Non-Insulin	99	10.1	15	15.2	3.1	3.0
Smoking						
No	730	74.6	122	16.7	3.7	5.4
Yes	249	25.4	39	15.7	3.3	4.6
Dyspnea						
No	923	94.3	148	16.0	3.5	5.1
Yes	56	5.7	13	23.2	5.0	6.1
Functional Status						
Dependent	45	4.6	19	42.2	8.2	9.9
Independent	934	95.4	142	15.2	3.4	4.7
COPD						
No	925	94.5	146	15.8	3.6	5.2
Yes	54	5.5	15	27.8	4.0	3.8
Hypertension						
No	494	50.5	69	14.0	3.2	4.7
Yes	485	49.5	92	19.0	4.1	5.6
Disseminated Cancer						
No	969	99.0	157	16.2	3.6	5.1
Yes	10	1.0	4	40.0	9.8	8.2
Chronic Steroid Use						
No	935	95.5	148	15.8	3.5	4.9
Yes	44	4.5	13	29.5	6.4	9.4
Bleeding Disorder						
No	959	98.0	157	16.4	3.6	5.2
Yes	20	2.0	4	20.0	5.5	5.2
Emergent Case						
No	950	97.0	150	15.8	3.5	4.9
Yes	29	3.0	11	37.9	7.8	10.9
ASA Classification						
1 or 2	490	50.2	44	9.0	2.3	2.6
3	453	46.4	101	22.3	4.6	5.6
4	34	3.5	15	44.1	10.9	13.1

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Table 2: Risk Factors for Any Complication

Variable	OR	95%CI		p-value
Age (per year)	1.02	1.00	1.04	0.0301
ASA (ref = 1 or 2)				
3	1.97	1.23	3.16	0.0048
4	5.18	2.08	12.91	0.0004
Operative Duration (per hour)	1.62	1.49	1.77	<.0001
Emergency (ref = No)				
Yes	5.06	2.06	12.46	0.0004

Table 3: Risk Factors for Increased Length of Stay

Variable	Percent Diff	95%CI		p-value
Age (per year)	1.01	1.00	1.01	0.0453
Operative Duration (per hour)	1.17	1.14	1.21	<.0001
Functional Status (ref = Independent)				
Dependent	1.52	1.07	2.15	0.0201
Surgical Specialty (ref = Neurosurgery)				
Orthopaedics	1.22	1.03	1.43	0.0192
Disseminated Cancer (ref = No)				
Yes	2.37	1.30	4.35	0.0051
Emergency Surgery (ref = No)				
Yes	2.07	1.37	3.10	0.0005
ASA (ref = 1 or 2)				
3	1.55	1.34	1.79	<.0001
4	2.95	1.96	4.43	<.0001

Minimally-Invasive Posterior Cervical Foraminotomy (mis-PCF) with Tubes Prevents Undesired Fusion with Long-term Follow-up

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Introduction: Minimally-Invasive Posterior Cervical Foraminotomy (mis-PCF) has proven effective in addressing symptoms of cervical radiculopathy and foraminal stenosis in appropriately indicated patients. The few studies that have compared the revision rates and functional outcome scores of the procedure directly to Anterior Cervical Discectomy and Fusion (ACDF) have been limited to 2-year of postoperative follow-up. Additionally, none of these studies have utilized a minimally-invasive technique with tubular decompression. While the immediate advantages of mis-PCF are numerous and well documented in the literature (no hardware, shortened length of stay and return to work, reduced blood loss, pain medication use and cost), there is concern that the revision rate will increase substantially as patients' follow-up increases beyond 2-years. If a substantial number of patients treated with mis-PCF are treated with an ACDF, a cost analysis will need to be reevaluated. Therefore, in order to better understand the consequences of choosing mis-PCF over ACDF in certain patients, studies with long term follow-up must be conducted. The object of this study was to determine the long-term revision proportion (overall as well as at the index and adjacent levels) and functional outcomes of mis-PCF when compared directly to similar patients treated with ACDF in a similar setting.

