45TH

FORTY-FIFTH ANNUAL MEETING

OF THE

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

November 30 – December 2, 2017

The Diplomat Beach Resort
Hollywood, Florida

Darrel S. Brodke, MD, *President*
Louis G. Jenis, MD, *Scientific Program Chair*

www.csrs.org

FUTURE INSTRUCTIONAL COURSES

Dec 5, 2018 The Phoenician, Scottsdale, Arizona

FUTURE ANNUAL MEETINGS

Dec 6 – 8, 2018 The Phoenician, Scottsdale, Arizona

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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 18 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

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

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CSRS 2017

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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

2017 Officers

President	Darrel S. Brodke, MD
Immediate Past President	Robert F. Heary, MD
Past President	Alan S. Hilibrand, MD
President Elect	Jeffrey C. Wang, MD
Vice President	Alexander Vaccaro, MD, PhD
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D. Greg Anderson, MD, Chair	2018
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Sukhvinder Kalsi-Ryan, MSc, PhD	2018
Michael P. Kelly, MD	2017
Brandon D. Lawrence, MD	2017
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Daniel M. Sciubba, MD	2019
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Board of Specialty Societies

Alan S. Hilibrand, MD, PL Rep	2018
R. Alden Milam, MD, Member Rep	2020

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Robert Hart, MD, Chair	2018
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W. Ryan Spiker, MD	2018
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John Heller, MD	2019
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John C. France, MD, Ortho Chair	2018
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Peter G. Whang, MD	2017
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Nominating Committee

Alan S. Hilibrand, MD, Chair	2017
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Eeric Truumees, MD	2017

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Program Committee

Louis G. Jenis, MD, Chair	2017
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Serena S. Hu, MD	2017
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Joon Yung Lee, MD	2017
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Sheeraz A. Qureshi, MD, MBA	2017
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Jean-Paul Wolinsky, MD	2018
Darrel S. Brodke, MD (ex officio)	2017
Michael D. Daubs, MD (ex officio)	2019
Alpesh A. Patel, MD (ex officio)	2019

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Research Committee

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Daniel M. Sciubba, MD	2018
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Research Committee (continued)

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Avinash Patwardhan, PhD	2018
Jason Savage, MD	2019
P. Justin Tortolani, MD	2019

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Themistocles Protopsaltis, MD	2017
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Special Projects Committee

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Christopher M. Bono, MD	2018
Clinton J. Devin, MD	2017
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Addisu Mesfin, MD	2018
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Michael G. Fehlings, MD, PhD	2018
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Thank you 2017 Exhibit Companies*
Please visit our Exhibitors in the Grand Ballrooms

Aegis Spine, Inc.
Greenwood Village, CO
Booth #104

AlloSource
Centennial, CO
Booth #200

Amedica
Salt Lake City, UT
Booth #408

Anjon Holdings
Jacksonville, FL
Booth #103

AxioMed
Malden, MA
Booth #306

Biologica Technologies, LLC
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Booth #310

Cardinal Spine, LLC
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Centinel Spine
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Cerapedics, Inc.
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Booth #311

DePuy Synthes Spine
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Booth #207

Globus Medical Inc.
Audubon, PA
Booth #206

Hans Biomed USA, Inc.
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Innovasis Inc.
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Jeunesse Innovations
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Booth #101

K2M, Inc.
Leesburg, VA
Booth #302

Life Instrument Corporation
Braintree, MA
Booth #205

Medtronic
Memphis, TN
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Medyssey USA, Inc.
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Booth #102

Neurostructures
Irvine, CA
Booth #400

NuVasive, Inc.
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Booth #305

Orthofix, Inc.
Lewisville, TX
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Providence Medical Technology, Inc.
Walnut Creek, CA
Booth #201

RTI Surgical
Austin, TX
Booth #405

SeaSpine
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Booth #309

SAGICO
Tampa, FL
Booth #211

Spine Wave, Inc.
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Stryker Spine
Allendale, NJ
Booth #300

Synaptive Medical
Toronto, ON, Canada
Booth #406

TeDan Surgical Innovations
Sugar Land, TX
Booth #404

Thompson Surgical Instruments, Inc.
Traverse City, MI
Booth #203

Titan Spine, LLC
Mequon, WI
Booth #402

Zimmer Biomet
Broomfield, CO
Booth #401

THANK YOU

*as of Nov. 1, 2017

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FORTY-FOURTH ANNUAL MEETING

OF THE

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FOUNDED 1973

November 30 – December 2, 2017

The Diplomat Beach Resort
Hollywood, Florida

President:	Darrel S. Brodke, MD
Program Chair:	Louis G. Jenis, MD
Local Arrangements:	Frank J. Eismont, 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** Louis G. Jenis, MD
7:11–7:48 am	**Session I: MYELOPATHY I** Moderators: D. Greg Anderson and Erica F. Bisson, MD, MPH
7:11–7:16 am Presentation #1 (pg. 98)	**Effect of Cervical Decompression Surgery on Gait in Cervical Spondylotic Myelopathy Patients** Ram Haddas, PhD; Raj Arakal, MD; Akwasi Boah, MD; Theodore Belanger, MD; **Kevin L. Ju, MD**
7:17–7:22 am Presentation #2 (pg. 99)	**Surgical Outcome of Elderly Patients Over 80 Years with Cervical Spondylotic Myelopathy** **Norihiro Isogai, MD**; Junichi Yamane; Akio Iwanami; Hitoshi Kono; Yoshiomi Kobayashi, MD, PhD; Nobuyuki Fujita; Mitsuru Yagi, MD, PhD; Kota Watanabe, MD, PhD; Kazuya Kitamura, MD, PhD; Yuta Shiono, MD; Ken Ishii, MD; Masaya Nakamura, MD; Morio Matsumoto, MD; Narihito Nagoshi, MD, PhD
7:23–7:28 am Presentation #3 (pg. 101)	**What is the Role of Gait Analysis in the Evaluation of Walking Disturbance in the Cervical Myelopathy Patients? A Comparison Between Pre- and Post-Operative Data in Surgically Treated Cervical Myelopathy Patients** Nam Ik Cho, MD; Jae Hwan Cho, MD; **Jung-Ki Ha, MD**; Chang Ju Hwang, MD, PhD; Choon Sung Lee, MD, PhD; Dong-Ho Lee, MD, PhD
7:29–7:34 am Presentation #4 (pg. 103)	**Two-Year Surgical Outcomes of Patients with Cervical Myelopathy: An Analysis of the Impact of Patient Characteristics, Operative Data, and Preoperative Nonoperative Treatment Modalities** Peter G. Passias, MD; Kristen E. Radcliff, MD; Paul M. Arnold, MD; Samantha R. Horn, BA; Gregory W. Poorman, BA; Anthony J. Boniello, BS; Sun Yang, BA; Alexander R. Vaccaro, MD, PhD, MBA; **Michael C. Gerling, MD**
7:35–7:48 am	**Discussion**
7:49–8:26 am	**Session II: MOTION PRESERVATION** Moderators: Praveen M. Mummaneni, MD and Darren R. Lebl, MD
7:49–7:54 am Presentation #5 (pg. 105)	**Facet Joint Osteoarthritis Progress After Insertion of Artificial Disc Replacement: A Five-Year Follow-Up of a Prospective Randomized Controlled Study** **Anna MacDowall, MD**; Martin Skeppholm, MD, PhD; Claes Olerud, MD, PhD
7:55–8:00 am Presentation #6 (pg. 106)	**Long-Term Outcomes of Arthroplasty for Cervical Myelopathy vs. Radiculopathy, and Arthroplasty vs. Arthrodesis for Cervical Myelopathy** **Jeffrey R. McConnell, MD**; Matthew F. Gornet, MD; K. Daniel Riew, MD; Todd H. Lanman, MD; J. Kenneth Burkus, MD

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8:01–8:06 am Presentation #7 (pg. 108)	**Comparison of 7-Year Results of One-Level vs. Two-Level Cervical Disc Arthroplasty and Anterior Cervical Fusion** **Jeffrey R. McConnell, MD**; Todd H. Lanman, MD; Matthew F. Gornet, MD; J. Kenneth Burkus, MD
8:07–8:12 am Presentation #8 (pg. 109)	**2nd Place Basic Science Research Award Winner** **Single-Level Cervical Arthrodesis Increases Adjacent Segment Midrange Motion** **William Anderst, PhD**; Tyler West; William Donaldson, MD; Joon Yung Lee, MD; James Kang, MD
8:13–8:26 am	**Discussion**
8:27–9:04 am	**Session III: CERVICAL DEFORMITY I** Moderators: Alexander R. Vaccaro, III, MD, PhD, MBA and Jeffrey C. Wang, MD
8:27–8:32 am Presentation #9 (pg. 112)	**Cervical Mismatch: The Normative Value of T1s-CL and Its Ability to Predict Ideal Cervical Lordosis** **Blake Staub, MD**; Renaud Lafage; Han Jo Kim, MD; Christopher I. Shaffrey, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Douglas C. Burton; Peter G. Passias, MD; Christopher P. Ames, MD; Eric O. Klineberg, MD; Robert Shay Bess, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group
8:33–8:38 am Presentation #10 (pg. 113)	**Analysis of Prospective Collection of 374 Osteotomies in 99 Patients with Adult Cervical Deformity** **Themistocles S. Protopsaltis, MD**; Alexandra Soroceanu, MD; Justin S. Smith, MD; Munish Gupta, MD; Renaud Lafage; Peter G. Passias, MD; D. Kojo Hamilton; Eric O. Klineberg, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Douglas Burton, MD; Robert Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group
8:39–8:44 am Presentation #11 (pg. 115)	**Prospective Multicenter Analysis of Clinical and Radiographic Outcomes Following Surgical Correction of Patients with Moderate to Severe Cervical Deformities and Horizontal Gaze Disruption** Themistocles S. Protopsaltis, MD; **Subaraman Ramchandran, MD**; Jared C. Tishelman; Justin S. Smith, MD; Daniel M. Sciubba, MD; Peter G. Passias, MD; Renaud Lafage, MS; Eric O. Klineberg, MD; Virginie Lafage, PhD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Christopher P. Ames, MD; International Spine Study Group
8:45–8:50 am Presentation #12 (pg. 117)	**Assessment of Cervical Spine Deformity Flexibility Using Supine Advanced Imaging** **Brandon P. Hirsch, MD**; Nina Fisher, BS; Yosef Dastagirzada, BA; Jared C. Tishelman, BA; Themistocles S. Protopsaltis, MD
8:51–9:04 am	**Discussion**

Individual Disclosures can be found on pages 41–95.
P=Highlighted Posters

9:05 – 9:35 am	**Break** Exhibit Hall – Grand Ballroom
9:36 – 10:13 am	**Session IV: TRAUMA** Moderators: Kristen E. Radcliff, MD and Daniel M. Sciubba, MD
9:36 – 9:41 am Presentation #13 (pg. 119)	**The Role of CT Angiography in Changing Management in Patients with Cervical Fractures** Arash Emami, MD; Conor Dunn, MD; Jeffrey Moore, MD; Nancy Moontasri, MD; **Kimona Issa, MD**; Michael Faloon, MD; Kumar Sinha, MD; Ki Soo Hwang, MD
9:42 – 9:47 am Presentation #14 (pg. 120)	**Early vs. Delayed Reduction of Cervical Spine Dislocation with Complete Motor Paralysis – A Multicenter Study** **Kosei Nagata, MD**; Yasushi Oshima, MD, PhD; Hirotaka Chikuda, MD, PhD
9:48 – 9:53 am Presentation #15 (pg. 121)	**Cervical Spine Trauma in Children: Analysis of Changes in Incidence, Etiology, and Concurrent Injuries Among 11,323 Pediatric Patients Over a 10-Year Period** Gregory W. Poorman, BA; Bryan M. Beaubrun; Samantha R. Horn, BA; Bassel G. Diebo, MD; Shaleen Vira; Olivia Bono; John Moon; Charles Wang; Brandon P. Hirsch, MD; Jared C. Tishelman, BA; Peter L. Zhou; **Michael C. Gerling, MD**; Peter G. Passias, MD
9:54 – 9:59 am Presentation #17 (pg. 123)	**Incidence of Cervical Spine Injuries Sustained During Sporting Activities** **J. Mason DePasse, MD**; Wesley Durand, BS; Mark A. Palumbo, MD; Alan H. Daniels, MD
10:00 – 10:13 am	**Discussion**
10:14 – 10:18 am	**Special Presentation**
10:19 – 10:24 am	**Introduction of Presidential Guest Speaker** Darrel S. Brodke, MD
10:25 – 11:15 am	**Henry H. Bohlman Presidential Guest Lecture: Lessons in Military Aviation & Leadership Applied to Surgery** Col. Lynn I. Scheel, USAF
11:16 – 11:25 am	**Discussion**
11:25 am	**Adjourn to Industry Workshops – Lunch Available for Workshop Attendees Only, Prior Registration Not Required, No CME Credits**

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INDUSTRY WORKSHOPS

LUNCH INCLUDED ~ No CME Credits

11:30 am – 1:30 pm	**Workshop 1: Medtronic:** Prestige LP™ Cervical Disc System: Long Term Data, Two-Level Indication, and New Streamlined Instruments **Workshop 2: K2M:** A 360 Review of Cervical Solutions featuring Balance™ ACS **Workshop 3: NuVasive:** Cervical Alignment Matters™: Emerging Techniques to Restore Global Alignment with Computer-assisted Surgery **Workshop 4: Stryker:** Evidence Based Biomaterials in Spine **Workshop 5: Zimmer Biomet:** An Interactive Debate on Myelopathy in the Multilevel Cervical Patient: Motion Preservation, Fusion and Everything in Between **Workshop 6: Globus Medical Inc.:** Laminectomy vs. Laminoplasty, A Retrospective Analysis on Outcomes
1:35 – 2:30 pm	**Symposium: How the Experts Deal with Adverse Events – Prevention, Identification and Management** Moderator: Darrel S. Brodke, MD Panel: Paul A. Anderson, MD; Bradford L. Currier, MD; John G. Heller, MD; K. Daniel Riew, MD
2:17 – 2:30 pm	**Discussion**
2:31 – 2:51 pm	**Break** Exhibit Hall – Grand Ballroom
2:52 – 3:41 pm	**Session V: ANTERIOR SURGERY I** Moderators: Paul M. Arnold, MD and Mark L. Prasarn, MD
2:52 – 2:57 pm Presentation #18 (pg. 125)	**Return to Play After Anterior Cervical Discectomy and Fusion in Professional Athletes** Robert G. Watkins IV, MD; David Chang, MD; **Robert G. Watkins III, MD**
2:58 – 3:03 pm Presentation #19 (pg. 126)	**Does Local Intraoperative Corticosteroids Delivered in a Gel-Matrix Minimize Dysphagia Following Anterior Discectomy and Fusion (ACDF): A Preliminary Analysis of an Ongoing Double Blinded Randomize Controlled Trial (RCT)** Daniel H. Stein, BS; Han Jo Kim, MD; **Darren R. Lebl, MD**; Russel C. Huang, MD; Shari T. Jawetz, MD; Virginie Lafage, PhD; Okezie K. Aguwa, MD; Todd J. Albert, MD

Individual Disclosures can be found on pages 41 – 95.
P=Highlighted Posters

3:04 – 3:09 pm Presentation #20 (pg. 128)	**Preliminary Results: Cervical Degenerative Disc Disease and Subclinical Discitis: Cause or Contaminant?** **Amit Bhandutia, MD**; Luke Brown, MD, MBA; Eve Hoffman, MD; Eugene Koh, MD, PhD; Kelley Banagan, MD; Steven Ludwig, MD; Daniel Gelb, MD
3:10 – 3:15 pm Presentation #21 (pg. 129)	**Surgical Management of Unilateral Multi-Level Cervical Spondylotic Radiculopathy: A Comparative Study of Clinical and Radiological Outcomes of Posterior Foraminotomy vs. Anterior Discectomy and Fusion** **Do-Yon Hwang, MD**; Dong-Ho Lee, MD, PhD; Jae Hwan Cho, MD; Chang Ju Hwang, MD, PhD; Choon Sung Lee, MD, PhD; Sae Min Hwang, MD
3:16 – 3:21 pm Presentation #22 (pg. 132)	**CT Scan: Always Necessary for the Preoperative Planning in the Cervical Spine Surgery?** **Seungjin Choi, MD**; Kyung-Soo Suk, MD; Hak-Sun Kim, MD; Seong-Hwan Moon, MD; Hwan-Mo Lee, MD; Jae-Ho Yang, MD; Michael Nelson Perez Lim, MD; Sung-Jin Park, MD; Adrian Alaras, MD
3:22 – 3:27 pm Presentation #23 (pg. 133)	**Prevalence, Progression, Clinical Implications, and Risk Factors of Heterotopic Ossification After Cervical Total Disc Replacement at 7 Years** **Pierce D. Nunley, MD**; David A. Cavanaugh, MD; Eubulus J. Kerr III, MD; Phillip Andrew Utter, MD; Peter G. Campbell, MD; Kelly A. Frank, MS; Marcus B. Stone, PhD
3:28 – 3:41 pm	**Discussion**
3:42 – 4:30 pm	**Session VI: MYELOPATHY II** Moderators: Themistocles S. Protopsaltis, MD and Masatoshi Sumi, MD, PhD
3:42 – 3:47 pm Presentation #24 (pg. 134)	**Comparison of Anterior and Posterior Surgery for Degenerative Cervical Myelopathy – An MRI-Based Propensity Score-Matched Analysis Using Data from the Prospective Multicenter AOSpine CSM North America and International Studies** **So Kato, MD**; Aria Nouri, MD, MSc; Dongjin Wu, MD; Satoshi Nori, MD, PhD; Michael Fehlings, MD, PhD
3:48 – 3:53 pm Presentation #25 (pg. 135)	**Do Laminoplasty Conducted by Junior Surgeons Affect Clinical Outcomes for the Treatment of Cervical Spondylotic Myelopathy? – Comparison Between Board- and Non- Board-Certified Spine Surgeons** **Narihito Nagoshi, MD, PhD**; Akio Iwanami, MD, PhD; Norihiro Isogai, MD; Masayuki Ishikawa, MD, PhD; Kenya Nojiri, MD, PhD; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Kota Watanabe, MD, PhD; Takashi Tsuji, MD, PhD; Kenshi Daimon, MD; Ken Ishii, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Junichi Yamane, MD, PhD