Materials/Methods: From 2009-2014, 210 consecutive patients underwent ACDF and 49 underwent mis-PCF for cervical radiculopathy without myelopathy refractory to conservative treatment and a minimum of 2-year follow-up were compared in separate cohorts. mis-PCF patients had a mean follow-up was 42.9 months while ACDF patients had 44.9 months. Demographic variables of cohorts were compared. Revisions and complications were reviewed and compared. Functional outcomes were assessed with NDI and VAS-a and VAS-n measurements preoperatively and at final follow-up visit. Standard binomial and categorical comparative analysis was performed.

Results: There was no difference found in proportion of revisions between mis-PCF and ACDF cohorts (4 of 29, 8.2% vs 12 of 210, 5.7%, p=0.514, respectively). There was no difference found in revision rate per level per year (3.1 vs 1.7, p=0.464). Likewise, there was no difference found in revision rate per level per year at the index level (1.8 vs 0.7, p=0.466) or at an adjacent level (1.3 vs 1.1, p=0.906). No difference was found between cohorts in regards to change from pre-op to final post-op functional outcome scores (NDI, VAS-a and VAS-n). There was 1 (2.7%) complication in the mis-PCF cohort (post-operative hematoma) and 7 (3.3%) complications in the ACDF cohort.

Conclusion: mis-PCF compared directly to ACDF, with a mean follow-up of nearly 43 months, has demonstrated similar revision proportions, rates, and functional outcome scores.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

Future studies with minimum 5 and 10 years follow-up are still warranted to conclusively determine the utility of the mis-PCF technique with tubular decompression and its ability to prevent unwanted fusions.

Impact of Tobacco Smoking on Outcomes After Posterior Decompression Surgery in Patients with Cervical Spondylotic Myelopathy

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Introduction: Smoking has been associated with poor outcomes in the field of spinal surgery. However, the impact of tobacco smoking on outcomes following posterior decompression surgery has not been fully evaluated in patients with cervical spondylotic myelopathy (CSM).

Methods: This is a retrospective multicenter study. Five hundred and eighty-seven patients diagnosed as CSM were enrolled at 17 high-volume institutions in Japan. Patients underwent cervical laminoplasty or laminectomy, and were followed up for at least one year after surgery. Outcome measures were: preoperative smoking status, perioperative complications, the Japanese Orthopedic Association scale (JOA), and the Visual Analog Scale (VAS) for neck. Smoking and nonsmoking groups were compared using unpaired t-test for continuous variables or a chi-square test for categorical variables.

Results: There were 182 (31%) current smokers and 405 (69%) nonsmokers including previous smokers. Smokers were younger than nonsmokers (average 65.1 vs. 68.4, P<.01). There were no significant differences in BMI, number of operated laminae, operative time, and number of co-morbidities; but the estimated blood loss during surgery was significantly higher in the smokers (57.6ml vs. 37.0ml, P<.01). Regarding postoperative complications, there was no significant difference in the rate of surgical site infection, cerebrospinal fluid leakage, hematoma, and neurological deficit. However, smokers showed a significantly higher risk for segmental motor paralysis (e.g. C5 palsy) (4.9% vs. 2.0%, P=.05) and delirium (3.3% vs. 0.2%, P<.01). Both smokers and nonsmokers had comparable functional recovery in JOA scores (difference 3.1 vs. 2.9, P=.33) and neck pain reduction using VAS (difference -1.8 vs. -1.4, P=.24) at the final follow up.

Conclusion: This is the largest studies analyzing the efficacy and safety of posterior surgical decompression in smokers with CSM. Although the estimated blood loss was larger in smokers, they gained functional restoration and neck pain reduction at the final follow up. Attention is required, however, on postoperative complications such as segmental motor paralysis and delirium. This is an important factor to note when explaining the risks of surgery to patients who smoke.

Individual Disclosures can be found in the Disclosure Index pages 45-102.

The Recovery of Motor Strength After Posterior Percutaneous Endoscopic Cervical Foraminotomy and Discectomy

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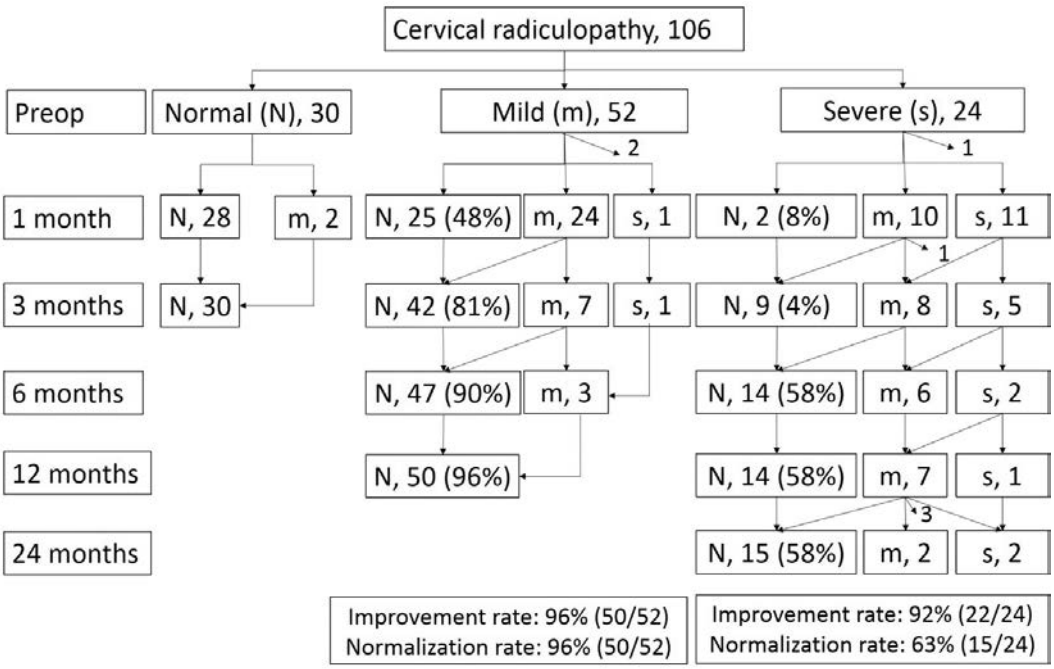
Objective: Cervical radiculopathy infrequently presents with motor weakness. Motor weakness was improved in >90% of patients after anterior cervical discectomy and fusion or posterior cervical foraminotomy. Posterior percutaneous endoscopic cervical foraminotomy and discectomy (PECF) is an alternative surgical technique, but the outcome of motor weakness has not been reported. The objective was to demonstrate the longitudinal outcomes of motor weakness following PECF.

Materials/Methods: A retrospective review of 106 consecutive patients was performed. Preoperative motor weakness was graded as mild (IV/V strength) or severe (less than III/V strength). The patients visited the outpatient clinic at 1, 3, 6 and 12 months after surgery and yearly thereafter. Improvement was defined as an improved weakness of more than one grade, and normalization was defined as the recovery of complete motor strength.

Results: Motor weakness preoperatively presented in 76/106 (72%) patients (49%, mild weakness; 23%, severe weakness). After PECF, the weakness improved in 72/76 (95%) patients and normalized in 65/76 (86%) patients. In the patients with mild weakness, the normalization rates were 48%, 81%, 90% and 96% at postoperative months 1, 3, 6 and 12, respectively (Fig. 1). In the patients with severe weakness, the improvement rates were 50%, 71%, 83%, 88% and 92%, and the normalization rates were 8%, 38%, 58%, 58% and 63% at postoperative months 1, 3, 6, 12 and 24, respectively.

Conclusions: Preoperative motor weakness was improved in 95% of the patients after PECF, but motor weakness was not normalized in 37% of the patients with severe weakness.