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3:54 – 3:59 pm Presentation #26 (pg. 137)	**A Comparative Study for Cervical Spondylotic Myelopathy with One- or Two-Level Lesions – Anterior Cervical Discectomy with Fusion vs. Selective Laminoplasty** **Kenichiro Sakai, MD, PhD**; Toshitaka Yoshii, Atsuyuki Kawabata, MD; Yu Matsukura, Tsuyoshi Yamada, Takashi Hirai, Yoshiyasu Arai, MD, PhD; Astushi Okawa
4:00 – 4:05 pm Presentation #27 (pg. 139)	**Comparison of Surgical Outcomes Between Open-Door, Double-Door Laminoplasty, and Selective Laminectomy with Muscle Preservation for Cervical Spondylotic Myelopathy: A Multicenter Study of 881 Cases** **Junichi Yamane, MD, PhD**; Akio Iwanami, MD; Hitoshi Kono, MD; Tokunaga Shigeyuki, MD, PhD; Mitsuru Yagi, MD, PhD; Nobuyuki Fujita; Kota Watanabe, MD, PhD; Norihiro Isogai, MD; Satoshi Suzuki, MD, PhD; Yoshiomi Kobayashi, MD, PhD; Ken Ishii, MD; Masaya Nakamura, MD; Morio Matsumoto, MD; Narihito Nagoshi, MD, PhD
4:06 – 4:11 pm Presentation #28 (pg. 141)	**2nd Place Resident / Fellow Research Award Winner** **Investigating the Utility of Intra-Operative Neurophysiological Monitoring for Anterior Cervical Discectomy and Fusion: Analysis of Over 140,000 Cases from a National Inpatient Dataset** **Jetan H. Badhiwala, MD**; Farshad Nassiri, MD; Christopher D. Witiw, MD, MSc; Alireza Mansouri, MD, MSc; Saleh A. Almenawer, MD, MSc; Leodante da Costa, MD, MSc; Michael G. Fehlings, MD, PhD; Jefferson R. Wilson, MD, PhD
4:12 – 4:17 pm Presentation #29 (pg. 144)	**3rd Place Resident / Fellow Research Award Winner** **Comparison of Preoperative and Postoperative Cervical Lordosis in Patients Undergoing Cervical Laminoplasty – Effect of C3 Laminectomy** **Philip M. Sinatra, MD**; Colleen Peters, MA; Steven J. McAnany, MD; Michael P. Kelly, MD; Lukas P. Zebala, MD
4:18 – 4:30 pm	**Discussion**
4:30 – 6:30 pm	**Welcome Reception** Exhibit Hall – Grand Ballroom

Individual Disclosures can be found on pages 41 – 95.
P=Highlighted Posters

7:00 – 7:10 am	**Welcome and Announcements** Louis G. Jenis, MD
7:11 – 7:54 am	**Session VII: POSTERIOR SURGERY** Moderators: James S. Harrop, MD and Clifford B. Tribus, MD
7:11 – 7:16 am Presentation #30 (pg. 146)	**A Comparative Study Between Two Types of Cervical Laminoplasty on the Deep-Extensor Volume and Axial Neck Pain-Minimum Two-Year Follow-Up Results** **Feifei Zhou, MD**; Yu Sun, MD
7:17 – 7:22 am Presentation #31 (pg. 147)	**The Correlation Between Cervical Alignment and Posterior Cervical Muscle Fatty Infiltration at Baseline in Cervical Deformity Patients** **Peter G. Passias, MD**; Charles Wang, BS; Gregory W. Poorman, BA; Samantha R. Horn, BA; Han Jo Kim, MD; Virginie Lafage, PhD; Michael C. Gerling, MD
7:23 – 7:28 am Presentation #32 (pg. 148)	**Increase in Cervical Lordosis Decreases Postoperative Neck Pain After Laminectomy and Fusion** Anthony M. DiGiorgio, DO, MHA; Darryl Lau, MD; Ethan A. Winkler, MD, PhD; Khoi Than, MD; **Andrew Chan, MD**; Dean Chou, MD; Praveen V. Mummaneni, MD
7:29 – 7:34 am Presentation #33 (pg. 151)	**A Prospective Cohort Study of Postoperative Spinal Epidural Hematoma After Cervical Laminoplasty** **Kenichiro Sakai, MD, PhD**; Toshitaka Yoshii, MD, PhD; Atsuyuki Kawabata, MD; Yu Matsukura, MD; Tsuyoshi Yamada, MD, PhD; Takashi Hirai; Yoshiyasu Arai, MD, PhD; Astushi Okawa, MD, PhD
7:35 – 7:40 am Presentation #34 (pg. 153)	**Long-Term Fate of C3-7 Arthrodesis: 4-Level ACDF vs. Cervical Laminectomy and Fusion** Colin W. Niezgoda, PA; **John K. Houten, MD, FAANS**
7:41 – 7:54 am	**Discussion**
7:55 – 8:38 am	**Session VIII: CERVICAL DEFORMITY II** Moderators: Howard S. An, MD and Sheeraz A. Qureshi, MD, MBA
7:55 – 8:00 am Presentation #35 (pg. 155)	**What Is a Right Distal Fusion Level for Prevention of Sagittal Imbalance in Multilevel Posterior Cervical Spine Surgery: C7 or T1?** Seungjin Choi, MD; **Kyung-Soo Suk, MD**; Hak-Sun Kim, MD; Hwan-Mo Lee, MD; Seong-Hwan Moon, MD; Jae-Ho Yang, MD; Michael Lim, MD; Sung-Jin Park, MD; Adrian Alaras, MD

• The FDA has not cleared the drug and/or medical device for the use described (i.e., the drug and/or medical device noted with an * is being discussed for an "off label" use). See inside back cover for information.

8:01 – 8:06 am Presentation #36 (pg. 157)	3rd Place Clinical Research Award Winner **Distal Junctional Kyphosis (DJK) After Cervical Deformity Surgery: Analysis with In-Construct Measurements** **Themistocles S. Protopsaltis, MD**; Jared C. Tishelman, BA; Subaraman Ramchandran, MD; Renaud Lafage; Justin S. Smith, MD; Han Jo Kim, MD; Peter G. Passias, MD; Gregory M. Mundis, MD; D. Kojo Hamilton, MD; Munish C. Gupta, MD; Robert A. Hart, MD; Robert Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group
8:07 – 8:12 am Presentation #37 (pg. 159)	**Cervical vs. Thoracolumbar Spinal Deformities: A Comparison of Baseline Quality-of-Life Burden** Peter G. Passias, MD; Gregory W. Poorman, BA; Virginie Lafage, PhD; Justin S. Smith, MD; Christopher P. Ames, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Samantha R. Horn, BA; Charles Wang, BA; Robert A. Hart, MD; Douglas C. Burton, MD; Renaud Lafage; Robert Shay Bess, MD; **Daniel M. Sciubba, MD**; International Spine StudyGroup
8:13 – 8:18 am Presentation #38 (pg. 161)	**High C2-T3 Sagittal Imbalance is an Independent Predictor of Recurrent Proximal Junctional Kyphosis** Shan-Jin Wang, Okezie K. Aguwa, MD; Christopher I. Shaffrey, MD; Gregory M. Mundis, MD; Richard A. Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Eric O. Klineberg, MD; Renaud Lafage; Justin S. Smith, MD; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; **Han Jo Kim, MD**; International Spine Study Group
8:19 – 8:24 am Presentation #39 (pg. 162)	**Improvement in Ames-ISSG Cervical Deformity Classification Modifier Grades Correlate to Clinical Improvement and Likelihood of Reaching MCID in Multiple Metrics: Series of 73 Patients with 1-Year Follow-Up** Samantha R. Horn, BA; Peter G. Passias, MD; Renaud Lafage; Justin S. Smith MD; Gregory W. Poorman, BA; Bassel G. Diebo, MD; Christopher I. Shaffrey, MD; **Daniel M. Sciubba, MD**; Eric O. Klineberg, MD; Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; Robert Shay Bess, MD; Virginie Lafage, PhD; Christopher P. Ames, MD; International Spine Study Group
8:25 – 8:38 am	**Discussion**
8:39 – 8:47 am	**2017 CSRS European Traveling Fellowship Report** Ahmad Nassr, MD
8:48 – 8:53 am	**Preview CSRS 2018 Annual Meeting in Scottsdale, Arizona** TBD
8:54 – 8:59 am	**Preview CSRS Asia Pacific Section 2018 Annual Meeting in New Dehli, India** Kuniyoshi Abumi, MD

Individual Disclosures can be found on pages 41 – 95.
P=Highlighted Posters

9:00 – 9:05 am	**Preview CSRS European Section 2018 Annual Meeting in Lisbon, Portugal** Ronald H M A Bartels, MD, PhD
9:06 – 9:36 am	**Break** Exhibit Hall – Grand Ballroom
9:37 – 10:39 am	**Session IX: HIGHLIGHT POSTER PRESENTATIONS** Moderators: Ahmad Nassr, MD and John M. Rhee, MD
Diagnostics / Imaging	
9:37 – 9:39 am Presentation #40 (pg. 164)	**Increased Signal Intensity of the Spinal Cord on T2-Weighted Magnetic Resonance Images and Correlation with Cervical Sagittal Alignment and the Severity of Spinal Cord Compression** **Bang-Ping Qian, MD**; Ji-Chen Huang, MD; Xin-Kun Cheng, MD; Yong Qiu, MD; Yang Yu, MD
9:40 – 9:42 am Presentation #41 (pg. 165)	**Congenital Cervical Spine Stenosis in a Global Cohort of Patients with Degenerative Cervical Myelopathy: A Report Based on a MRI Diagnostic Criterion** **Aria Nouri, MD, MSc**; Allan Martin, MD; Satoshi Nori, MD; Michael G. Fehlings, MD, PhD
9:43 – 9:45 am Presentation #42 (pg. 168)	**A 20-Year Prospective Longitudinal Study on Degeneration of the Cervical Spine Using MRI in Volunteers** **Kenshi Daimon, MD**; Hirokazu Fujiwara, MD, PhD; Yuji Nishiwaki, MD, PhD; Eijiro Okada, MD, PhD; Kenya Nojiri, MD, PhD; Masahiko Watanabe, MD, PhD; Hiroyuki Katoh, MD, PhD; Kentaro Shimizu, MD, PhD; Hiroko Ishihama, MD; Nobuyuki Fujita, MD, PhD; Takashi Tsuji, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD
9:46 – 9:48 am Presentation #43 (pg. 170)	**Does the Sagittal Alignment of the Cervical Spine Have an Impact on Disc Degeneration? 20-Year Follow-Up of Asymptomatic Volunteers** **Eijiro Okada, MD, PhD**; Kenshi Daimon, MD; Hirokazu Fujiwara, MD, PhD; Yuji Nishiwaki, MD, PhD; Kenya Nojiri, MD, PhD; Masahiko Watanabe, MD, PhD; Hiroyuki Katoh, MD, PhD; Kentaro Shimizu, MD, PhD; Hiroko Ishihama, MD; Nobuyuki Fujita, MD, PhD; Takashi Tsuji, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD
9:49 – 9:51 am Presentation #44 (pg. 172)	**The Many Faces of the Japanese Orthopaedic Association (JOA) Score: An Outcome Measure with Face Validity for Assessment of Patients with Cervical Spondylotic Myelopathy** **Julio C. Furlan, MD, MBA, MSc, PhD, FRCPC**; B. Catharine Craven, BA, MD, MSc, FRCPC
9:52 – 9:57 am	**Discussion**

Surgical Techniques	
9:58 – 10:00 am Presentation #45 (pg. 174)	**The Effectiveness of Local Autogenous Bone Dust as an Implantation Filler in Anterior Cervical Discectomy and Fusion** **Sae Min Hwang, MD**; Dong-Ho Lee, MD, PhD; Jae Hwan Cho, MD; Chang Ju Hwang, MD, PhD; Choon Sung Lee, MD, PhD; Do-yon Hwang, MD; Sung Hoo Kim, MD
10:01 – 10:03 am Presentation #46 (pg. 176)	**Safety and Efficacy of a Novel Anterior Decompression Technique (Vertebral Body Sliding Osteotomy) for Ossification of Posterior Longitudinal Ligament of the Cervical Spine** Chul Gie Hong, MD; Jae Hwan Cho, MD; Chang Ju Hwang, MD, PhD; Choon Sung Lee, MD, PhD; Jung-Ki Ha, MD; **Dong-Ho Lee, MD**
10:04 – 10:06 am Presentation #47 (pg. 179)	**Dose Additional Uncinate Resection Increase Pseudarthrosis Following Anterior Cervical Discectomy and Fusion?** Jong-Min Baik, MD; Jae Hwan Cho, MD; Youn-Suk Joo, MD; Chang Ju Hwang, MD; Choon Sung Lee, MD, PhD; **Dong-Ho Lee, MD**
10:07 – 10:09 am Presentation #48 (pg. 181)	**Sulfated Glycopeptide Nanostructures Scaffold for Spinal Arthrodesis** Gurmit Singh, BS; Sungsoo S. Lee, PhD; Timmy Fyrner, PhD; Mark T. McClendon, PhD; Andrew D. Schneider, MD; Karina M. Katchko, BS; Danielle S. Chun, MD; Joseph A. Weiner, BS; Ralph W. Cook, BS; Sameer Singh, BS; Soyoen Jeong, MS; Chawon Yun, PhD; Samuel I. Stupp, PhD; Erin L. Hsu, PhD; **Wellington K. Hsu, MD**
10:10 – 10:12 am Presentation #49 (pg. 183)	**Surgical Site Drains and Postoperative Complications Following Posterior Cervical Spine Surgery: A Multicenter Retrospective Study** Daniel B. Herrick; **Joseph E. Tanenbaum**; Marc Mankarious, MD; Sagar Vallabh; Eitan Fleischman; Swamy Kurra, MBBS; Shane M. Burke, MD, BS; Marie Roguski, MD; Thomas E. Mroz, MD; William F. Lavelle, MD; Jeffrey E. Florman, MD; Ron I. Riesenburger, MD
10:13 – 10:18 am	**Discussion**
Healthcare Economics / Value	
10:19 – 10:21 am Presentation #50 (pg. 184)	**Cost-Utility Analysis of Cervical Deformity Surgeries Using One-Year Outcome** Gregory W. Poorman, BA; Peter G. Passias, MD; Rabia Qureshi, BS; **Hamid Hassanzadeh, MD**; Michael P. Kelly, MD; Richard A. Hostin, MD; Christopher P. Ames, MD; Justin S. Smith, MD; Virginie LaFage, PhD; Douglas C. Burton, MD; Robert Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Munish C. Gupta, MD; International Spine Study Group

10:22–10:24 am Presentation #51 (pg. 186)	**Preparing for Bundled Payments in Cervical Spine Surgery: Do We Understand the Influence of Patient, Hospital, and Procedural Factors on the Cost and Length of Stay?** **Andrew J. Pugely, MD**; Cameron Barton, MD; Comron Saifi, MD; Yubo Gao, PhD
10:25–10:27 am Presentation #52 (pg. 187)	**What are the Costs of Cervical Radiculopathy in the Year Prior to Anterior Cervical Discectomy and Fusion?** **Cameron Barton, MD**; Nicholas Bedard, MD; Comron Saifi, MD; Andrew J. Pugely, MD
10:28–10:30 am Presentation #54 (pg. 190)	**The Medico-Legal Landscape of Spine Surgery: How Do Surgeons Fare?** **Melvin C. Makhni, MD, MBA**; Paul J. Park, MD; Comron S. Saifi, MD; Jon-Michael Caldwell, MD; Alex Ha, MD; Ronald A. Lehman Jr., MD; Mark Weidenbaum, MD
10:31–10:39 am	**Discussion**
10:40–11:23 am	**Session X: SPINAL CORD** Moderators: Michael C. Gerling, MD and Chrisopher I. Shaffrey, MD
10:40–10:45 am Presentation #55 (pg. 192)	**Physical Performance Decreases in the Early Stage of Cervical Myelopathy Before the Myelopathic Signs Appear: The Wakayama Spine Study** **Keiji Nagata, MD**; Noriko Yoshimura, MD, PhD; Hiroshi Hashizume, MD; Yuyu Ishimoto; Hiroshi Yamada, MD; Akihito Minamide; Shigeyuki Muraki; Munehito Yoshida, MD
10:46–10:51 am Presentation #56 (pg. 193)	**3rd Place Basic Science Research Award Winner** **Enhancement of Neurological Recovery and Attenuation of Inflammation in Cervical Spondylotic Myelopathy with Intravenous IgG** Wen Ru Yu, MD; Pia Maria Vidal, BS, PhD; Anna Maria Badner, BS; **Michael G. Fehlings, MD, PhD**
10:52–10:57 am Presentation #57 (pg. 195)	**1st Place Basic Science Research Award Winner** **Neural Stem Cell Mediated Recovery is Enhanced by Chondroitinase ABC Pretreatment in Chronic Cervical Spinal Cord Injury** **Hidenori Suzuki, MD, PhD**; Christopher S. Ahuja; Narihito Nagoshi, MD, PhD; Toshihiko Taguchi, MD, PhD; Michael G. Fehlings, MD, PhD
10:58–11:03 am Presentation #58 (pg. 197)	**Does Spinal Cord Compression Status Affect Pre- and Post-Operative Neurological Conditions?** **Takanori Niimura, MD**; Hisanori Mihara, MD; Yasunori Tatara, MD

11:04–11:09 am Presentation #59 (pg. 198)	**Multiparametric Quantitative MRI Detects Tissue Injury in Asymptomatic Cervical Spinal Cord Compression** **Allan R. Martin, MD**; Benjamin De Leener, MSc; Julien Cohen-Adad, PhD; David W. Cadotte, MD, PhD; Aria Nouri, MD, MSc; Jefferson R. Wilson, MD, PhD; David J. Mikulis, MD, PhD; Howard Ginsberg, MD, PhD; Michael G. Fehlings, MD, PhD
11:10–11:23 am	**Discussion**
11:24–11:29 am	**Introduction of CSRS President** Jeffrey C. Wang, MD
11:30 am–12:00 pm	**PRESIDENTIAL ADDRESS** Darrel S. Brodke, MD
12:02–1:05 pm	**Non-Member Lunch** Location: Grand Ballroom
12:02–1:05 pm	**Member Lunch** Location: Atlantic Ballroom
1:06–1:53 pm	**Session XI: COMPLICATIONS** Moderators: Jeffrey S. Fischgrund, MD and Timothy A. Moore, MD
1:06–1:11 pm Presentation #60 (pg. 200)	**Predicting the Occurrence of Complications Following Corrective Cervical Deformity Surgery: Analysis of a Prospective Multicenter Database Using Predictive Analytics** **Peter G. Passias, MD**; Cheongeun Oh, PhD; Samantha R. Horn, BA; Jessica Lavery, MS; Han Jo Kim, MD; D. Kojo Hamilton, MD; Daniel M. Sciubba, MD; Brian J. Neuman, MD; Aaron J. Buckland, MD; Gregory W. Poorman, BA; Themistocles S. Protopsaltis, MD; Eric O. Klineberg, MD; Christopher P. Ames, MD; Justin S. Smith, MD; Virginie Lafage, PhD; International Spine Study Group
1:12–1:17 pm Presentation #61 (pg. 202)	**Risk Factor Analysis of Postoperative Subaxial Cervical Alignment Change Following Upper Cervical Fixation** **Jae Taek Hong, MD, PhD**
1:17–1:22 pm Presentation #62 (pg. 203)	**The Risk Factor Analysis of Change of Intraoperative Neurophysiologic Monitoring During Cervical Open-Door Laminoplasty** Sanghyun Han, MD; Seung-Jae Hyun, MD, PhD; **Ki-Jeong Kim, MD, PhD**; Kyung Seok Park, MD, PhD
1:23–1:28 pm Presentation #63 (pg. 204)	**What is the Best Available Patient-Reported Outcome Measure for Dysphagia in Cervical Spine Surgery? A Comparison of the Eating Assessment Tool (EAT-10) and SWAL-QOL** **Tyler J. Jenkins, MD**; Surabhi Bhatt, BS; Kern Singh, MD; Wellington K. Hsu, MD; Alpesh A. Patel, MD