Figure 1. longitudinal outcome of weakness



2nd Place Clinical Research Award Winner

Comparative Analysis between Early Surgical and Conservative Treatment of the Incomplete Cervical Spinal Cord Iinjury without Major Fracture and Dislocation in the Preexisting Cervical Spinal Stenosis

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Introduction: There continues to be debate over the benefits of surgical and conservative treatment for the cervical spinal cord injury (CSCI) without major fracture and dislocation in the preexisting cervical spinal canal stenosis (CSCS), especially early surgical treatment. In the previous animal models of cervical spinal cord injury, early surgical decompression may be a potentially reversible source from secondary injury if treated at the early period of the initial insult. However, the clinical outcomes of early surgery for incomplete CSCI with preexisting CSCS is still controversial in the human study. The purpose of this study is to evaluate the clinical outcomes of early surgical treatment (< 24 hours) and conservative treatment for incomplete SCI with preexisting CSCS without major fracture or dislocation.

Methods: We retrospectively reviewed medical records and radiographic data of 54 patients with the American Spinal Injury Association Impairment Scale (AIS) grade B, C with preexisting CSCS without major fracture or dislocation between 2005 and 2015 were reviewed. Thirty-three patients (age, 57.4 ± 14.0 years) underwent early surgical treatment within 24 hours after initial trauma (S group) and 21 patients (age, 56.9 ± 13.6 years) underwent conservative treatment (C group) respectively by two spine surgeons in accordance with the surgeon's preference. The primary outcome was comparison about the degree of improvement in AIS between the both group at 1 and 2 years follow-up. Secondary outcomes included assessment of the factors associated with the improved neurologic outcome between age, sex, trauma cause, canal compression rate, spinal diameter, initial AIS grade and treatment type (early surgical treatment versus conservative treatment).

Results: There was no significant difference in the distribution of age, sex, trauma cause, canal compression rate, spinal diameter and initial AIS grade between the two groups. At 2 years follow-up, 90.9% of S group showed a more than 1 grade improvement in AIS compared to 57.1 % in C group (p=0.004). Especially, in the cases of showing AIS improvement over 2 grades, S group (30.3 %) was more than 3 times more than C group (9.5 %) (Table 1). In the multivariate analysis of adjusted for age, sex, trauma cause, canal compression rate, spinal canal diameter, initial AIS grade and treatment type, presence or absence of early surgical treatment was the only significant associated factor of AIS improvement at 2 years follow-up (p=0.0044).

Conclusion: In the incomplete CSCI without major fracture or dislocation in the preexisting CSCS, the neurological outcome in early surgical treated patients was more superior than conservative treated patient in addition to long term outcome. Therefore, early surgical treatment which could prevent the secondary deterioration after initial insult would be considered in incomplete CSCI without major fracture and dislocation in the preexisting CSCS.

Table 1. Ordinal changes in AIS grade from admission to 2 years follow-up between conservative treatment (C group) and early surgical treatment (< 24 hours) (S group)

Preoperative AIS grade	B	C	D	E	Total (n = 54)
B (C group)	3 (14.3 %)	2 (9.5 %)	0 (0 %)	0 (0 %)	21 (100 %)
C (C group)	0 (0 %)	6 (28.6 %)	8 (38.1 %)	2 (9.5 %)	
B (S group)	1 (3.0 %)	1 (3.0 %)	3 (12.1 %)	0 (0 %)	33 (100%)
C (S group)	0 (0 %)	2 (6.1%)	19 (57.6%)	6 (18.2 %)	

1st Place Resident/Fellow Research Award Winner

The Impact of Time to Surgical Decompression on Clinical Outcomes in Patients with Acute Traumatic Central Cord Syndrome

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Introduction: The role of early surgical decompression for traumatic central cord syndrome (TCCS) remains controversial.[1-7] With the aging population, TCCS is expected to become the most common form of acute traumatic spinal cord injury (SCI),[8,9] making the identification of treatment strategies that mitigate disability in this vulnerable population a key public health priority. To that end, we sought to evaluate the impact of time to surgery on clinical outcomes of TCCS.