1:29–1:34 pm Presentation #64 (pg. 206)	**Etiology and Surgical Strategies of Reoperation After Cervical Laminoplasty** **Yanbin Zhao, MD**; Yu Sun, MD
1:35–1:40 pm Presentation #65 (pg. 207)	**Prevention of Pseudoarthrosis in Multilevel ACDF with Individual Level Plate Fixation vs. Single Long Plate** **Richard A. Hynes, MD**; Devin K. Datta, MD
1:41–1:53 pm	**Discussion**
1:54–2:04 pm	**Special Projects Committee Report** Jeffrey A. Rihn, MD
2:05–3:11 pm	**Session XII: RESEARCH SESSION** Moderators: Zoher Ghogawala, MD, FACS
2:05–2:15 pm	**Announcement–2017 Research Grant Winners**
2:16–2:17 pm	**Introduction–Research Grant Updates**
2:18–2:23 pm	**2016 Medtronic** **Analysis of the Human Serum Proteome in Cervical Radiculopathy Patients to Predict Who Will Fail Conservative Treatment and Require Surgery** Steven M. Presciutti, MD
2:24–2:29 pm	**2016 Medtronic** **Does Psychological Distress Impact the Clinical Outcomes in Patients Undergoing Cervical Spine Surgery, and Should We Intervene? A Prospective, Blind and Placebo-Controlled Trial** Peter G. Passias, MD
2:30–2:35 pm	**2016 CSRS 21st Century Research and Education Grants** **Resveratrol as a Therapeutic to Reverse the Adverse Effects of Cigarette Smoke on Bone** Wellington K. Hsu
2:36–2:41 pm	**Exploration for Novel Molecular Biomarkers of Acute Spinal Cord Injury** Masao Koda, MD
2:42–2:47 pm	**2016 Seed Starter Grants** **Loss of Range of Motion Following Cervical Fusion: Effect on Activities of Daily Living Kinematics and Patient Satisfaction** Kevin M. Bell, PhD
2:48–2:53 pm	**Evaluation of Gait Recovery and Energy Expenditure Following Decompression and Stabilization for Cervical Spondylotic Myelopathy** Hamid Hassanzadeh, MD
2:54–3:11 pm	**Discussion**
3:11 pm	**Adjourn**

- **The FDA has not cleared the drug and/or medical device for the use described (i.e., the drug and/or medical device noted with an * is being discussed for an "off label" use). See inside back cover for information.**

7:00–7:05 am	**Welcome and Announcements** Louis G. Jenis, MD
7:06–7:49 am	**Session XIII: ANTERIOR SURGERY II** Moderators: Kazuhiro Chiba, MD, PhD and Timothy A. Garvey, MD
7:06–7:11 am Presentation #66 (pg. 209)	**1st Place Clinical Research Award Winner** **The Real Costs of ACDF: A Time-Driven Activity-Based Costing Analysis** **Gregory D. Schroeder, MD**; Alan S. Hilibrand, MD; Christopher K. Kepler, MD, MBA; Kristen J. Nicholson, PhD; Christie Stawicki, BS; Jonathan Paul, BS; Priyanka Kumar, BS; Douglas Hollern, MD; Hamadi Murphy, MD; Mark F. Kurd, MD; Barret I. Woods, MD; Kristen E. Radcliff, MD; D. Greg Anderson, MD; Alexander R. Vaccaro, MD, PhD, MBA; Jeffery A. Rihn, MD
7:12–7:17 am Presentation #67 (pg. 211)	**1st Place Resident/Fellow Research Award Winner** **Favorable Prognosis for Significant Preoperative Upper Extremity Weakness Following Elective Anterior Cervical Discectomy and Fusion** **Arjun S. Sebastian, MD**; Scott C. Wagner, MD; Patrick B. Morrisey, MD; Ian D. Kaye, MD; Alan S. Hilibrand, MD; Alexander Vaccaro, MD, PhD, MBA; Christopher K. Kepler, MD, MBA
7:18–7:23 am Presentation #68 (pg. 213)	**Comparison of Neck Pain and Complications of Stand-Alone vs. Conventional Plate and Interbody Fusion** **Christian Fisahn, MD**; Shiveindra Jeyamohan, MD; Marc Moisi, MD; Fernando Alonso, MD; Daniel C. Norvell, PhD; R. Shane Tubbs, PhD; Rod J. Oskouian, MD; Thomas A. Schildhauer, MD; Jens R. Chapman, MD
7:24–7:29 am Presentation #69 (pg. 214)	**Is Two-Level Cervical Disc Replacement More Cost-Effective than Anterior Cervical Discectomy and Fusion at 7-Years?** Robert K. Merrill, BS; Steven J. McAnany, MD; Todd J. Albert, MD; **Sheeraz A. Qureshi, MD**
7:30–7:35 am Presentation #70 (pg. 215)	**Impact of Body Mass Index on Surgical Outcomes, Narcotic Consumption, and Costs Following Anterior Cervical Discectomy and Fusion** Ankur S. Narain, BA; **Fady Y. Hijji, MD**; Brittany E. Haws, BS; Krishna T. Kudaravalli, BS; Kelly H. Yom, BA; Jonathan Markowitz, BS; Kern Singh, MD
7:36–7:49 am	**Discussion**

Individual Disclosures can be found on pages 41–95.
P=Highlighted Posters

7:50 – 8:45 am	**Symposium: 8 Unique Tips and Pearls for Cervical Spine Surgeons** Moderators: Louis G. Jenis, MD Panel: Frank J. Eismont, MD; Jeffrey S. Fischgrund, MD; Rick Sasso, MD; Christopher I. Shaffrey, MD; Alexander Vacarro, MD, PhD, MBA; Jeffrey C. Wang, MD; Thomas A. Zdeblick, MD
8:33 – 8:45 am	**Discussion**
8:50 – 9:33 am	**Session XIV: OUTCOMES** Moderators: Bruce V. Darden II, MD and R. Alden Milam, IV, MD
8:50 – 8:55 am Presentation #71 (pg. 218)	**Clinical and Radiographic Outcomes of Patients with Cervical Deformity Secondary to Thoracolumbar Proximal Junctional Kyphosis** Peter G. Passias, MD; Samantha R. Horn, BA; Gregory W. Poorman, BA; Alan H. Daniels, MD; D. Kojo Hamilton, MD; Daniel M. Sciubba, MD; Justin S. Smith, MD; Christopher I. Shaffrey, MD; Renaud Lafage; **Virginie Lafage, PhD**; Christopher P. Ames, MD; Gregory Mundis, MD; Robert Eastlack, MD; Frank J. Schwab, MD; International Spine Study Group
8:56 – 9:01 am Presentation #72 (pg. 220)	**The Relationship Between Improvements in Myelopathy and Sagittal Realignment in Cervical Deformity Surgery** **Brian J. Neuman, MD** Peter G. Passias, MD; Samantha R. Horn, BA; Subaraman Ramchandran, MD; Douglas C. Burton, MD; Themistocles S. Protopsaltis, MD; Renaud Lafage; Virginie Lafage, PhD; Gregory W. Poorman, BA; Justin S. Smith, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Alexandra Soroceanu, MD; Eric O. Klineberg, MD; International Spine Study Group
9:02 – 9:07 am Presentation #73 (pg. 222)	**Cost-Effectiveness Analysis of Intraoperative Corticosteroid Administration in Anterior Cervical Discectomy and Fusion for Degenerative Disease** **Juneyoung L. Yi, MD**; Brandon K. Bellows, PharmD, MD; Tyler J. Jenkins, MD; Alpesh A. Patel, MD; Erica F. Bisson, MD, MPH
9:08 – 9:13 am Presentation #74 (pg. 224)	**Is There a Preoperative Morphine Equianalgesic Dose that Predicts Ability to Achieve a Clinically Meaningful Improvement Following Spine Surgery?** Joseph B. Wick, BA; **Ahilan Sivaganesan, MD**; Silky Chotai, MD; Kristin R. Archer, PhD, DPT; Samuel L. Posey, BS; Parker T. Evans, BS; Joel R. Campbell, MD; Clinton J. Devin, MD
9:14 – 9:19 am Presentation #75 (pg. 226)	**The Natural History of Acute Cervical Radicular Pain** William J. Beckworth, MD; **Benjamin Abramoff, MD**; Laura Ward, Jacob Jacob Lee, DO; Marly Dows-Martinez, S. Tim Yoon, MD, PhD
9:20 – 9:33 am	**Discussion**

9:34 – 9:38 am	**Announcement of Poster Award Winners**
9:39 – 9:44 am	**Presentation of CSRS Medallion to Jeffrey C. Wang, MD**
9:45 – 10:00 am	**Break** Exhibit Hall – Grand Ballroom
10:01 – 10:44 am	**Session XV: SURGICAL OUTCOMES** Moderators: Michael D. Daubs, MD and Michael G. Fehlings, MD, PhD
10:01 – 10:06 am Presentation #76 (pg. 228)	**2nd Place Clinical Research Award Winner** **The Impact of Local Steroid Application on Dysphagia Following an Anterior Cervical Discectomy and Fusion: Preliminary Results of a Prospectively, Randomized, Single Blind Trial** Ankur S. Narain, BA; **Fady Y. Hijji, MD**; Brittany E. Haws, BS; Benjamin C. Mayo, BA; Dustin H. Massel, BS; Kelly H. Yom, BA; Krishna T. Kudaravalli, BS; Khaled Aboushaala, MD; Kern Singh, MD
10:07 – 10:12 am Presentation #77 (pg. 231)	**Do Cervical Spine Surgery Patients Recall Their Preoperative Status? A Cohort Study of Recall Bias in Patient-Reported Outcomes** **M. Tayseer Shamaa, MBBS**; Ilyas S. Aleem, MD, MSc, FRCSC; Bradford L. Currier, MD; Michael J. Yaszemski, MD, PhD; Heidi Poppendeck; Paul M. Huddleston, MD; Jason Eck, DO, MS; John Rhee, MD; Mohamad Bydon, MD; Brett Freedman, MD; Ahmad Nassr, MD
10:13 – 10:18 am Presentation #78 (pg. 233)	**The Impact of Preoperative Depression on Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) Survey Results in a Cervical Spine Surgery Setting** **Jay M. Levin, BA**; Joseph E. Tanenbaum, BA; Thomas E. Mroz, MD; Michael P. Steinmetz, MD
10:19 – 10:24 am Presentation #79 (pg. 234)	**Psychosocial Risk Factors for Chronic Opioid Use After Single-Level Cervical Fusion for Radiculopathy: A Workers' Compensation Population** **Mhamad Faour, MD**; Joshua T. Anderson, MD; Uri M. Ahn, MD; Nicholas U. Ahn, MD
10:25 – 10:30 am Presentation #80 (pg. 235)	**The Impact of Multiple Patient-Reported Allergies on Clinical Outcomes After Anterior Cervical Discectomy and Fusion** **Douglas L. Nestorovski, MD**; Steven J. McAnany, MD; Michael P. Kelly, MD; Colleen M. Peters, MA; Lukas P. Zebala, MD
10:31 – 10:44 am	**Discussion**

10:45–11:00 am	**Session XVI: HIGHLIGHT POSTERS II** Moderators: Robert F. Heary, MD and Rick Sasso. MD
Deformity	
10:45–10:47 am Presentation #81 (pg. 237)	**Impact of Obesity on Radiographic Alignment and Short-Term Complications After Surgical Treatment of Adult Cervical Deformity** Peter G. Passias, MD; Gregory W. Poorman, BA; Samantha R. Horn, BA; **Alan H. Daniels, MD**; D. Kojo Hamilton, MD; Daniel M. Sciubba, MD; Justin S. Smith, MD; Brian J. Neuman, MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Renaud Lafage; Christopher P. Ames, MD; Robert A. Hart, MD; Alex Soroceanu, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; International Spine Study Group
10:48–10:50 am Presentation #82 (pg. 239)	**Predictive Model for Distal Junctional Kyphosis After Cervical Deformity Surgery** Peter G. Passias, MD; Dennis Vasquez-Montes, MD; Gregory W. Poorman, BA; Themistocles S. Protopsaltis, MD; Samantha R. Horn, BA; Bassel G. Diebo, MD; Christopher P. Ames, MD; Justin S. Smith, MD; **Virginie Lafage, PhD**; Renaud Lafage, Eric O. Klineberg, MD; Christopher I. Shaffrey, MD; Robert Shay Bess, MD; Frank J. Schwab, MD; International Spine Study Group
10:51–10:53 am Presentation #83 (pg. 241)	**Identifying Sources of Improvement of Axial Pain in Corrective Cervical Deformity Surgery** Peter G. Passias, MD; Gregory W. Poorman, BA; Samantha R. Horn, BA; Eric O. Klineberg, MD; Christopher I. Shaffrey, MD; Virginie LaFage, PhD; Themistocles S. Protopsaltis, MD; Christopher P. Ames, MD; Justin S. Smith, MD; Gregory M. Mundis, MD; **Brian J. Neuman, MD**; Robert A. Hart, MD; Douglas C. Burton, MD; International Spine Study Group
10:54–10:56 am Presentation #84 (pg. 243)	**Sagittal Alignment Parameters Associated with Adjacent Segment Pathology After Anterior Cervical Discectomy and Fusion** Justin C. Paul, MD; Bryce A. Basques, MD; **Philip K. Louie, MD**; Arya Varthi, MD; Jonathan Markowitz, BS; Steve Heidt, BS; Sumender Sharma, MS; Edward J. Goldberg, MD; Howard S. An, MD
10:57–10:59 am Presentation #85 (pg. 246)	**Predictive Model for Achieving a Good Overall Outcome at One-Year Following Surgical Correction of Adult Cervical Deformity** **Alan H. Daniels, MD** Peter G. Passias, MD; Cheongeun Oh, PhD; Samantha R. Horn, BA; Gregory W. Poorman, BA; Renaud Lafage; Bassel Diebo, MD; Justin K. Scheer, MD; Justin S. Smith MD; Christopher I. Shaffrey, MD; Themistocles S. Protopsaltis, MD; Han Jo Kim, MD; Robert A. Hart, MD; Virginie Lafage, PhD; Christopher P. Ames, MD; International Spine Study Group
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Myelopathy III	
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12:12–12:13 pm	**Closing Remarks** Louis G. Jenis, MD
12:14 pm	**Adjourning Notices** Jeffrey C. Wang, MD

- **The FDA has not cleared the drug and/or medical device for the use described (i.e., the drug and/or medical device noted with an * is being discussed for an "off label" use). See inside back cover for information.**

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Name	Disclosure Information	Presentations	E-Posters
Abalos, Andrew Thomas	No Conflicts to Disclose; Submitted on: 05/01/2017		28
Aboushaala, Khaled Abdulsalam	No Conflicts to Disclose; Submitted on: 05/31/2017	76	
Abramoff, Benjamin	No Conflicts to Disclose; Submitted on: 04/13/2017	75	
Abumi, Kuniyoshi SP	Submitted on: 11/08/2017 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 Robert-Reid-Japan: Paid consultant SAS Journal: Editorial or governing board Spine: Editorial or governing board		
Aguwa, Okezie K	No Conflicts to Disclose; Submitted on: 05/01/2017	19, 37	
Ahn, Nicholas Utchan	Submitted on: 06/25/2017 North American Spine Society: Board or committee member Spine: Editorial or governing board The Spine Journal: Editorial or governing board Ulrich: Other financial or material support; Research support	79	
Ahn, Uri	Submitted on: 06/08/2017 Alphatec Spine: IP royalties Osseus: IP royalties; Paid consultant; Stock or Stock Options	79	
Ahuja, Christopher S	No Conflicts to Disclose; Submitted on: 05/01/2017	57	
Aidlen, Jessica Pelow	Submitted on: 06/28/2017 Mozaic (Healthcare IT company): Stock or stock Options; Unpaid consultant Precision Spine: Paid consultant Stryker: Paid consultant	91	
Alaras, Adrian	No Conflicts to Disclose; Submitted on: 05/01/2017	22, 35	

Name	Disclosure Information	Presentations	E-Posters
Albert, Todd J	Submitted on: 05/01/2017 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: Paid consultant; 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 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	19, 69, 94	16, 30
Aleem, Ilyas	No Conflicts to Disclose; Submitted on: 04/28/2017	77	
Almenawer, Saleh A	No Conflicts to Disclose; Submitted on: 05/02/2017	28	
Alonso, Fernando	No Conflicts to Disclose; Submitted on: 03/30/2017	68	
Ames, Christopher P	Submitted on: 04/10/2017 Biomet Spine: IP royalties DePuy: Paid consultant Fish & Richardson, P.C.: Other financial or material support Medtronic: Paid consultant Stryker: IP royalties; Paid consultant	9, 10, 11, 36, 37, 38, 39, 50, 60, 71, 72, 81, 82, 83, 85, 94	37, 45
An, Howard S M	Submitted on: 10/17/2017 American Journal of Orthopedics: Editorial or governing board Articular Engineering LLC: Stock or stock Options Bioventis Inc.: Paid consultant Medyssey Inc: Research support Medyssey Inc.: Stock or stock Options Spinal Kinetics Inc.: Stock or stock Options Spinalcyte Inc.: Research support Spine: Editorial or governing board U & I Inc.: IP royalties; Stock or stock Options Zimmer: IP royalties	84	41, 55

Name	Disclosure Information	Presentations	E-Posters
Anderson, D Greg [A]	Submitted on: 04/15/2017 Cervical Spine Research Society, Society for Minimally Invasive Spinal Surgery: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant ISD: Stock or stock Options PST: Stock or stock Options Thieme: Publishing royalties, financial or material support	66, 93	
Anderson, Joshua T	No Conflicts to Disclose; Submitted on:10/08/2017	79	
Anderson, Paul A [S]	Submitted on: 04/07/2017 AAOS: Board or committee member American Orthopaedic Association: Board or committee member ASTM: Board or committee member Clinical Orthopaedics and Related Research: Editorial or governing board Expanding Orthopedics: Stock or stock Options; Unpaid consultant Globus Medical: Paid consultant Journal of Bone and Joint Surgery–American: Editorial or governing board Journal of Orthopaedics and Traumatology: Editorial or governing board Journal of spinal disorders: Editorial or governing board Lumbar Spine Research Society: Board or committee member Neurosurgery: Editorial or governing board North American Spine Society: Board or committee member Pioneer: IP royalties Saunders/Mosby-Elsevier: Publishing royalties, financial or material support SI Bone: Stock or stock Options; Unpaid consultant Spartec: Stock or stock Options; Unpaid consultant Spine: Editorial or governing board Spine Arthroplasty Journal: Editorial or governing board Spine Arthroplasty Society: Board or committee member Spine Journal: Editorial or governing board Spine section of AANS/CNS: Board or committee member Stryker: IP royalties Titan surgical: Stock or stock Options; Unpaid consultant		
Anderst, William	Submitted on: 05/31/2017 Journal of Biomechanics: Editorial or governing board Journal of Orthopaedic Research: Editorial or governing board Smith & Nephew: Research support	8	

Name	Disclosure Information	Presentations	E-Posters
Anil, Utkarsh	No Conflicts to Disclose; Submitted on: 04/30/2017		23
Aoyama, Ryoma	No Conflicts to Disclose; Submitted on: 04/30/2017		38, 44
Araghi, Ali	Submitted on: 05/02/2017 ABSSNASSISASS: Board or committee member bacteria: Paid presenter or speaker benovo, PDP and ISOI: Stock or stock Options Globus Medical: IP royalties LDRVertiflex: Research support Ortho todaySpine JournalJournal of ISASS: Editorial or governing board spinal kinetics, zyga: Research support Vertebral TechnologiesAlphatecOrthokinematicsSurgifileBacterin International: Stock or stock Options zyga: Paid presenter or speaker		47
Arai, Yoshiyasu	No Conflicts to Disclose; Submitted on: 04/29/2017	26, 33	
Arakal, Rajesh	Submitted on: 05/01/2017 DePuy, A Johnson & Johnson Company: Paid consultant Stryker: Paid consultant	1	
Archer, Kristin	Submitted on: 04/03/2017 American Physical Therapy Association: Board or committee member Foundation for Physical Therapy: Board or committee member Pacira: Paid consultant Physical Therapy: Editorial or governing board	74	

Name	Disclosure Information	Presentations	E-Posters
Arnold, Paul M [M, RC]	Submitted on: 05/01/2017 AANS/CNS Joint Section on Neurotrauma & Critical Care: Board or committee member AO Spine North America(this is a past relationship): Board or committee member AOSpine North America: Research support AOSpine North America- Sponsored or Reimbursed Travel for Myself only: Other financial or material support Cerapedics: Research support Covidien: Research support DePuy Spine: Research support Evoke Medical: IP royalties; Stock or stock Options IAMI, Asubio Pharmaceuticals, Spineology, AOSpine International, Acorda Therapeutics, AOSpine International: Research support Invivo: Paid consultant Journal of Spinal Disorders and Techniques,The Spine Journal, Spine, Yonsei Medical Journal, Journal of Neurosurgery: Spine, Indian Journal of Cancer, Neurosurgery, Indian Journal of Orthopedics, Journal of Spinal Cord Medicine, Global Spine Journal, Journal of Pediatric Neuroradiology, World Journal of Surgical Oncology, Nigerian Journal of Surgery, Surgical Neurology International, Journal Radiology Case Reports, 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 SpineWave: Paid consultant Stryker: Paid consultant Z-plasty: Stock or stock Options	4	
Arvind, Varun	No Conflicts to Disclose; Submitted on: 05/01/2017		18, 35
Badner, Anna Maria	No Conflicts to Disclose; Submitted on: 11/08/2017	56	
Badhiwala, Jetan Hari	No Conflicts to Disclose; Submitted on: 05/02/2017	28	
Baik, Jong-Min	No Conflicts to Disclose; Submitted on: 04/30/2017	47	54
Banagan, Kelley E	Submitted on: 06/06/2017 K2M: Employee Orthofix, Inc.: Research support	20	
Bao, Hongda	No Conflicts to Disclose; Submitted on: 05/01/2017	94	
Barnard, Zachary	No Conflicts to Disclose; Submitted on: 06/05/2017		

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Barnes, Allen	No Conflicts to Disclose; Submitted on: 05/31/2017		31
Bartels, Ron[SP]	Submitted on: 11/07/2017 Cervical Spine Research Society: Board or committee member European Spine Journal: Editorial or governing board		
Barton, Cameron	No Conflicts to Disclose; Submitted on: 05/02/2017	51, 52	
Basques, Bryce A	No Conflicts to Disclose; Submitted on: 05/26/2017	84	41, 55
Beaubrun, Bryan M	No Conflicts to Disclose; Submitted on: 04/26/2017	15	21
Beckworth, William Jeremy	Submitted on: 04/16/2017 Mesoblast: Research support Spine Intervention Society: Board or committee member	75	
Bedard, Nicholas	No Conflicts to Disclose; Submitted on: 04/05/2017	52	
Belanger, Theodore Andrew	No Conflicts to Disclose; Submitted on: 04/27/2017	1	
Bell, Kevin Michael [RS]	(This individual reported nothing to disclose); Submitted on: 09/28/2017		
Bellows, Brandon K	Submitted on: 04/27/2017 Johnson & Johnson: Research support	73	
Bernstein, David	Submitted on: 04/09/2017 American Academy of Pediatrics – Ex Officio, Committee on Infectious Diseases: Board or committee member Current Opinion in Pediatrics: Editorial or governing board PediaLink: Editorial or governing board Red Book Online: Editorial or governing board		17
Bess, Robert Shay	Submitted on: 05/01/2017 Biomet: Research support DePuy, A Johnson & Johnson Company: Research support k2 medical: IP royalties; Paid consultant; Paid presenter or speaker; Research support Medtronic Sofamor Danek: Research support North American Spine Society: Board or committee member Nuvasive: Research support Pioneer Spine: IP royalties Scoliosis Research Society: Board or committee member Stryker: Research support	9, 10, 36, 37, 38, 39, 50, 82	37, 45

Name	Disclosure Information	Presentations	E-Posters
Bhatia, Nitin N [P]	Submitted on: 04/05/2017 Alphatec Spine: IP royalties; Paid consultant; Paid presenter or speaker; Research support Biomet: IP royalties; Paid consultant; Paid presenter or speaker DiFusion: Paid consultant; Stock or stock Options North American Spine Society: Board or committee member OKO: Editorial or governing board Seaspine: IP royalties; Paid consultant; Paid presenter or speaker; Research support Spineart: Paid presenter or speaker Spineart, Zimmer: Paid consultant SpineLine: Editorial or governing board Stryker: IP royalties; Paid consultant; Paid presenter or speaker Western Orthopaedic Association: Board or committee member		
Bhandutia, Amit Ketan	No Conflicts to Disclose; Submitted on: 05/01/2017	20	
Bhatt, Surabhi A	No Conflicts to Disclose; Submitted on: 04/13/2017	63	
Bisson, Erica Fay [M, P]	Submitted on: 04/27/2017 AANS Ethics, AANS / CNS Spine SPC: Board or committee member AANS Neurosurgeon: Editorial or governing board nView: Paid consultant; Stock or stock Options	73	
Boah, Akwasi Ofori	No Conflicts to Disclose; Submitted on: 04/30/2017	1	
Boniello, Anthony J	No Conflicts to Disclose; Submitted on: 04/06/2017	4	12
Bono, Olivia Jane	Submitted on: 05/01/2017 Springer: Other financial or material support Stryker: Other financial or material support	15	
Bovonratwet, Patawut	No Conflicts to Disclose; Submitted on: 05/04/2017	95	
Boyajian, Haroutioun Hratch	No Conflicts to Disclose; Submitted on: 06/13/2017	92	
Brodke, Darrel S [M, SP, P]	Submitted on: 04/04/2017 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		
Brown, Luke	No Conflicts to Disclose; Submitted on: 06/05/2017	20	

Name	Disclosure Information	Presentations	E-Posters
Buchowski, Jacob [P]	Submitted on: 11/09/2017 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		
Buckland, Aaron	No Conflicts to Disclose; Submitted on: 05/01/2017	60	43
Bueff, Hans-Ulrich [P]	Submitted on: 07/09/2017 Cervical Spine Research Society: Board or committee member		
Burke, Shane M	No Conflicts to Disclose; Submitted on: 04/28/2017	49	
Burkus, J Kenneth	Submitted on: 04/27/2017 American Journal of Orthopedics: Editorial or governing board Clinical Orthopaedics and Related Research: Editorial or governing board Clinical Spine Surgery: Editorial or governing board Medtronic Sofamor Danek: Research support Medtronic Sofamor DanekBiomet: Paid consultant Vertera Spine: IP royalties; Stock or stock Options Zimmer: IP royalties; Paid consultant	7	
Burton, Douglas C	Submitted on: 05/02/2017 Bioventus: Research support DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Research support Pfizer: Research support Scoliosis Research Society: Board or committee member Spine Deformity: Editorial or governing board	9, 10, 11, 37, 38, 72, 83	37, 45
Buser, Zorica	Submitted on: 05/08/2017 AO Spine (past): Paid consultant Xenco Medical: Paid consultant		13, 26
Butler, Joseph	No Conflicts to Disclose; Submitted on: 05/02/2017		19
Bydon, Mohamad	No Conflicts to Disclose; Submitted on: 05/09/2017	77	
Cadotte, David	Submitted on: 11/07/2017 7D Surgical: Stock or stock Options	59, 89	

Name	Disclosure Information	Presentations	E-Posters
Caldwell, Jon-Michael	No Conflicts to Disclose; Submitted on: 05/25/2017	54	
Campbell, Joel	No Conflicts to Disclose; Submitted on: 04/03/2017	74	
Campbell, Peter	No Conflicts to Disclose; Submitted on: 05/02/2017	23	
Cannestra, Andrew	Submitted on: 05/02/2017 Alliance spine: Paid consultant Atlas spine: Paid consultant MAZOR Surgical Technologies: Paid consultant; Stock or stock Options Nuvasive: IP royalties; Paid consultant; Stock or stock Options Picra pharmaceutical: Stock or stock Options Regeneration Technologies, Inc.: IP royalties; Paid consultant Spinal Elements: Paid consultant		28
Caridi, John	Submitted on: 05/02/2017 North American Spine Society: Board or committee member Scoliosis Research Society: Board or committee member Zimmer: Paid consultant; Research support		18
Cassinelli, Eqequiel H [P]	Submitted on: 07/18/2017 Cervical Spine Research Society: Board or committee member Irrisept: Stock or stock Options Stryker: Paid consultant; Paid presenter or speaker		
Cavanaugh, David Albert	No Conflicts to Disclose; Submitted on: 05/02/2017	23	
Chan, Andrew	No Conflicts to Disclose; Submitted on: 05/02/2017	32	
Chang, David	Submitted on: 05/08/2017 amedica: Stock or stock Options Regeneration Technologies, Inc.: Paid consultant	18	
Chapman, Jens R	Submitted on: 03/30/2017 AO North America Board of Directors: Board or committee member Evidence Based Spine Journal Global Spine Journal: Editorial or governing board Evidence Based 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	68	

Name	Disclosure Information	Presentations	E-Posters
Cheng, Ivan [RC]	Submitted on: 04/04/2017 AAOS: Board or committee member Cervical Spine Research Society: Board or committee member Globus Medical: Paid consultant Nuvasive: IP royalties Scoliosis Research Society: Board or committee member Spinal Cyte: Stock or stock Options Spine Wave: Stock or stock Options SpineCraft: Paid consultant SpineThe Spine Journal: Editorial or governing board		
Cheng, Xin-Kun	No Conflicts to Disclose; Submitted on: 04/29/2017	40	
Chi, Debbie	No Conflicts to Disclose; Submitted on: 05/02/2017		16, 17
Chiba, Kazuhiro [M]	Submitted on: 10/08/2017 Asahi Kasei Pharma Corp.: Research support; Astellas Pharma Inc.: Research support; Bristol-Myers Squibb: Paid presenter or speaker; Cervical Spine Research Society Asia-Pacific Section: Board or committee member; Chug Pharmaceutical Co. Ltd.: Research support; Daiichi Sankyo Co. Ldt: Research support; Eastern Japan Association of Orthopedics and Traumatology: Board or committee member; Eisai Co. Ltd.: Paid presenter or speaker; Research support; Eli Lilly: Research support; European Spine Journal: Editorial or governing board; Hisamitsu Pharmaceutical Co. Inc.: Paid presenter or speaker; International Society for the Study of the Lumbar Spine: Board or committee member; Japanese Orthopedic Association: Board or committee member; Japanese Society for Spine Surgery and Related Research: Board or committee member; Journal of Orthopaedic Research: Editorial or governing board; Journal of Orthopaedic Science: Editorial or governing board; Kaken Pharmaceutical Co. Ltd.: Paid presenter or speaker; Kanto Society of Orthopedics and Traumatology: Board or committee member; Medical View: Publishing royalties, financial or material support; Medtronic Sofamor Danek: Research support; Miwa Shoten Ltd.: Publishing royalties, financial or material support; MSD K.K.: Research support; Nankodo Co. Ltd.: Publishing royalties, financial or material support; Nikkei BP: Publishing royalties, financial or material support; Pfeizer Japan Inc.: Paid presenter or speaker; Pfizer: Research support; Seikagaku Corp.: Paid consultant; Research support; Shionogi & Co. Ltd.: Paid presenter or speaker; Research support; Spine: Editorial or governing board; Spine Surgery and Related Research: Editorial or governing board; Taisho-Toyama Pharmaceutical Co. Ltd.: Research support; The Japanese Society of Lumbar Spine Disorders: Board or committee member; The Study Group for Nerve and Spine: Board or committee member; Tiejin Pharma Ltd.: Paid presenter or speaker		

Name	Disclosure Information	Presentations	E-Posters
Chikuda, Hirotaka	No Conflicts to Disclose; Submitted on: 10/06/2017	13	
Cho, Jae Hwan	No Conflicts to Disclose; Submitted on: 05/01/2017	3, 45, 46, 47	10, 54
Cho, Nam Ik	No Conflicts to Disclose; Submitted on: 05/01/2017	3	
Cho, Samuel Kang-Wook	Submitted on: 10/06/2017 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 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		18, 20, 34, 35
Choi, Seungjin	No Conflicts to Disclose; Submitted on: 05/01/2017	22, 35	
Chotai, Silky	No Conflicts to Disclose; Submitted on: 03/24/2017	74	
Chou, Dean	Submitted on: 05/03/2017 Globus Medical: IP royalties; Paid consultant Medtronic: Paid consultant	32	
Chu, Ray	No Conflicts to Disclose; Submitted on: 05/04/2017		
Chun, Danielle	No Conflicts to Disclose; Submitted on: 04/29/2017	48	
Cohen, Jeffrey	Submitted on: 05/01/2017 SpecialtyCare: Employee		
Cohen-Adad, Julien	No Conflicts to Disclose; Submitted on: 11/07/2017	59, 89	28
Cook, Ralph	No Conflicts to Disclose; Submitted on: 05/01/2017	48	
Craven, Cathy	Submitted on: 05/02/2017 Rick Hansen Institute Care Committee: Board or committee member	44	
Cui, Jonathan	Submitted on: 05/17/2017 Merck: Employee; Stock or stock Options	95	
Currier, Bradford L [S]	Submitted on: 10/08/2017 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	77	
Da Costa, Leodante	No Conflicts to Disclose; Submitted on: 05/02/2017	28	

Name	Disclosure Information	Presentations	E-Posters
Daffner, Scott D [RC]	Submitted on: 05/31/2017 Amgen Co: Stock or stock Options Bioventus: Paid consultant; Research support Cervical Spine Research Society: Board or committee member Lumbar Spine Research Society: Board or committee member North American Spine Society: Board or committee member Orthopedic & Muscular System: Current Research: Editorial or governing board Pfizer: Research support; Stock or stock Options Spinal Kinetics: Research support		47
Dailey, Andrew T [RC]	Submitted on: 05/01/2017 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		
Daimon, Kenshi	No Conflicts to Disclose; Submitted on: 05/01/2017	25, 42, 43	
Daniels, Alan H	Submitted on: 06/01/2017 DePuy, A Johnson & Johnson Company: Paid consultant Globus Medical: Paid consultant Orthofix, Inc.: Paid consultant; Research support SpineArt: Paid consultant Springer: Publishing royalties, financial or material support Stryker: Paid consultant	17, 71, 81, 85	49
Darden, Bruce V [M]	Submitted on: 12/12/2016 4Web: Paid consultant; Stock or stock Options BioMedFlex: Stock or stock Options Cervical Spine Research Society, Lumbar Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: Research support Journal of Spinal Disorders and techniques, Journal of Spinal Cord Medicine, JAAOS: Editorial or governing board Spine: Editorial or governing board Spineguard: Paid consultant Stryker: IP royalties; Paid consultant; Paid presenter or speaker Synthes: Paid presenter or speaker; Research support		
Dastagirzada, Yosef Michael	No Conflicts to Disclose; Submitted on: 04/30/2017	12	

Name	Disclosure Information	Presentations	E-Posters
Datta, Devin K	Submitted on: 05/03/2017 Brevard County Medical Society: Board or committee member Medtronic Sofamor Danek: Paid consultant; Paid presenter or speaker Providence medical: Paid presenter or speaker Spinewave: Paid consultant; Paid presenter or speaker	65	
Daubs, Michael D [M, P]	Submitted on: 04/10/2017 Cervical Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties The Spine Journal: Editorial or governing board		
Davis, Reginald	Submitted on: 05/02/2017 American Board of Spine Surgeons: Board or committee member Biomet: Paid consultant LDR, Paradigm, Zimmer, Vertiflex, Orthokinematic: Research support surgical neurology: Editorial or governing board Zimmer: IP royalties Zimmer, Paradigm, LDR,: Paid consultant		47
De La Garza Ramos, Rafael	No Conflicts to Disclose; Submitted on: 05/23/2017	15	
De Leener, Benjamin	No Conflicts to Disclose; Submitted on: 11/07/2017	59, 89	
Depasse, John Mason	No Conflicts to Disclose; Submitted on: 04/06/2017	17	49
Devin, Clinton J [P]	Submitted on: 04/21/2017 Cervical Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: Paid consultant; Research support Exparel: Paid consultant Medtronic Sofamor Danek: Other financial or material support North American Spine Society: Board or committee member Stryker: Paid consultant; Research support	74	
Di Capua, John	No Conflicts to Disclose; Submitted on: 05/01/2017		20, 34, 35
Dibattista, Jacob Victor	No Conflicts to Disclose; Submitted on: 05/01/2017		46
Diebo, Bassel	No Conflicts to Disclose; Submitted on: 04/27/2017	15, 39, 82, 85	11, 22, 60
Digiorgio, Anthony Michael	No Conflicts to Disclose; Submitted on: 05/02/2017	32	
Donaldson, William F	Submitted on: 04/12/2017 AAOS: Board or committee member	8	