Methods: Patients with TCCS, defined by a ≥10-point difference between the initial ASIA lower extremity motor score (LEMS) and ASIA upper extremity motor score (UEMS) (LEMS–UEMS≥10)[10,11] were identified from two multi-center international prospective SCI datasets: 1) the NACTN SCI Registry (ClinicalTrials.gov NCT00178724);[12] and 2) the STASCIS dataset.[13] Motor recovery, as evaluated by the ASIA motor score (AMS)[14], and functional outcome, as assessed by the Functional Independence Measure (FIM),[15] were evaluated at 6 months. The primary outcome was change in AMS. Secondary outcomes were ASIA impairment scale (AIS) conversion (≥ 1 grade improvement), change in FIM motor subscore, and complications.

Baseline characteristics and outcomes were compared in patients who underwent early (<24 hrs.) versus delayed (≥24 hrs.) surgery by Fisher's exact test for proportions and t-test for means. Multiple linear regression was performed for change in AMS at 6 months with age, initial AMS, initial AIS, time to surgery, and instability (fracture/dislocation) as independent variables. Interaction terms were included for time to surgery ´ initial AIS ´ instability based on a priori hypotheses that: 1) the potential for recovery with early surgical decompression differs between AIS C and D injuries, with the latter demonstrating a favorable recovery profile, regardless of intervention; and 2) injuries resulting from low-energy mechanisms, as manifested by absence of spinal column disruption, are more likely to respond favorably to early decompression due to a less severe primary insult and more substantive role of secondary injury.

Results: Seventy-three patients met criteria; 28 (38.4%) underwent early surgery. Mean improvement in AMS at 6 months was greater in the early (30.4 points) than delayed (20.9 points) surgery group (P=0.045). Early surgery was also associated with greater improvement in FIM motor subscore (38.2 vs. 20.3 points, P=0.006). There was no significant difference in AIS conversion (P=0.265) or complications (P=0.139). On multiple linear regression (Table

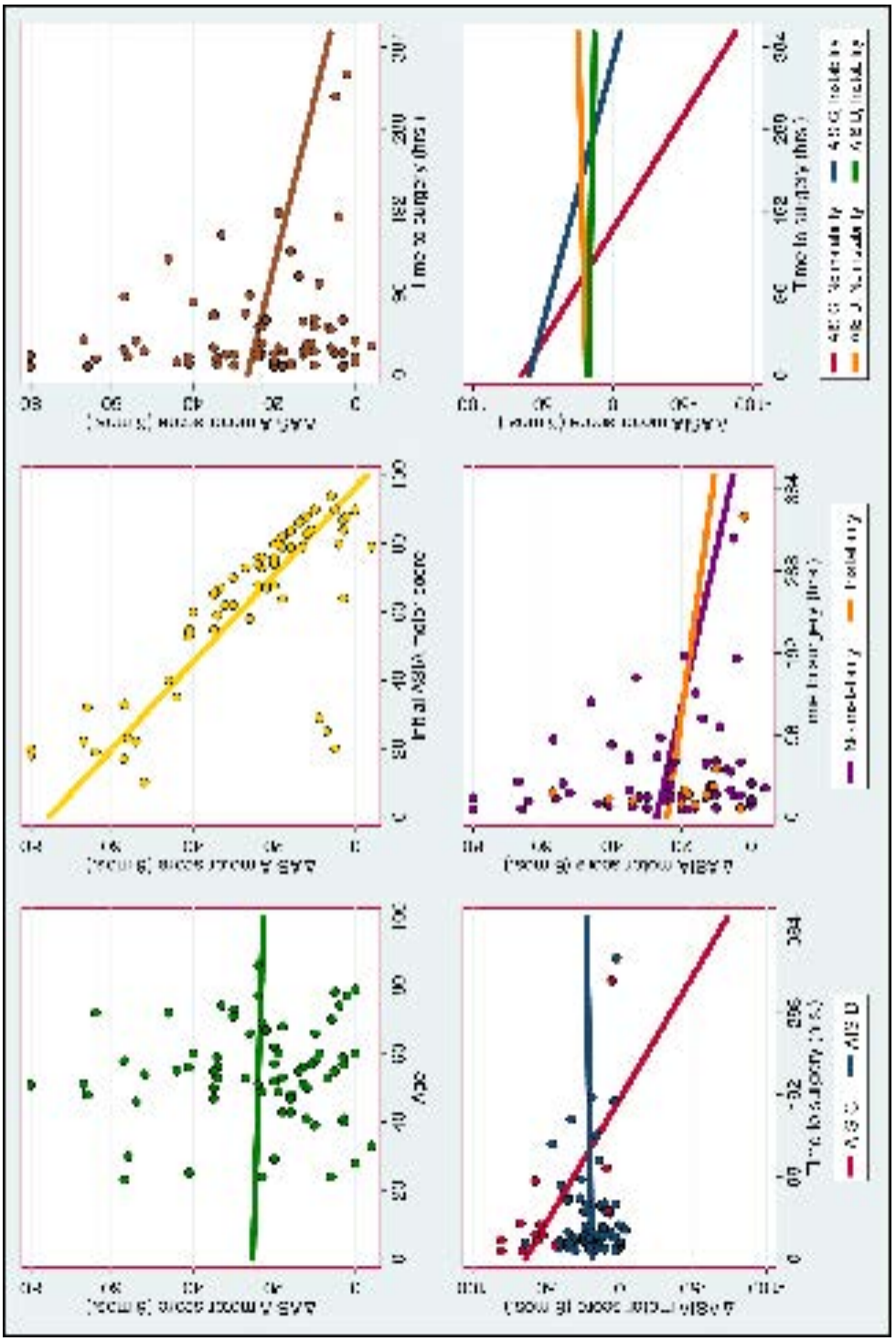
A), initial AMS (P<0.001) and time to surgery (P<0.001) were significant negative predictors of change in AMS at 6 months. Time to surgery and initial AIS demonstrated a statistically significant interaction (P=0.001). There were also strong interactions between time to surgery and instability (P=0.06), as well as time to surgery, initial AIS grade, and instability (3-way interaction; P=0.05). The beneficial effect of earlier surgery on motor recovery was most pronounced in patients with AIS C injuries without instability (Fig 1).

Conclusion: Early surgical decompression is safe and effective in patients with TCCS. Shorter time to surgery positively impacts motor recovery in TCCS; this effect is most pronounced in patients with AIS C injuries, those without instability, and especially in patients with stable AIS C injuries.

Table A. Results of multiple linear regression for change in ASIA motor score at 6 months among patients with TCCS (*N* = 73)

	Coefficient	95% CI	P
Age	-0.03	-0.23 to 0.18	0.800
Initial ASIA motor score	-0.78	-0.98 to -0.58	< 0.001*
Initial AIS grade	-6.91	-22.85 to 9.03	0.389
Time to surgery (hrs.)	-0.38	-0.59 to -0.17	< 0.001*
Instability (fracture/subluxation)	-10.14	-35.95 to 15.67	0.435
Interaction (time to surgery × AIS)	0.39	0.18 to 0.61	0.001*
Interaction (time to surgery × instability)	0.22	-0.009 to 0.44	0.060
Interaction (AIS × instability)	9.32	-17.83 to 36.46	0.495
Interaction (time to surgery × AIS × instability)	-0.24	-0.49 to 0.003	0.053
R^2 = 0.74			
*Statistically significant (*P* < 0.05)			

Figure 1. Multiple linear regression for change in ASIA motor score at 6 months among patients with TCCS (*N* = 73). Plots for effect of age, initial ASIA motor score, time to surgery, and interaction between time to surgery, initial AIS, and instability.



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

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Individual Disclosures can be found in the Disclosure Index pages 45-102.

The Clinical Implications of Adding Computed Tomography Angiography in the Evaluation of Cervical Spine Fractures: A Propensity Matched Analysis

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Andrew J. Schoenfeld, MD, Boston, MA

Introduction: Screening asymptomatic blunt trauma patients for cervical arterial injury is controversial. Vertebral artery injury (VAI) is most commonly associated with cervical spine fracture and many guidelines advocate indiscriminate screening of all cervical spine fractures.
The purpose of this study is to determine whether the addition of computed tomography angiography (CT-A) results in a change in management for patients with cervical spine fractures.