Name	Disclosure Information	Presentations	E-Posters
Dowdell, James E	No Conflicts to Disclose; Submitted on: 05/02/2017		35
Dows-Martinez, Marly	Submitted on: 04/14/2017 Cryolife: Employee; Stock or stock Options	75	
Driscoll, Adam	No Conflicts to Disclose; Submitted on: 05/01/2017		1
Duncan, Kurt Joseph	No Conflicts to Disclose; Submitted on: 05/02/2017		57
Dunn, Conor	No Conflicts to Disclose; Submitted on: 05/15/2017	13	
Durand, Wesley Michael	No Conflicts to Disclose; Submitted on: 04/29/2017	17	49
DuShane, Lisa [C]	No Conflicts to Disclose; Submitted on: 03/07/2017		
Eastlack, Robert Kenneth	Submitted on: 04/28/2017 Aesculap/B.Braun: Paid consultant Alphatec Spine: Paid consultant; Stock or stock Options Carevature: Stock or stock Options DiFusion: Stock or stock Options Globus Medical: IP royalties Invuity: Stock or stock Options K2M: Paid consultant Nuvasive: Paid consultant; Research support; Stock or stock Options Scoliosis Research Society: Board or committee member Seaspine: Paid consultant Society of Lateral Access Surgery: Board or committee member Spine Innovations: Stock or stock Options Stryker: Paid consultant Titan: Paid consultant	71, 81	
Eck, Jason Cecil	Submitted on: 04/28/2017 AO Spine: Paid presenter or speaker JayPee Brothers Publishers: Publishing royalties, financial or material support	77	
Egawa, Satoru	No Conflicts to Disclose; Submitted on: 04/26/2017		27
Eismont, Frank J [SP]	Submitted on: 04/04/2017 Alphatec Spine: IP royalties; Paid consultant; Stock or stock Options Saunders / Mosby-Elsevier: Publishing royalties, financial or material support		
Emami, Arash	Submitted on: 04/25/2017 Nuvasive: Research support	13	
Endo, Teruaki	No Conflicts to Disclose; Submitted on: 04/19/2017		

Name	Disclosure Information	Presentations	E-Posters
Errico, Thomas J	Submitted on: 04/26/2017 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		43
Evans, Parker T	No Conflicts to Disclose; Submitted on: 03/24/2017	74	
Faloon, Michael	Submitted on: 04/04/2017 AAOS: Board or committee member DePuy, A Johnson & Johnson Company: Unpaid consultant K2M: Paid presenter or speaker; Research support North American Spine Society: Board or committee member Scoliosis Research Society: Board or committee member	13	
Faour, Mhamad	No Conflicts to Disclose; Submitted on: 04/08/2017	79	
Fehlings, Michael [M]	Submitted on: 03/09/2017 InVivo Therapeutics: Paid consultant None: Board or committee member; Editorial or governing board Pfizer: Paid consultant Zimmer: Paid consultant	24, 28, 41, 56, 57, 59, 86, 89	8
Fisahn, Christian	No Conflicts to Disclose; Submitted on: 04/04/2017	68	
Fischgrund, Jeffrey S [M, SP]	Submitted on: 10/09/2017 Cervical Spine Research Society: Board or committee member FzioMed: Paid consultant JAAOS: Editorial or governing board Journal of the American Academy of Orthopaedic Surgeons: Publishing royalties, financial or material support Lumbar Spine research Society: Board or committee member Relievant: Paid consultant Smith & Nephew: Research support Stryker: Paid consultant; Research support understand.com: Stock or stock Options		
Fisher, Nina	No Conflicts to Disclose; Submitted on: 04/30/2017	12	
Fleischman, Eitan	No Conflicts to Disclose; Submitted on: 04/25/2017	49	

Name	Disclosure Information	Presentations	E-Posters
Florman, Jeffrey E	Submitted on: 04/25/2017 Stryker: IP royalties; Paid consultant	49	
Frank, Kelly	No Conflicts to Disclose; Submitted on: 05/02/2017	23	
Freedman, Brett	Submitted on: 04/10/2017 Medtronic: Other financial or material support	77	
Fujita, Nobuyuki	No Conflicts to Disclose; Submitted on: 04/27/2017	2, 25, 27, 42, 43	51
Fujiwara, Hirokazu	Submitted on: 05/01/2017 Magnetic Resonance in Medical Sciences: Editorial or governing board	42, 43	
Fujiyoshi, Kanehiro	No Conflicts to Disclose; Submitted on: 04/29/2017		51
Furlan, Julio C	No Conflicts to Disclose; Submitted on: 04/03/2017	44	
Furuya, Takeo	No Conflicts to Disclose; Submitted on: 04/28/2017		42
Fyrner, Timmy	No Conflicts to Disclose; Submitted on: 05/01/2017	48	
Gangneung Asan Hospital	No Conflicts to Disclose; Submitted on: 05/03/2017		
Garvey, Timothy A [M]	Submitted on: 11/09/2017 Medtronic: Paid presenter or speaker Medtronic Sofamor Danek: IP royalties		
Gao, Yubo	No Conflicts to Disclose; Submitted on: 05/02/2017	51	
Gelb, Daniel E	Submitted on: 04/21/2017 Advanced Spinal Intellectual Property: Stock or stock Options Depuy-Synthes Spine: IP royalties; Paid presenter or speaker Globus Medical: IP royalties	20	
George, Andrew	No Conflicts to Disclose; Submitted on: 05/01/2017		1
Gerling, Michael C [M]	Submitted on: 05/02/2017 AAOS: Board or committee member Brooklyn Orthopedic Society: Board or committee member Cervical Spine Research Society: Board or committee member CTL Medical: Other financial or material support Fusion Medical Education Corp: Paid consultant Stryker: Other financial or material support Zyga Medical: Other financial or material support	4, 15, 31	11, 12, 60
Ghogawala, Zoher [M, RC]	Submitted on: 11/09/2017 Cervical Spine Research Society: Board or committee member North American Spine Society: Board or committee member		
Ginsberg, Howard	Submitted on: 11/07/2017 Stryker: Other financial or material support; Paid consultant; Research support	59, 89	
Goldberg, Edward Jay	No Conflicts to Disclose; Submitted on: 04/04/2017	84	41, 55
Goon, Kelsey Cayun	No Conflicts to Disclose; Submitted on: 05/01/2017	87	

Name	Disclosure Information	Presentations	E-Posters
Gornet, Matthew F	Submitted on: 05/02/2017 Aesculap / B.Braun: Paid consultant Bonovo: Stock or stock Options International Spine & Orthopedic Institute, LLC: Stock or stock Options K2M: Paid consultant Medtronic: Paid consultant; Research support Nocimed: Stock or stock Options OuroBorus: Stock or stock Options Paradigm Spine: Stock or stock Options	6, 7	
Gould, Heath	No Conflicts to Disclose; Submitted on: 05/01/2017	87	
Grabowski, Gregory	Submitted on: 04/27/2017 DePuy, A Johnson & Johnson Company: Paid presenter or speaker Johnson & Johnson: Paid consultant		31
Grauer, Jonathan N [RC]	Submitted on: 04/04/2017 AAOS: Board or committee member American Journal of Orthopedics: Editorial or governing board Bioventus: Paid consultant Cervical Spine Research Society: Board or committee member Contemporary Spine Surgery: Editorial or governing board Lumbar Spine Research Society: Board or committee member Medtronic: Paid consultant North American Spine Society: Board or committee member Stryker: Paid consultant The Spine Sournal: Editorial or governing board	95	
Gupta, Munish C	Submitted on: 04/05/2017 DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Paid presenter or speaker European Spine Journal-Reviewer: Editorial or governing board Global Spine Journal-Reviewer: Editorial or governing board Johnson & Johnson: Stock or stock Options Orthofix, Inc.: Paid consultant; Paid presenter or speaker Procter & Gamble: Stock or stock Options Spine Deformity, Associate Editor: Editorial or governing board	10, 36, 50, 94	37, 45
Ha, Alex	No Conflicts to Disclose; Submitted on: 06/06/2017	54	
Ha, Jung-Ki	No Conflicts to Disclose; Submitted on: 05/01/2017	3, 46	10, 54
Haddas, Ram	No Conflicts to Disclose; Submitted on: 04/26/2017	1	
Haines, Colin	No Conflicts to Disclose; Submitted on: 05/02/2017	87	

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Hamilton, D Kojo	Submitted on: 04/27/2017 European Spine Journal: Editorial or governing board Nuvasive: Research support Pfizer: Research support	10, 36, 60, 71, 81	45
Han, Sanghyun	No Conflicts to Disclose; Submitted on: 05/03/2017	62	
Hardy, Nathan	No Conflicts to Disclose; Submitted on: 05/03/2017		14
Harris, Mitchel B [P]	Submitted on: 10/06/2017 North American Spine Society: Board or committee member		
Harrop, James S [M]	Submitted on: 05/03/2017 Asterias: Other financial or material support; Unpaid consultant Bioventus: Other financial or material support; Unpaid consultant DePuy, A Johnson & Johnson Company: Paid consultant; 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 Tejin: Unpaid consultant Tejjin: Other financial or material support		28
Hart, Robert A [SP]	Submitted on: 04/29/2017 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	11, 36, 37, 81, 83, 85	
Hashizume, Hiroshi	No Conflicts to Disclose; Submitted on: 04/04/2017	55	
Hassanzadeh, Hamid [RS]	Submitted on: 05/30/2017 Orthofix, Inc.: Research support Pfizer: Research support	50	

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Haws, Brittany	No Conflicts to Disclose; Submitted on: 04/29/2017	70, 76	46, 48, 52, 53
Heary, Robert F [M]	Submitted on: 02/21/2017 American Association of Neurological Surgeons: Board or committee member Cervical Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties Lumbar Spine Research Society: Board or committee member Thieme Medical Publishers, Inc.: Publishing royalties, financial or material support Zimmer: IP royalties		
Heidt, Steven Thomas	No Conflicts to Disclose; Submitted on: 04/26/2017	84	
Heindel, Patrick	No Conflicts to Disclose; Submitted on: 04/28/2017		
Heller, John G [S]	John G Heller, MD: Submitted on: 05/31/2017 Cervical Spine Research Society: Board or committee member Medtronic: IP royalties; Paid consultant; Stock or stock Options		
Herrick, Daniel B	No Conflicts to Disclose; Submitted on: 04/25/2017	49	
Hijji, Fady Yousef	No Conflicts to Disclose; Submitted on: 05/01/2017	70, 76	
Hilibrand, Alan S	Submitted on: 04/09/2017 AAOS: Board or committee member Amedica: IP royalties; Stock or stock Options Benvenue Medical: Stock or stock Options Biomet: IP royalties Cervical Spine Research Society: Board or committee member Lifespine: Stock or stock Options Nexgen: Stock or stock Options North American Spine Society: Board or committee member Paradigm spine: Stock or stock Options PSD: Stock or stock Options spinal ventures: Stock or stock Options Vertiflex: Stock or stock Options	66, 67, 93	19
Hirai, Takashi	No Conflicts to Disclose; Submitted on: 04/25/2017	26, 33	27
Hirai, Takayuki	No Conflicts to Disclose; Submitted on: 05/02/2017		33
Hirata, Hiroaki	No Conflicts to Disclose; Submitted on: 05/01/2017		4, 32, 56
Hirsch, Brandon P	No Conflicts to Disclose; Submitted on: 04/26/2017	12, 15	23
Hoffman, Eve	No Conflicts to Disclose; Submitted on: 05/02/2017	20	
Hollern, Douglas	No Conflicts to Disclose; Submitted on: 08/15/2017	66	
Hong, Chul Gie	No Conflicts to Disclose; Submitted on: 05/01/2017	46	

Name	Disclosure Information	Presentations	E-Posters
Hong, Jae Taek	Submitted on: 04/28/2017 Korean Neurosurgical Spine Society: Board or committee member	61	
Honjoh, Kazuya	No Conflicts to Disclose; Submitted on: 05/02/2017		3, 29, 33
Horiuchi, Yosuke	No Conflicts to Disclose; Submitted on: 05/02/2017		51
Horn, Samantha	No Conflicts to Disclose; Submitted on: 04/26/2017	4, 15, 31, 37, 39, 60, 71, 72, 81 82, 83, 85	11, 12, 22, 60
Hostin, Richard A	Submitted on: 05/02/2017 DePuy, A Johnson & Johnson Company: Paid consultant; Research support DJ Orthopaedics: Research support K2M: Research support Nuvasive: Research support Seeger: Research support	9, 38, 50	
Houten, John Kenneth	Submitted on: 04/21/2017 Medtronic: Paid consultant	34	
Hsu, Erin L.	Submitted on: 05/01/2017 AAOS: Board or committee member Bacterin: Paid consultant Bioventus: Paid consultant CeramTec: Paid consultant Cervical Spine Research Society: Board or committee member Globus Medical: Paid consultant Graftys: 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 RTI: Paid consultant SI Bone: Paid consultant Spinesmith: Paid consultant Stryker: IP royalties; Paid consultant Terumo: Paid consultant Zimmer: Paid consultant	48	1

Name	Disclosure Information	Presentations	E-Posters
Hsu, Wellington K [RS, A]	Submitted on: 04/30/2017 AAOS: Board or committee member Allosource: Paid consultant AONA: Paid consultant; Paid presenter or speaker CeramTec: Paid consultant Cervical Spine Research Society: Board or committee member Globus Medical: Paid consultant Graftys: Paid consultant Journal of Spinal Disorders and Techniques: 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 Rti: Paid consultant Stryker: IP royalties; Paid consultant Xtant: Paid consultant	48, 63	1
Hu, Emily	No Conflicts to Disclose; Submitted on: 05/01/2017	87	
Hu, Serena [P]	Submitted on: 05/29/2017 American Orthopaedic Association: Board or committee member DePuy, A Johnson & Johnson Company: Paid presenter or speaker Nuvasive: IP royalties; Stock or stock Options Scoliosis Research Society: Board or committee member		
Hu, Yong	No Conflicts to Disclose; Submitted on: 05/01/2017		9
Huang, Ji-Chen	No Conflicts to Disclose; Submitted on: 04/23/2017	40	
Huang, Russel C	Submitted on: 05/02/2017 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	19	30
Huddleston, Paul M	Submitted on: 04/28/2017 Minnesota Orthopedic Society: Board or committee member	77	
Hussain, Awais K	No Conflicts to Disclose; Submitted on: 05/02/2017		20, 34
Hwang, Chang Ju	No Conflicts to Disclose; Submitted on: 05/02/2017	3, 21, 46, 47	10, 54
Hwang, Do-Yon	No Conflicts to Disclose; Submitted on: 05/02/2017		10
Hwang, Ki S	No Conflicts to Disclose; Submitted on: 04/26/2017	13	
Hwang, Saemin	No Conflicts to Disclose; Submitted on: 05/02/2017	21, 45	10

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Name	Disclosure Information	Presentations	E-Posters
Hynes, Richard A	Submitted on: 04/26/2017 Medtronic Sofamor Danek: IP royalties; Paid consultant; Paid presenter or speaker; Research support spineguard: Paid consultant spinewave: Paid consultant	65	
Hyun, Seung-Jae	Submitted on: 04/28/2017 Medtronic: Unpaid consultant	62	
Idowu, Olumuyiwa	No Conflicts to Disclose; Submitted on: 04/24/2017	92	
Iida, Tsuyoshi	No Conflicts to Disclose; Submitted on: 04/30/2017		2, 6
Iijima, Yasushi	No Conflicts to Disclose; Submitted on: 04/24/2017		42
Inoue, Hirokazu	No Conflicts to Disclose; Submitted on: 04/20/2017		
International Spine Study Group	Submitted on: 05/04/2017 Biomet: Research support DePuy, A Johnson & Johnson Company: Other financial or material support; Research support Innovasis: Other financial or material support K2M: Research support Medtronic Sofamor Danek: Research support Nuvasive: Research support Orthofix, Inc.: Research support Stryker: Research	9, 10, 11, 36, 37, 38, 39, 50, 60, 71 72, 81, 82, 83, 85, 94	
Ishihama, Hiroko	No Conflicts to Disclose; Submitted on: 05/01/2017	42, 43	
Ishihara, Shinichi	No Conflicts to Disclose; Submitted on: 04/29/2017		51
Ishii, Ken	No Conflicts to Disclose; Submitted on: 05/01/2017	2, 25, 27	51
Ishikawa, Masayuki	No Conflicts to Disclose; Submitted on: 04/28/2017		
Ishimoto, Yuyu	No Conflicts to Disclose; Submitted on: 04/30/2017	55	
Isogai, Norihiro	No Conflicts to Disclose; Submitted on: 04/26/2017	2, 25, 27	
Issa, Kimona	No Conflicts to Disclose; Submitted on: 05/29/2017	13	
Itakura, Go	No Conflicts to Disclose; Submitted on: 04/03/2017		6
Ito, Masaaki	No Conflicts to Disclose; Submitted on: 05/02/2017		4
Ito, Shuhei	No Conflicts to Disclose; Submitted on: 04/20/2017		5, 6, 7
Iwanami, Akio	No Conflicts to Disclose; Submitted on: 05/01/2017	2, 25, 27	
Iyer, Sravisht	No Conflicts to Disclose; Submitted on: 05/01/2017		30
Jackson, James Benjamin	Submitted on: 06/06/2017 American Orthopaedic Foot and Ankle Society: Board or committee member Medline: Paid consultant		31
Jain, Nikhil	No Conflicts to Disclose; Submitted on: 05/01/2017		36
Janjua, M Burhan	No Conflicts to Disclose; Submitted on: 05/13/2017		22
Jawetz, Shari T	No Conflicts to Disclose; Submitted on: 05/01/2017	19	