Methods: Adult patients with acute cervical spine fractures after blunt trauma between 2000 – 2015 were retrospectively identified. Patients with penetrating trauma, neoplasm or prior cervical spine surgery were excluded. The following variables were recorded: age, biologic sex, medical comorbidities, Injury Severity Score (ISS), mechanism of injury, whether computed tomography-angiography (CT-A) of the neck was obtained in addition to CT, cervical spine fracture characteristics, and the presence of VAI. Recommendation for a change in management with antithrombosis was the primary outcome measure. Detection of stroke and VAI were secondary outcomes. Propensity score matching was performed to negate the significant baseline demographic and clinical characteristics.

Results: There were 3,943 patients screened and 2,831 patients eligible. Propensity score matching yielded one cohort receiving CT-A and one cohort that did not, both with 644 patients and equivalent demographic and clinical characteristics (Figure 1). CT-A identified definite or indeterminate VAI in 113 patients and 62 patients had antithrombosis recommended. In the cohort without CT-A, VAI was discovered in 11 patients incidentally through other imaging and 8 were recommended antithrombosis. Two patients in the CT-A group had major adverse bleeding events as a result of antithrombosis initiation. There were no preventable strokes in either group (Table 1).

Conclusion: The addition of CT-A increased detection of VAI and antithrombosis recommendation. There was a high incidence of indeterminate CT-A findings. There were no preventable strokes in either cohort and two major adverse bleeding events as a result of recommended pharmacologic antithrombosis. Non-selective screening is not warranted and should be limited to a high-risk subset of patients.

Figure 1. Flow diagram of patients eligible and included in propensity score matching

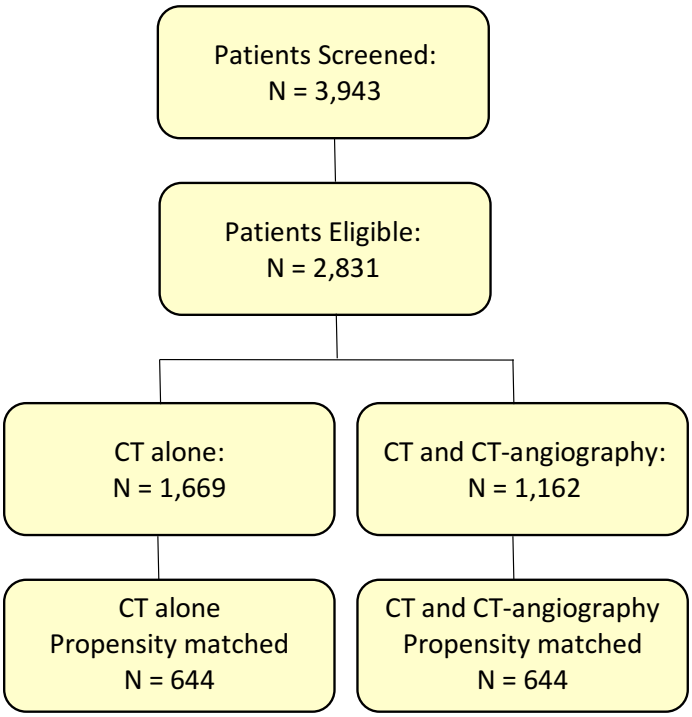

Table 1. Characteristics of vertebral artery injuries (VAI) found and treatment recommendations.
*Arterial injury graded according to Biffl et al. *Am J Surg* 1999

	CT-A (%)	CT alone (%)
Patients screened	644	644
Definite VAI identified	56 (8.7)	11 (1.7)
Grade* 1 or 2	23 (3.6)	6 (0.9)
Grade 3 or 4	33 (5.1)	5 (0.8)
Indeterminate VAI identified	57 (8.9)	0
Antithrombosis recommend-ed	62 (9.6)	8 (1.2)
Antithrombosis initiated	56 (8.7)	5 (0.8)
Major adverse event from antithrombosis	2 (0.3)	0
Delayed stroke	1 (0.2)	0

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The names of authors presenting papers are printed in **boldface.** All presenters, secondary authors, and any other participant in the Annual Meeting have been asked to disclose if he/she, or a member of his/her immediate family has a financial interest in or other relationship with a commercial company or institution within the last twelve months.