Name	Disclosure Information	Presentations	E-Posters
Jenis, Louis G [M, P]	Submitted on: 10/09/2017 Cervical Spine Research Society: Board or committee member Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board MicroMedicine: Paid consultant Stryker: IP royalties; Paid consultant Surgivisio: Paid consultant The Spine Journal: Editorial or governing board		
Jenkins, Tyler James	No Conflicts to Disclose; Submitted on: 04/27/2017	63, 73	
Jeong, Soyeon	No Conflicts to Disclose; Submitted on: 04/29/2017	48	1
Jeyamohan, Shiveindra	No Conflicts to Disclose; Submitted on: 03/31/2017	67, 68	
Joo, Youn-Suk	No Conflicts to Disclose; Submitted on: 05/01/2017	47	
Ju, Kevin L	No Conflicts to Disclose; Submitted on: 04/26/2017	1	
Kaito, Takashi	Submitted on: 05/01/2017 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 Kyocera: Paid consultant Medtronic Sofamor Danek: Paid consultant; Paid presenter or speaker Nippon Zoki Pharma: Paid presenter or speaker Nuvasive: Paid presenter or speaker Pfizer: Paid presenter or speaker PIP: 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 Zimmer: Paid presenter or speaker	88, 90	
Kaji, Deepak	No Conflicts to Disclose; Submitted on: 05/02/2017		18, 20, 35
Kakiuchi, Yuji	No Conflicts to Disclose; Submitted on: 05/03/2017		4
Kakutani, Kenichiro	Submitted on: 05/04/2017 Hisamitu Phaemaceutical Co. Inc: Paid presenter or speaker Teijin Pharma Limited.: Paid presenter or speaker		4

Name	Disclosure Information	Presentations	E-Posters
Kalsi-Ryan, Sukhvinder [A]	Submitted on: 05/02/2017 Asterias: Paid consultant Daichii Sankyo: Paid consultant Stem Cells Inc: Paid consultant Vertex: Paid consultant	89	
Kan, Shigeyuki	No Conflicts to Disclose; Submitted on: 05/01/2017	88, 90	
Kanemura, Aritetsu	No Conflicts to Disclose; Submitted on: 05/04/2017		
Kaneyama, Shuichi	No Conflicts to Disclose; Submitted on: 04/29/2017		56
Kang, James D	No Conflicts to Disclose; Submitted on: 04/12/2017		
Katchko, Karina M	No Conflicts to Disclose; Submitted on: 04/25/2017	8, 48	1
Kato, So	No Conflicts to Disclose; Submitted on: 05/28/2017	24, 86	
Katoh, Hiroyuki	No Conflicts to Disclose; Submitted on: 05/01/2017	42, 43	
Kawabata, Atsuyuki	No Conflicts to Disclose; Submitted on: 04/30/2017	26, 33	
Kawabata, Shigenori	No Conflicts to Disclose; Submitted on: 04/30/2017		50
Kawabata, Soya	No Conflicts to Disclose; Submitted on: 04/03/2017		6
Kaye, Ian	No Conflicts to Disclose; Submitted on: 05/28/2017	67	19
Kelly, Michael Patrick [RC, A]	No Conflicts to Disclose; Submitted on: 04/04/2017	29, 50, 80, 94	
Kepler, Christopher	Submitted on: 05/30/2017 Biomet: Research support Clinical spine surgery: Editorial or governing board Medtronic: Research support Pfizer: Research support	66, 67, 93	19
Kerr, Eubulus J	No Conflicts to Disclose; Submitted on: 05/02/2017	23	
Keswani, Aakash	No Conflicts to Disclose; Submitted on: 05/02/2017		16, 17
Khan, Safdar N	No Conflicts to Disclose; Submitted on: 05/01/2017		36, 47
Kim, Dong Ha	No Conflicts to Disclose; Submitted on: 03/21/2017		
Kim, Hak-Sun	No Conflicts to Disclose; Submitted on: 05/02/2017	22, 35	
Kim, Han Jo	Submitted on: 04/13/2017 AO SPINE: Board or committee member HSS Journal, Asian Spine Journal: Editorial or governing board ISSGF: Research support K2M, Inc: Paid consultant Scoliosis Research Society: Board or committee member ZimmerBiomet: Paid consultant	9, 19, 31, 36, 38, 60, 72, 85, 94	30
Kim, Jun Sup	No Conflicts to Disclose; Submitted on: 05/01/2017		18, 20, 34, 35
Kim, Ki-Jeong	No Conflicts to Disclose; Submitted on: 04/28/2017	62	
Kim, Sunghoo	No Conflicts to Disclose; Submitted on: 05/03/2017	45	10
Kim, Terrence T	Submitted on: 06/01/2017 Medtronic: Paid consultant; Research support		
Kimura, Atsushi	No Conflicts to Disclose; Submitted on: 04/17/2017		

Name	Disclosure Information	Presentations	E-Posters
Kitade, Makoto	No Conflicts to Disclose; Submitted on: 05/02/2017		
Kitamura, Kazuya	No Conflicts to Disclose; Submitted on: 04/28/2017	2	51
Kitamura, Mitsuhiro	No Conflicts to Disclose; Submitted on: 04/29/2017		42
Klineberg, Eric O	Submitted on: 04/04/2017 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 OREF: Research support Springer: Paid consultant Stryker: Paid consultant Trevena: Paid consultant	9, 10, 38, 39, 60, 72, 82, 83, 94	45
Kobayashi, Yoshiomi	No Conflicts to Disclose; Submitted on: 04/27/2017	2, 27	
Koda, Masao [RS]	No Conflicts to Disclose; Submitted on: 04/28/2017		42
Koh, Eugene Young	Submitted on: 04/19/2017 Biomet: Paid consultant DePuy, A Johnson & Johnson Company: Paid presenter or speaker	20	
Kojima, Kota	No Conflicts to Disclose; Submitted on: 04/03/2017		5, 6, 7
Kono, Hitoshi	No Conflicts to Disclose; Submitted on: 05/02/2017	2, 27	
Kudaravalli, Krishna	No Conflicts to Disclose; Submitted on: 05/01/2017	70, 76	46, 48, 52, 53
Kumar, Priyanka	No Conflicts to Disclose; Submitted on: 05/02/2017	66	
Kurd, Mark F	Submitted on: 04/04/2017 Clinical Spine Surgery: Editorial or governing board Duratap LLC: Stock or stock Options Innovative Surgical Designs: Research support ISASS: Board or committee member Stryker: Paid consultant	66, 93	
Kuroda, Ryosuke	Submitted on: 05/05/2017 Arthrex, Inc: Paid presenter or speaker Biomet: Paid presenter or speaker Smith & Nephew: Paid presenter or speaker		4
Kurra, Swamy	No Conflicts to Disclose; Submitted on: 05/26/2017	49	47
Kushioka, Junichi	No Conflicts to Disclose; Submitted on: 08/16/2017	88	
Kwon, Brian K [P]	(This individual reported nothing to disclose); Submitted on: 06/12/2017		
Lafage, Renaud	No Conflicts to Disclose; Submitted on: 05/17/2017	9, 10, 11, 36, 37, 38, 39, 71, 72 81, 82, 85	37, 45

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Lafage, Virginie	Submitted on: 05/09/2017 DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Research support International Spine Study Group: Board or committee member Medtronic: Paid presenter or speaker Nemaris INC: Board or committee member; Stock or stock Options Scoliosis Research Society: Board or committee member	9, 10, 11, 19, 31, 37, 38, 39, 50, 60, 71, 72, 82, 83, 85, 94	30, 45
Lanman, Todd Hopkins	Submitted on: 11/07/2017 Medtronic: Paid consultant Medtronic Sofamor Danek (prestige LP study): Research support Stryker: IP royalties	6, 7	
Laratta, Joseph	No Conflicts to Disclose; Submitted on: 04/25/2017		14
Lau, Darryl	No Conflicts to Disclose; Submitted on: 05/03/2017	32	
Lavelle, William Francis	Submitted on: 04/04/2017 DePuy, A Johnson & Johnson Company: Research support IntegraLife: Research support K2M, Inc.: Research support Medtronic: Research support Providence Technologies: Research support SAS: Editorial or governing board Sigmus, Inc.: Research support Spinal Kinetics: Research support Stryker: Research support Vertebral Technologies, Inc.: Research support	49	47
Lavery, Jessica A	No Conflicts to Disclose; Submitted on: 10/03/2017	60	
Lawrence, Brandon D [RC, A]	Submitted on: 05/02/2017 AO Spine Fellowship Committee: Board or committee member AO Spine North America: Paid presenter or speaker Cervical Spine Research Society: Board or committee member		
Lebl, Darren Richard [M]	Submitted on: 05/01/2017 American Orthopaedic Association: Board or committee member Cervical Spine Research Society: Board or committee member K2M: Paid consultant Medtronic: Paid consultant North American Spine Society: Board or committee member Scoliosis Research Society: Board or committee member	19	30
Lee, Choon Sung	No Conflicts to Disclose; Submitted on: 05/01/2017	3, 21, 46, 47	10, 54
Lee, Dong-Ho	No Conflicts to Disclose; Submitted on: 04/30/2017	3, 21, 45, 46, 47	10, 54

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Lee, Hwan-Mo	No Conflicts to Disclose; Submitted on: 05/01/2017	22, 35	
Lee, Jacob	No Conflicts to Disclose; Submitted on: 04/18/2017	75	
Lee, Joon Yung P	No Conflicts to Disclose; Submitted on: 04/04/2017	8	
Lee, Jun Seok	No Conflicts to Disclose; Submitted on: 03/21/2017		
Lee, Michael J	Submitted on: 05/03/2017 DePuy, A Johnson & Johnson Company: Paid consultant Stryker: Paid consultant	92	
Lee, Nathan John	No Conflicts to Disclose; Submitted on: 05/02/2017		34
Lee, Seungjun	No Conflicts to Disclose; Submitted on: 04/29/2017		1
Lee, Su Hun	No Conflicts to Disclose; Submitted on: 06/27/2017		
Lee, Sungsoo	No Conflicts to Disclose; Submitted on: 05/02/2017	48	
Lehman, Ronald Arthur RC	Submitted on: 07/19/2017 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	54	14
Lemons, Alexander Clayton	No Conflicts to Disclose; Submitted on: 05/02/2017		57
Levin, Jay Micael	No Conflicts to Disclose; Submitted on: 05/02/2017	78	
Li, Xudong Joshua	No Conflicts to Disclose; Submitted on: 05/25/2017		58
Lim, Michael Nelson Perez	No Conflicts to Disclose; Submitted on: 05/01/2017	22, 35	
Lin, James	No Conflicts to Disclose; Submitted on: 05/02/2017		58
Lombardi, Joseph	No Conflicts to Disclose; Submitted on: 05/02/2017		14
Louie, Philip	Submitted on: 05/29/2017 StreaMD: Stock or stock Options	84	41, 55
Lubbe, Ryan	No Conflicts to Disclose; Submitted on: 05/01/2017		1

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Ludwig, Steven C	Submitted on: 04/17/2017 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	20	
Mac Dowall, Anna Marianne	No Conflicts to Disclose; Submitted on: 05/02/2017	5	
Makhni, Melvin	No Conflicts to Disclose; Submitted on: 04/04/2017	54	
Makino, Takahiro	No Conflicts to Disclose; Submitted on: 04/30/2017	88, 90	
Maloney, Ryan Russell	No Conflicts to Disclose; Submitted on: 05/04/2017		11
Mankarious, Marc	No Conflicts to Disclose; Submitted on: 04/25/2017	49	
Mansouri, Alireza	No Conflicts to Disclose; Submitted on: 05/02/2017	28	
Markowitz, Jonathan S.	No Conflicts to Disclose; Submitted on: 04/07/2017	70, 84	46
Martin, Allan	No Conflicts to Disclose; Submitted on: 05/07/2017	41, 59, 86, 89	
Martin, Eugene M	Submitted on: 05/01/2017 Spark Therapeutics: Stock or stock Options		28
Mason, Andrew	No Conflicts to Disclose; Submitted on: 05/04/2017	91	
Massel, Dustin H	No Conflicts to Disclose; Submitted on: 04/29/2017	76	46, 48, 52
Massicotte, Eric	Submitted on: 05/06/2017 AOSpine North America: Paid presenter or speaker Watermark Research Partners: Paid consultant	89	
Mathews, Candler Grady	No Conflicts to Disclose; Submitted on: 06/01/2017		31
Matsubayashi, Yoshitaka	No Conflicts to Disclose; Submitted on: 05/02/2017		25
Matsukura, Yu	No Conflicts to Disclose; Submitted on: 04/29/2017	26, 33	
Matsumine, Akihiko	No Conflicts to Disclose; Submitted on: 05/02/2017		3, 29, 33

Name	Disclosure Information	Presentations	E-Posters
Matsumoto, Morio	Submitted on: 05/02/2017 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 LDR: Paid consultant Medtronic Sofamor Danek: Paid presenter or speaker; Research support Merck: Paid presenter or speaker Monthly Orthopedics: Editorial or governing board Nuvasive: 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	2, 25, 27, 42, 43	2, 5, 6, 7, 51
Mayo, Benjamin C	No Conflicts to Disclose; Submitted on: 04/30/2017	76	46, 48, 52
McAnany, Steven	No Conflicts to Disclose; Submitted on: 04/30/2017	29, 69, 80	35, 39, 40
McClendon, Mark Trosper	No Conflicts to Disclose; Submitted on: 05/01/2017	48	
McConnell, Jeffrey Ross	Submitted on: 03/21/2017 Globus Medical: IP royalties; Paid consultant; Paid presenter or speaker; Research support; Stock or stock Options IMSE: Paid consultant Medtronic: Research support Zimmer: Paid presenter or speaker	6, 7	
McLynn, Ryan	No Conflicts to Disclose; Submitted on: 05/30/2017	95	
Mead, Loren Benjamin	No Conflicts to Disclose; Submitted on: 05/01/2017	93	
Merrill, Robert Kent	No Conflicts to Disclose; Submitted on: 04/28/2017	69	35
Mesfin, Addisum P	Submitted on: 10/01/2017 AAOS: Board or committee member AxioMed: Stock or stock Options Cervical Spine Research Society: Board or committee member Corelink: Research support Globus Medical: Research support J. Robert Gladden Society: Board or committee member North American Spine Society: Board or committee member Scoliosis Research Society: Board or committee member		
Metkar, Umesh	No Conflicts to Disclose; Submitted on: 05/02/2017		47

Name	Disclosure Information	Presentations	E-Posters
Mihara, Hisanori	Submitted on: 04/30/2017 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	58	
Mikulis, David	Submitted on: 05/02/2017 GE Healthcare: Research support Thornhill Research, Inc.: Stock or stock Options	59, 89	
Milam, R Alden M	Submitted on: 06/06/2017 AO Foundation: Other financial or material support Bioventus: Research support Cervical Spine Research Society: Board or committee member Cutting Edge Spine: IP royalties K2M: Paid consultant Pacira: Research support RTI: Paid consultant Spinal Kinetics: Research support Spinewave: Paid consultant Stryker: IP royalties; Paid consultant		47
Miller, Taylor	No Conflicts to Disclose; Submitted on: 06/02/2017		16
Minamide, Akihito	No Conflicts to Disclose; Submitted on: 04/30/2017	55	
Mink, Kerri C	No Conflicts to Disclose; Submitted on: 10/10/2017		
Miyamoto, Takuya	No Conflicts to Disclose; Submitted on: 05/01/2017		42
Miyazaki, Shingo	No Conflicts to Disclose; Submitted on: 05/03/2017		4
Miyoshi, Hiroyuki	No Conflicts to Disclose; Submitted on: 04/04/2017		6
Moisi, Marc	Submitted on: 03/31/2017 Synaptive Medical: Paid presenter or speaker	68	
Moliver, Brittany	No Conflicts to Disclose; Submitted on: 05/02/2017	93	
Moon, John	No Conflicts to Disclose; Submitted on: 04/26/2017	15	11, 21, 22, 43
Moon, Seong-Hwan	No Conflicts to Disclose; Submitted on: 04/30/2017	22, 35	
Moontasri, Nancy J	No Conflicts to Disclose; Submitted on: 04/28/2017	13	
Moore, Don K	Submitted on: 04/04/2017 Lumbar Spine Research Society: Board or committee member North American Spine Society: Board or committee member	87	
Moore, Jeffrey	No Conflicts to Disclose; Submitted on: 04/19/2017	13	
Moore, Timothy A M			
Mormol, Jeremy D	No Conflicts to Disclose; Submitted on: 04/25/2017		55
Morrissey, Patrick B	No Conflicts to Disclose; Submitted on: 05/31/2017	67	19

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Mosenthal, William	No Conflicts to Disclose; Submitted on: 05/02/2017	92	
Moses, Michael	No Conflicts to Disclose; Submitted on: 07/17/2017		21
Mroz, Thomas Edward	Submitted on: 04/25/2017 AO Spine: Paid presenter or speaker Ceramtec: Paid consultant Chairman, Research Committee, AOSpine North AmericaEducation Committee, NASSRadiology Section, NASS: Board or committee member Pearl Diver, Inc: Stock or stock Options SpineLine, EditorGlobal Spine Journal, Deputy Editor: Editorial or governing board Stryker: IP royalties; Paid consultant	49, 78, 87	
Mummaneni, Praveen V [M]	Submitted on: 05/07/2017 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 presenter or speaker 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: Unpaid consultant Taylor and Francis: Publishing royalties, financial or material support World Neurosurgery: Editorial or governing board	32	
Mundis, Gregory Michael	Submitted on: 05/16/2017 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	9, 36, 38, 71, 81, 83, 94	37
Muraki, Shigeyuki	No Conflicts to Disclose; Submitted on: 04/30/2017	55	
Murphy, Hamadi	No Conflicts to Disclose; Submitted on: 05/03/2017	66, 93	
Nagata, Keiji	No Conflicts to Disclose; Submitted on: 04/30/2017	14, 55	
Nagata, Kosei	No Conflicts to Disclose; Submitted on: 04/25/2017		