An indication of the participant's disclosure as well as the commercial company or institution that provided the support appears in the disclosure index beginning on page 45.

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Any such occurrences were unintentional.
–CSRS Staff

2018 Instructional Course & Annual Meeting

DAILY SCHEDULE

DAILY SCHEDULE

Tuesday, December 4, 2018

12:00 pm – 7:00 pm	Technical Exhibit Set-up	*Camelback Ballroom*
5:00 pm – 7:00 pm	Registration	*Grand Ballroom Registration*

Wednesday, December 5, 2018 – Scheduled Meetings

12:30 pm – 6:00 pm	Board of Director's Meeting	*Pine Room*

Wednesday, December 5, 2018 – Instructional Course

6:00 am – 7:00 pm	Registration	*Grand Ballroom Registration*
6:30 am – 4:30 pm	Technical Exhibits	*Camelback Ballroom*
7:00 am – 8:00 am	Continental Breakfast	Camelback Ballroom
7:45 am – 5:00 pm	CSRS 23rd Instructional Course	*Grand Ballroom DEFG*
9:25 am – 9:45 am	Break	*Camelback Ballroom*
12:00 pm – 1:00 pm	Lunch	*Camelback Ballroom*
3:10 pm – 3:30 pm	Break	*Camelback Ballroom*
5:00 pm – 6:00 pm	Reception	*Camelback Ballroom*

Thursday, December 6, 2018 – Annual Meeting

6:00 am – 5:00 pm	Registration	*Grand Ballroom Registration*
6:00 am – 6:30 pm	Technical Exhibits	*Camelback Ballroom*
6:00 am – 7:30 am	Continental Breakfast	*Camelback Ballroom*
6:00 am – 5:00 pm	E-Poster Viewing	*Grand Ballroom East Foyer*
7:00 am – 4:37 pm	Annual Meeting Scientific Session	*Grand Ballroom DEFG*
9:11 am – 9:41 am	Break	*Camelback Ballroom*
11:30 am – 1:30 pm	Industry Workshops	*Third Floor Meeting Rooms*
2:50 pm – 3:20 pm	Break	*Camelback Ballroom*
4:30 pm – 6:30 pm	Welcome Reception	*Camelback Ballroom*

Friday, December 7, 2018 – Annual Meeting

6:00 am – 4:30 pm	Registration	*Grand Ballroom Registration*
6:00 am – 1:30 pm	Technical Exhibits	*Camelback Ballroom*
6:00 am – 7:30 am	Continental Breakfast	*Camelback Ballroom*
6:00 am – 4:30 pm	E-Poster Viewing	*Grand Ballroom East Foyer*
7:00 am – 4:30 pm	Annual Meeting Scientific Session	*Grand Ballroom DEFG*
8:57 am – 9:27 am	Break	*Camelback Ballroom*
12:00 pm – 12:55 pm	Non-Member Lunch	*Camelback Ballroom*
12:00 pm – 12:55 pm	Members Lunch	*Grand Ballroom AB*
3:24 pm – 3:40 pm	Break	*Grant Ballroom East Foyer*

Saturday, December 8, 2018 – Annual Meeting

6:00 am – 12:00 pm	Registration	Grand Ballroom Registration
6:00 am – 1:00 pm	E-Poster Viewing	*Grand Ballroom East Foyer*
6:00 am – 7:30 am	Continental Breakfast	*Grand Ballroom East Foyer*
7:00 am – 12:57 pm	Annual Meeting Scientific Session	*Grand Ballroom DEFG*
10:27 am – 10:48 am	Break	*Grand Ballroom East Foyer*
12:57 pm	Annual Meeting Adjourns	

NYC 2019

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