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Nagoshi, Narihito	No Conflicts to Disclose; Submitted on: 04/03/2017	2, 25, 27, 57	2, 5, 6, 51
Nakajima, Hideaki	No Conflicts to Disclose; Submitted on: 05/02/2017		3, 29, 33
Nakamura, Hiroaki	Submitted on: 05/01/2017 DAIICHI SANKYO COMPANY, LIMITED: Paid presenter or speaker SHIONOGI & CO., LTD: Paid presenter or speaker		13, 26
Nakamura, Masaya	Submitted on: 04/03/2017 Eli Lilly: Paid presenter or speaker Medtronic Sofamor Danek: Paid presenter or speaker Pfizer: Paid presenter or speaker	2, 25, 27, 42, 43	2, 5, 6, 7, 51
Narain, Ankur Shah	No Conflicts to Disclose; Submitted on: 04/29/2017	70, 76	46, 48, 52, 53
Nassiri, Farshad	No Conflicts to Disclose; Submitted on: 05/01/2017	28	
Nassr, Ahmad [SP, M, RC]	Submitted on: 04/28/2017 American Orthopaedic Association: Board or committee member AO Spine: Research support Cervical Spine Research Society: Board or committee member Lumbar spine research society: Board or committee member Pfizer: Research support Scoliosis Research Society: Board or committee member Synthes: Research support Techniques in Orthopedics: Editorial or governing board Vikon Surgical: Unpaid consultant	77	
Nater, Anick	No Conflicts to Disclose; Submitted on: 04/29/2017		
Nestorovski, Douglas	No Conflicts to Disclose; Submitted on: 04/30/2017	80	
Neuman, Brian J	Submitted on: 05/16/2017 DePuy, A Johnson & Johnson Company: Research support	60, 72, 81, 83	37
Nicholson, Kristen	No Conflicts to Disclose; Submitted on: 05/02/2017	66, 93	
Niezgoda, Colin	No Conflicts to Disclose; Submitted on: 04/26/2017	34	
Niimura, Takanori	No Conflicts to Disclose; Submitted on: 05/02/2017	58	
Ninomiya, Ken	No Conflicts to Disclose; Submitted on: 05/01/2017		38, 44
Nishida, Kotaro	No Conflicts to Disclose; Submitted on: 05/03/2017		4
Nishiwaki, Yuji	No Conflicts to Disclose; Submitted on: 05/01/2017	42, 43	
Nojiri, Kenya	No Conflicts to Disclose; Submitted on: 05/01/2017	25, 42, 43	
Nomoto, Edward K	No Conflicts to Disclose; Submitted on: 05/04/2017		
Nori, Satoshi	No Conflicts to Disclose; Submitted on: 03/08/2017	24, 41	
Norvell, Daniel	No Conflicts to Disclose; Submitted on: 06/05/2017	68	

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Nouri, Aria	Submitted on: 05/02/2017 North American Spine Society: Board or committee member Rexahn Pharmaceuticals: Stock or stock Options	24, 41, 59, 86, 89	
Nunley, Pierce Dalton	Submitted on: 04/27/2017 ABSS–American Board of Spine Surgery: Board or committee member Amedica: Stock or stock Options K2M: IP royalties; Paid consultant; Paid presenter or speaker LDR: Paid presenter or speaker LDR Spine: IP royalties Paradigm Spine: Stock or stock Options Spineology: Stock or stock Options	23	47
Oh, Cheongeun	No Conflicts to Disclose; Submitted on: 04/26/2017	60, 85	
Oichi, Takeshi	No Conflicts to Disclose; Submitted on: 05/01/2017		25
Okada, Eijiro	No Conflicts to Disclose; Submitted on: 05/01/2017	42, 43	
Okawa, Atsushi	Submitted on: 04/28/2017 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	26, 33	27, 50
Okubo, Toshiki	No Conflicts to Disclose; Submitted on: 03/29/2017		7

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Olerud, Claes	Submitted on: 05/01/2017 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	5	
Ondeck, Nathaniel Thomas	No Conflicts to Disclose; Submitted on: 05/04/2017	95	
Oshima, Yasushi	No Conflicts to Disclose; Submitted on: 05/01/2017	14	25
Oskouian, Rod J	Submitted on: 06/02/2017 Globus Medical: IP royalties Nuvasive: Paid consultant Stryker: Paid consultant	68	
Overley, Samuel	No Conflicts to Disclose; Submitted on: 05/02/2017		16, 34, 35
Owen, Robert	No Conflicts to Disclose; Submitted on: 05/01/2017		39, 40
Ozaki, Masahiro	No Conflicts to Disclose; Submitted on: 04/03/2017		6
Paholpak, Permsak	No Conflicts to Disclose; Submitted on: 05/01/2017		13, 26
Palumbo, Mark A	Submitted on: 04/09/2017 DePuy, A Johnson & Johnson Company: Paid consultant Globus Medical: IP royalties; Paid consultant North American Spine Society: Board or committee member Orthofix, Inc.: Paid consultant Spineart: IP royalties; Paid consultant Stryker: Paid consultant	17	49
Park, Kyung Seok	No Conflicts to Disclose; Submitted on: 05/04/2017	62	
Park, Paul	No Conflicts to Disclose; Submitted on: 05/10/2017	54	
Park, Sehan	No Conflicts to Disclose; Submitted on: 05/02/2017		10
Park, Sung-Jin	No Conflicts to Disclose; Submitted on: 05/01/2017	22, 35	
Pashman, Robert S	Submitted on: 05/05/2017 Phygen: Stock or stock Options		
Passias, Peter Gust [RS]	Submitted on: 04/26/2017 Cervical Scoliosis Research Society: Research support Medicrea: Unpaid consultant Zimmer: Paid consultant	4, 9, 10, 11, 15, 31, 36, 37, 38, 39, 50, 60, 71, 72, 81, 82, 83, 85, 94	11, 12, 22, 43, 45, 60

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Patel, Alpesh Ashwin [P]	Submitted on: 04/19/2017 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 International Society for the Advancement of Spine Surgery: Board or committee member Journal of the American Academy of Orthopaedic Surgeons: 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 nView Medical Inc: Stock or stock Options Pacira: Paid consultant Springer: Publishing royalties, financial or material support Surgical Neurology International: Editorial or governing board Vital5: Stock or stock Options Wolters Kluwer Health–Lippincott Williams & Wilkins: Editorial or governing board Zimmer: IP royalties; Paid consultant	63, 73	

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Patel, Vikas Vanarsi	Submitted on: 05/01/2017 Aesculap: Research support Aesculap / B.Braun: IP royalties; Paid consultant Arbeitsgemeinschaft fuer Osteosynthesewesen: Board or committee member Baxter: Paid consultant; Paid presenter or speaker Biomet: IP royalties Globus Medical: Paid consultant Medtronic: Paid consultant Medtronic, Medicrea: Research support North American Spine Society: Board or committee member OREF: Research support Orthofix: Research support Orthopedics: Editorial or governing board Pfizer: Research support Scoliosis Research Society: Board or committee member 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		47
Patwardhan, Avinash G [RC]	Submitted on: 04/04/2017 Spinal Kinetics: Paid consultant; Stock or stock Options		
Paul, Jonathan	No Conflicts to Disclose; Submitted on: 05/01/2017	66	
Paul, Justin	No Conflicts to Disclose; Submitted on: 04/29/2017	84	41, 55
Peluso, Richard	No Conflicts to Disclose; Submitted on: 04/26/2017		41, 55
Perra, Joseph H	Submitted on: 05/02/2017 Medtronic: IP royalties Scoliosis Research Society: Board or committee member		57
Peters, Colleen M	No Conflicts to Disclose; Submitted on: 05/01/2017	28, 80	

Name	Disclosure Information	Presentations	E-Posters
Phillips, Frank M	Submitted on: 05/02/2017 Cervical Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties 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 Options PearDiver: Stock or stock Options Provident: Stock or stock Options SI Bone: Stock or stock Options Society of Minimally invasive Spine Surgery: Board or committee member Spinal Kinetics: Stock or stock Options Stryker: IP royalties Theracell: Stock or stock Options Vertera: Stock or stock Options Vital 5: Stock or stock Options		36
Pierce, Ayal Zev	No Conflicts to Disclose; Submitted on: 04/25/2017	91	
Poorman, Gregory W	No Conflicts to Disclose; Submitted on: 04/26/2017	4, 15, 31, 37, 39, 50, 60, 71, 72 81, 82, 83, 85	11, 12, 22, 60
Poppendeck, Heidi Marie	No Conflicts to Disclose; Submitted on: 04/28/2017	77	
Posey, Samuel L	No Conflicts to Disclose; Submitted on: 03/23/2017	74	
Prasarn, Mark L [M]	Submitted on: 06/01/2017 Eli Lilly: Paid presenter or speaker Nuvasive: Paid presenter or speaker Stryker: Paid consultant; Paid presenter or speaker		
Presciutti, Steven M [RS]			
Protopsaltis, Themistocles S [M, RC]	Submitted on: 04/26/2017 Cervical Spine Research Society: Research support Globus Medical: Paid consultant Innovasis: Paid consultant Medicrea International: Paid consultant Nuvasive: Paid consultant Zimmer: Research support	10, 11, 12, 36, 39, 60, 72, 82, 83, 85, 94	

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Pugely, Andrew James	Submitted on: 05/30/2017 AAOS: Board or committee member Clinical Orthopaedics and Related Research: Editorial or governing board	51, 52	14
Qian, Bang-Ping	No Conflicts to Disclose; Submitted on: 04/23/2017	40	
Qiu, Yong	No Conflicts to Disclose; Submitted on: 04/24/2017	40	
Qureshi, Rabia	No Conflicts to Disclose; Submitted on: 05/15/2017	50	
Qureshi, Sheeraz [M, P]	Submitted on: 05/02/2017 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 presenter or speaker Medtronic: Paid consultant Medtronic Sofamor Danek: Paid presenter or speaker Musculoskeletal Transplant Foundation: Board or committee member NASS: Board or committee member Orthofix, Inc.: Paid consultant Spine (reviewer): Editorial or governing board Spine Journal (reviewer): Editorial or governing board Stryker: Paid consultant; Paid presenter or speaker Zimmer: IP royalties; Paid consultant	69	16, 17
Radcliff, Kristen E [M, RC, A]	Submitted on: 04/10/2017 4 Web Medical: Stock or stock Options AAOS: Board or committee member ACSR: Board or committee member Cervical Spine Research Society: Board or committee member Globus Medical: IP royalties; Paid consultant Medtronic: Paid consultant NEXXT Spine: Other financial or material support North American Spine Society: Board or committee member Nuvasive: Other financial or material support Orthofix, Inc.: Other financial or material support Orthopedic Sciences, Inc: IP royalties; Paid consultant Pacira pharmaceuticals: Research support Simplify Medical: Research support Stryker: Other financial or material support Zimmer: Other financial or material support; Unpaid consultant	4, 66, 93	12
Ramchandran, Subaraman	No Conflicts to Disclose; Submitted on: 05/01/2017	11, 36, 72	
Ramos, Edwin	No Conflicts to Disclose; Submitted on: 05/03/2017	92	

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Rawlins, Bernard A	No Conflicts to Disclose; Submitted on: 05/02/2017		30
Rhee, John JM [M]	Submitted on: 04/17/2017 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	77	
Riehm, Lauren Esther	No Conflicts to Disclose; Submitted on: 04/29/2017	86	
Riesenburger, Ron	No Conflicts to Disclose; Submitted on: 04/25/2017	49	
Riew, K Daniel [S]	Submitted on: 06/28/2017 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 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 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	6	14, 58

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Rihn, Jeffrey A [SP]	Submitted on: 05/01/2017 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	66, 93	
Riley III, Lee H [P]	Submitted on: 03/31/2017 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 SpineThe Journal of Spinal Disorders: Editorial or governing board		
Rogerson, Ashley	No Conflicts to Disclose; Submitted on: 05/26/2017	91	
Roguski, Marie	No Conflicts to Disclose; Submitted on: 05/05/2017	49	
Ross, Thomas	No Conflicts to Disclose; Submitted on: 05/01/2017		30
Saifi, Comron	Submitted on: 05/22/2017 Gilead: Stock or stock Options Novartis: Stock or stock Options Vertera: Stock or stock Options	51, 52, 54	14
Saito, Junya	No Conflicts to Disclose; Submitted on: 04/29/2017		42
Sakai, Kenichiro	No Conflicts to Disclose; Submitted on: 04/29/2017	26, 33	27
Sakai, Yusuke	No Conflicts to Disclose; Submitted on: 04/30/2017	88, 90	
Salzler, Matthew J	Submitted on: 04/10/2017 American Orthopaedic Society for Sports Medicine: Board or committee member	91	
Sandhu, Faheem	Submitted on: 05/01/2017 Globus Medical: IP royalties; Stock or stock Options K2M: IP royalties; Paid consultant; Paid presenter or speaker; Stock or stock Options LinkSpine: Paid consultant Precision Spine: IP royalties Spineart: IP royalties; Paid consultant		47

Name	Disclosure Information	Presentations	E-Posters
Sasso, Rick C [SP, M]	Submitted on: 05/02/2017 Biomet: Stock or stock Options 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 Trans1: Stock or stock Options		
Sandhu, Harvinder S	Submitted on: 05/02/2017 Allergan: Stock or stock Options Amedica: Stock or stock Options Paradigm Spine: Stock or stock Options Providence Medical Technology: Stock or stock Options Spinewave: Stock or stock Options		30
Savage, Jason W	Submitted on: 05/02/2017 Journal of Spinal Disorders and Techniques: Editorial or governing board Stryker: Paid consultant		
Schallmo, Michael S	No Conflicts to Disclose; Submitted on: 09/17/2017		1
Scheel, Lynn I [SP]	No Conflicts to Disclose		
Scheer, Justin K	No Conflicts to Disclose; Submitted on: 05/02/2017	85	37
Schildhauer, Thomas A	Submitted on: 04/26/2017 Aesculap/B.Braun: Paid presenter or speaker BayerHealthCare: Paid presenter or speaker Cyberdyne JP: Paid consultant Journal of Orthopaedic Trauma: Editorial or governing board Stryker: Paid presenter or speaker	68	
Schmitz, Trevor R	No Conflicts to Disclose; Submitted on: 05/02/2017		57
Schneider, Andrew	No Conflicts to Disclose; Submitted on: 04/29/2017	48	1
Schroeder, Gregory Douglas	Submitted on: 04/06/2017 AOSpine: Other financial or material support Medtronic: Other financial or material support Medtronic Sofamor Danek: Research support Wolters Kluwer Health–Lippincott Williams & Wilkins: Editorial or governing board	66, 93	

Name	Disclosure Information	Presentations	E-Posters
Schwab, Frank J	Submitted on: 09/20/2017 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 Scoliosis Research Society: Board or committee member spine deformity: Editorial or governing board VP of International Spine Society Group (ISSG): Board or committee member Zimmer: IP royalties; Paid consultant; Paid presenter or speaker	9, 10, 11, 38, 39, 50, 71, 82	37, 45
Sciubba, Daniel [M, RC, A]	Submitted on: 05/01/2017 DePuy, A Johnson & Johnson Company: Paid consultant Globus Medical: Paid consultant Medtronic: Paid consultant Nuvasive: Paid consultant Stryker: Paid consultant	11, 36, 37, 39, 60, 71, 81	
Sebastian, Arjun	No Conflicts to Disclose; Submitted on: 04/04/2017	67	19
Segebarth, Paul Bradley [P]	Submitted on: 05/02/2017 K2M: Paid consultant Medtronic Sofamor Danek: Paid consultant; Research support Nuvasive: Paid consultant; Paid presenter or speaker		
Sessumpun, Kittipong	No Conflicts to Disclose; Submitted on: 05/01/2017		26
Sestokas, Anthony K	Submitted on: 04/28/2017 ASNM Monitor/American Society of Neurophysiological Monitoring: Editorial or governing board Journal of Clinical Monitoring and Computing/Springer: Editorial or governing board		28

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Shaffrey, Christopher I [M, SP]	Submitted on: 05/17/2017 AANS: Board or committee member ABNS: Board or committee member Biomet: Paid consultant Cervical Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: Research support K2M: Paid presenter or speaker Medtronic: Other financial or material support; Paid consultant Medtronic Sofamor Danek: IP royalties; Paid presenter or speaker Nuvasive: IP royalties; Paid consultant; Paid presenter or speaker; Stock or stock Options Scoliosis Research Society: Board or committee member Spinal Deformity: Editorial or governing board Spine: Editorial or governing board Stryker: Paid consultant; Paid presenter or speaker Zimmer: IP royalties	9, 10, 11, 36, 37, 38, 39, 50, 71, 72, 81, 82, 83, 85, 94	37, 45
Shamaa, Mhd Tayseer	No Conflicts to Disclose; Submitted on: 06/01/2017	77	
Sharma, Sumender Ompal	No Conflicts to Disclose; Submitted on: 04/26/2017	84	55
Shi, Lewis L	Submitted on: 04/05/2017 AAOS Shoulder / Elbow content committee: Board or committee member DePuy, A Johnson & Johnson Company: Paid consultant Novation Orthopaedic Council: Board or committee member	92	
Shibata, Masahiko	No Conflicts to Disclose; Submitted on: 05/01/2017	88, 90	
Shigeyuki, Tokunaga	No Conflicts to Disclose; Submitted on: 05/03/2017	27	
Shillingford, Jamal	No Conflicts to Disclose; Submitted on: 05/02/2017		14, 58
Shimer, Adam L.	Submitted on: 05/02/2017 Biomet: Paid presenter or speaker European Spine Journal: Editorial or governing board Medtronic: Paid consultant Nuvasive: IP royalties; Paid consultant Orthobullets.com: Publishing royalties, financial or material support Stryker: Paid presenter or speaker		36
Shimizu, Kentaro	No Conflicts to Disclose; Submitted on: 05/01/2017	42, 43	
Shiono, Yuta	No Conflicts to Disclose; Submitted on: 04/28/2017	2	
Shiraishi, Tateru	No Conflicts to Disclose; Submitted on: 05/01/2017		38, 44
Shiraishi, Yasuyuki	No Conflicts to Disclose; Submitted on: 04/20/2017		
Shultz, Blake Norman	No Conflicts to Disclose; Submitted on: 09/03/2017	95	

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Shweikeh, Faris	No Conflicts to Disclose; Submitted on: 05/07/2017		
Sinatra, Philip M	No Conflicts to Disclose; Submitted on: 04/29/2017	29	
Singh, Gurmit	No Conflicts to Disclose; Submitted on: 04/29/2017		1
Singh, Kern	Submitted on: 05/01/2017 AAOS: Board or committee member Avaz Surgical, LLC: Stock or stock Options Cervical Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: Paid consultant ISASS: Board or committee member Jaypee Publishing: Publishing royalties, financial or material support 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 Stryker, Zimmer: Paid consultant 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	63, 70, 76	46, 48, 52, 53
Singh, Sameer Kumar	No Conflicts to Disclose; Submitted on: 12/21/2016	48	
Sinha, Kumar Gautam	No Conflicts to Disclose; Submitted on: 05/02/2017	13	
Siow, Matthew	No Conflicts to Disclose; Submitted on: 04/26/2017		23
Sivaganesan, Ahilan	No Conflicts to Disclose; Submitted on: 03/29/2017	74	
Skeppholm, Martin	Submitted on: 11/07/2017 DePuy, A Johnson & Johnson Company: Paid presenter or speaker	5	
Skolasky Jr, Richard [RC]	Submitted on: 06/01/2017 AT&T Foundation: Research support Cervical Spine Research Society: Board or committee member DePuy, A Johnson & Johnson Company: Research support I receive research support from DePuy Spine: Research support North American Spine Society: Board or committee member Quality of Life Research: Editorial or governing board		
Slucky, Andrew V	No Conflicts to Disclose; Submitted on: 04/28/2017		24

Name	Disclosure Information	Presentations	E-Posters
Smith, Justin S [P]	Submitted on: 05/16/2017 Cervical Spine Research Society: Board or committee member DePuy: Research support K2M: Paid consultant Neurosurgery: Editorial or governing board Nuvasive: Paid consultant Zimmer: IP royalties; Paid consultant	10, 11, 36, 37, 38, 39, 50, 60, 71, 72, 81, 82, 83, 85, 94	37, 45
Son, Dongwuk	No Conflicts to Disclose; Submitted on: 03/16/2017		
Song, Geun Sung	No Conflicts to Disclose; Submitted on: 03/20/2017		
Soroceanu, Alexandra	No Conflicts to Disclose; Submitted on: 05/02/2017	10, 72, 81	45
Spector, Leo R [P]	Submitted on: 10/06/2017 Stryker: Paid consultant; Paid presenter or speaker		
Spiker, William Ryan [P]	Submitted on: 05/02/2017 DePuy, A Johnson & Johnson Company: Research support Nexus Orthopaedics: Paid consultant NEXXT Orthopaedics: Paid consultant Synthes: Research support		
Staub, Blake N.	No Conflicts to Disclose; Submitted on: 05/01/2017	9	
Stawicki, Christie Elizabeth	No Conflicts to Disclose; Submitted on: 05/01/2017	66	
Stein, Daniel H	No Conflicts to Disclose; Submitted on: 05/01/2017	19	30
Steinhaus, Michael	No Conflicts to Disclose; Submitted on: 04/08/2017		30
Steinmetz, Michael P [RC, A]	Submitted on: 10/06/2017 AANS/CNS Section on Disorders of the Spine and Peripheral Nerves: Board or committee member Biomet: IP royalties Council 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	78	
Stone, Marcus	No Conflicts to Disclose; Submitted on: 05/02/2017	23	
Stupp, Samuel Isaac	Submitted on: 05/03/2017 Medtronic: Research support	48	

Name	Disclosure Information	Presentations	E-Posters
Su, Brian W [P]	Submitted on: 07/10/2017 Cervical Spine Research Society: Board or committee member North American Spine Society: Board or committee member Stryker: Paid consultant		
Sugita, Daisuke	No Conflicts to Disclose; Submitted on: 05/02/2017		33
Suk, Kyung-Soo	Submitted on: 04/30/2017 Cervical Spine Research Society-Asia pacific section: Board or committee member Clinics in Orthopaedic Surgery: Editorial or governing board Journal of Koean Society of Spine Surgery: Editorial or governing board Korean Orthopaedic Association: Board or committee member Korean Society of Spine Surgery: Board or committee member	22, 35	
Sumi, Masatoshi [M]	No Conflicts to Disclose; Submitted on: 04/30/2017		32, 56
Sumiya, Satoshi	No Conflicts to Disclose; Submitted on: 04/30/2017	64	50
Sun, Yu	No Conflicts to Disclose; Submitted on: 04/30/2017	30	
Suzuki, Hidenori	No Conflicts to Disclose; Submitted on: 05/01/2017	57	
Suzuki, Satoshi	No Conflicts to Disclose; Submitted on: 05/02/2017	27	38, 44
Swanson, David	No Conflicts to Disclose; Submitted on: 05/01/2017	95	
Tachibana, Naohiro	No Conflicts to Disclose; Submitted on: 05/01/2017		25
Taguchi, Toshihiko	Submitted on: 05/01/2017 Pfizer: Paid presenter or speaker	57	
Takada, Toru	No Conflicts to Disclose; Submitted on: 05/04/2017		4
Takenaka, Shota	No Conflicts to Disclose; Submitted on: 05/01/2017	88, 90	
Takeoka, Yoshiki	No Conflicts to Disclose; Submitted on: 05/03/2017		4
Takeshita, Katsushi	No Conflicts to Disclose; Submitted on: 04/17/2017		
Tallarico, Richard Alfred	Submitted on: 04/30/2017 Stryker Spine: Paid consultant Vertiflex: Research support		47
Tamai, Koji	No Conflicts to Disclose; Submitted on: 04/24/2017		13, 26
Tan, Lee A	No Conflicts to Disclose; Submitted on: 04/30/2017		58
Tanaka, Hisashi	No Conflicts to Disclose; Submitted on: 05/01/2017	88, 90	
Tanenbaum, Joseph	No Conflicts to Disclose; Submitted on: 04/25/2017	49, 78, 87	
Taniguchi, Yuki	No Conflicts to Disclose; Submitted on: 05/01/2017		25
Tatara, Yasunori	No Conflicts to Disclose; Submitted on: 05/03/2017	58	
Terashima, Yoshiki	No Conflicts to Disclose; Submitted on: 05/02/2017		4
Tesdahl, Eric	Submitted on: 05/01/2017 SpecialtyCare: Employee		28

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Than, Khoi Duc	No Conflicts to Disclose; Submitted on: 05/05/2017	32	
Tishelman, Jared	No Conflicts to Disclose; Submitted on: 04/26/2017	11, 12, 15, 36	21, 22, 23, 37, 43, 60
Tortolani, P Justin [RC]	Submitted on: 06/18/2017 Globus Medical: IP royalties; Paid consultant Innovasis: Paid consultant J. of Spinal Deformity: Editorial or governing board Medstar Union Memorial Hospital: Board or committee member Spineology: Paid consultant; Research support Surgical Neurology International: Editorial or governing board		
Tribus, Clifford B [M, P]	Clifford B Tribus, MD: Submitted on: 07/09/2017 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 SocietyAAOS: 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		
Tsuji, Osahiko	No Conflicts to Disclose; Submitted on: 04/05/2017		2, 5, 6, 7
Tsuji, Takashi	Submitted on: 05/01/2017 Eli Lilly: Paid presenter or speaker Medtronic: Research support Nuvasive: Research support Pfizer: Paid presenter or speaker Stryker: Research support	25, 42, 43	51
Tubbs, Shane	No Conflicts to Disclose; Submitted on: 03/30/2017	68	
Tuchman, Alexander	No Conflicts to Disclose; Submitted on: 04/30/2017		58
Tybor, David J	No Conflicts to Disclose; Submitted on: 04/25/2017	91	
Ulndreaj, Antigona	No Conflicts to Disclose; Submitted on: 05/01/2017		8
Utter, Andrew	No Conflicts to Disclose; Submitted on: 05/02/2017	23	

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Vaccaro, Alexander [M, SP]	Submitted on: 04/17/2017 Advanced Spinal Intellectual Properties: Stock or stock Options Aesculap: IP royalties Alphatec Spine: IP royalties Atlas Spine: Paid consultant; Stock or stock Options 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 Dimension Orthotics LLC: Stock or stock Options Electrocore: Stock or stock Options Elsevier: Publishing royalties, financial or material support Flagship Surgical: Board or committee member; Stock or stock Options FlowPharma: Stock or stock Options Gamma Spine: Stock or stock Options Gerson Lehrman Group: Paid consultant Globus Medical: IP royalties; Paid consultant; Stock or stock Options Innovative Surgical Design: Board or committee member; Stock or stock Options Insight Therapeutics: Stock or stock Options Medacorp: Paid consultant Medtronic: Paid consultant none: Other financial or material support Nuvasive: Paid consultant; Stock or stock Options Paradigm Spine: Stock or stock Options Prime Surgeons: Board or committee member; Stock or stock Options Progressive Spinal Technologies: Board or committee member; Stock or stock Options Replication Medica: Stock or stock Options Spine Journal: Editorial or governing board Spine Medica: Stock or stock Options Spine Therapy Network Inc: Board or committee member SpineWave: Stock or stock Options Spinology: Stock or stock Options Springer: Publishing royalties, financial or material support Stout Medical: Stock or stock Options Stryker: Paid consultant Taylor Franics/Hodder & Stoughton: Publishing royalties, financial or material support Thieme: Publishing royalties, financial or material support Vertiflex: Stock or stock Options Vexim: Stock or stock Options	4, 66, 67, 93	12, 19, 28
Vallabh, Sagar	No Conflicts to Disclose; Submitted on: 04/25/2017	49	

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Varthi, Arya Giri	No Conflicts to Disclose; Submitted on: 05/01/2017	84, 95	41, 55
Vasquez-Montes, Dennis	No Conflicts to Disclose; Submitted on: 04/26/2017	82	22, 23
Vaynrub, Maksim	No Conflicts to Disclose; Submitted on: 04/26/2017		23
Vidal, Pia Maria	No Conflicts to Disclose; Submitted on: 04/26/2017	56	8
Vig, Khushdeep	No Conflicts to Disclose; Submitted on: 05/02/2017		20, 34
Vira, Shaleen	No Conflicts to Disclose; Submitted on: 04/26/2017	15	22, 60
Virk, Sohrab	No Conflicts to Disclose; Submitted on: 05/02/2017		36
Wagner, Scott	No Conflicts to Disclose; Submitted on: 05/02/2017	67	19
Wan, Shan-Jin		38	
Wang, Charles	No Conflicts to Disclose; Submitted on: 04/26/2017	15, 31, 37	11, 22
Wang, Christopher	Submitted on: 05/30/2017 Aesculap / B.Braun: IP royalties Amedica: IP royalties AOSpine International: Board or committee member benvenue: Stock or stock Options 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 flexuspine: Stock or stock Options fziomed: Stock or stock Options global spine journal: Editorial or governing board JAAOS: Editorial or governing board nexgen: Stock or stock Options North American Spine Society: Board or committee member pearldiver: Stock or stock Options promethean: Stock or stock Options seaspine: IP royalties spine: Editorial or governing board surgitech: Stock or stock Options Synthes: IP royalties the spine journal: Editorial or governing board		13

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Wang, Jeffrey C [M, SP]	Submitted on: 04/05/2017 Amedica: IP royalties; Stock or stock Options AOSpine International: Board or committee member benevenue: Stock or stock Options 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 nexgen: Stock or stock Options North American Spine Foundation: Board or committee member North American Spine Society: Board or committee member paradigm spine: Stock or stock Options pearldiver: Stock or stock Options promethean spine: Stock or stock Options Seaspine: IP royalties surgitech: Stock or stock Options Synthes: IP royalties The Spine Journal: Editorial or governing board vertiflex: Stock or stock Options		13, 26
Wang, Shan-Jin	No Conflicts to Disclose; Submitted on: 05/02/2017	38	
Ward, Laura	No Conflicts to Disclose; Submitted on: 04/17/2017	75	
Watanabe, Kota	No Conflicts to Disclose; Submitted on: 05/05/2017	2, 25, 27, 42, 43	51
Watanabe, Masahiko	No Conflicts to Disclose; Submitted on: 05/01/2017	42, 43	
Watanabe, Shuji	No Conflicts to Disclose; Submitted on: 05/02/2017		3, 29, 33
Watanabe, Yoshiyuki	Submitted on: 05/01/2017 GE Healthcare: Paid presenter or speaker	88, 90	
Watkins III, Robert G	Robert G Watkins III, MD (Marina Del Rey, CA) Submitted on: 04/11/2017 Aesculap / B.Braun: Paid consultant; Paid presenter or speaker Amedica: Paid consultant; Paid presenter or speaker Journal of Neurosurgery: Editorial or governing board Medtronic Sofamor Danek: IP royalties RTI Surgical: Paid consultant; Paid presenter or speaker Spine: Editorial or governing board	18	

Name	Disclosure Information	Presentations	E-Posters
Watkins IV, Robert G	Robert G Watkins, IV MD (Marina Del Rey, CA) Submitted on: 04/25/2017 Aesculap / B.Braun: IP royalties; Paid consultant; Paid presenter or speaker Amedica: IP royalties; Paid consultant Brainlab: Paid presenter or speaker Medtronic Sofamor Danek: IP royalties RTI / Pioneer: IP royalties; Paid consultant; Paid presenter or speaker Wolters Kluwer Health – Lippincott Williams & Wilkins: Publishing royalties, financial or material support	18	
Watkins IV, Robert G		18	
Weidenbaum, Mark	Submitted on: 05/04/2017 Scoliosis Research Society: Board or committee member Spinecraft: Other financial or material support	54	
Weiner, Joseph Arnold	No Conflicts to Disclose; Submitted on: 05/01/2017	49	
Welch, William C	Submitted on: 05/02/2017 Transcendental Spine: Stock or stock Options		28
West, Tyler	No Conflicts to Disclose; Submitted on: 04/25/2017	8	
Whang, Peter G	Submitted on: 04/27/2017 Bioventus: Research support DiFusion: Stock or stock Options; Unpaid consultant Histogenics: Paid consultant Medtronic: Paid consultant; Paid presenter or speaker Pacira: Paid consultant Pacira Pharmaceuticals: Paid presenter or speaker Relievant: Paid consultant SI BONE: Paid consultant; Research support Spinal Kinetics: Research support Spine: Editorial or governing board Stryker: Paid consultant; Paid presenter or speaker		47
Wick, Joseph Bradley	No Conflicts to Disclose; Submitted on: 03/21/2017	74	
Wiggins, Cheryl R	No Conflicts to Disclose; Submitted on: 05/02/2017		28
Wilent, William Bryan	No Conflicts to Disclose; Submitted on: 05/02/2017		28
Wilson, Jefferson R	Submitted on: 05/02/2017 Stryker: Paid consultant	28, 59, 89	
Winkler, Ethan A	No Conflicts to Disclose; Submitted on: 05/03/2017	32	
Witiw, Christopher	No Conflicts to Disclose; Submitted on: 05/02/2017	28	
Wolinksy, Jean-Paul			

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Woods, Barrett Ivory	Submitted on: 08/08/2017 Altus: IP royalties NEXXT Spine: Paid consultant Precision Spine: Paid consultant Stryker: Paid consultant	66, 93	
Wu, Dongjin	No Conflicts to Disclose; Submitted on: 04/16/2017	24	
Yagi, Mitsuru	No Conflicts to Disclose; Submitted on: 05/23/2017	2, 25, 27	51
Yamada, Hiroshi	No Conflicts to Disclose; Submitted on: 04/30/2017	55	
Yamada, Tsuyoshi	No Conflicts to Disclose; Submitted on: 04/28/2017	26, 33	27
Yamamoto, Yusuke	No Conflicts to Disclose; Submitted on: 05/02/2017		29
Yamane, Junichi	No Conflicts to Disclose; Submitted on: 04/30/2017	2, 25, 27	38, 44, 51
Yamazaki, Masashi	No Conflicts to Disclose; Submitted on: 05/31/2017		42
Yang, Jae-Ho	No Conflicts to Disclose; Submitted on: 05/01/2017	22, 35	
Yang, Jingyan	No Conflicts to Disclose; Submitted on: 05/01/2017		30
Yang, Sun	No Conflicts to Disclose; Submitted on: 09/07/2017	4	
Yao, Dong-Han	No Conflicts to Disclose; Submitted on: 05/02/2017		17
Yaszemski, Michael J	Submitted on: 05/17/2017 AAOS: Board or committee member Journal of Biomedical Materials Research-J. Wiley, Inc.: Editorial or governing board K2M, Inc.: Paid consultant Medtronic: Paid consultant Society of Military Orthopaedic Surgeons: Board or committee member Techniques in Orthopedics: Editorial or governing board	77	
Yi, Juneyoung Lynn	No Conflicts to Disclose; Submitted on: 04/02/2017	73	
Yom, Kelly H	No Conflicts to Disclose; Submitted on: 04/29/2017	70, 76	46, 48, 52, 53

Name	Disclosure Information	Presentations	E-Posters
Yoon, S Tim [RC]	Submitted on: 06/01/2017 American Journal of Orthopedics: Editorial or governing board Biomet: Research support International Society for the Study of the Lumbar Spine: Board or committee member Journal of Bone and Joint Surgery–American: Editorial or governing board Journal of Orthopaedic Research: Editorial or governing board Meditech: Paid consultant Meditech Advisor: IP royalties Meditech Advisors: Stock or stock Options Medtronic Sofamor Danek: Research support Medyssey: Stock or stock Options Nuvasive: Research support Phygen: Stock or stock Options Spine: Editorial or governing board Stryker: IP royalties The Spine Journal: Editorial or governing board	75	
Yoshida, Hideaki	No Conflicts to Disclose; Submitted on: 05/02/2017		51
Yoshida, Munehito	No Conflicts to Disclose; Submitted on: 05/01/2017	55	
Yoshii, Toshitaka	Submitted on: 04/25/2017 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	26, 33	27, 50
Yoshimura, Noriko	No Conflicts to Disclose; Submitted on: 05/02/2017	55	
Yu, Elizabeth M	Submitted on: 05/31/2017 AAOS: Board or committee member Nuvasive: Research support		36
Yu, Matsukura	This individual reported nothing to disclose); Submitted on: 04/29/2017	33	

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Yu, Wenru	No Conflicts to Disclose; Submitted on: 04/28/2017	56	
Yu, Yang	No Conflicts to Disclose; Submitted on: 08/03/2017	40	
Yuan, Philip S	Submitted on: 11/08/2017 Alphatec Spine: Stock or stock Options Choice Spine: Paid consultant Mesoblast: Research support spine journal: Editorial or governing board		47
Yuan, Zhen-shan			
Yuasa, Masato	No Conflicts to Disclose; Submitted on: 04/29/2017		27
Yun, Chawon	No Conflicts to Disclose; Submitted on: 04/29/2017	48	1
Yun, Jonghwa	No Conflicts to Disclose; Submitted on: 04/29/2017		1
Yurube, Takashi	No Conflicts to Disclose; Submitted on: 04/30/2017		4, 32
Zebala, Lukas Peter	Submitted on: 05/02/2017 American Spinal Injury Association: Board or committee member Broadwater LLC: Paid presenter or speaker K2M: Paid consultant Medtronic: Paid consultant; Paid presenter or speaker Pacira Pharma: Research support	29, 80	39, 40
Zdeblick, Thomas A [SP]	Submitted on: 01/18/2017 Lumbar Spine Research Society: Board or committee member Medtronic Sofamor Danek: IP royalties		
Zhang, Hao	No Conflicts to Disclose; Submitted on: 11/08/2017		58
Zhao, Yanbin	No Conflicts to Disclose; Submitted on: 05/02/2017	64	
Zhou, Feifei	No Conflicts to Disclose; Submitted on: 04/30/2017	30	
Zhou, Peter	No Conflicts to Disclose; Submitted on: 05/19/2017	15	21, 22, 43, 60

CERVICAL SPINE RESEARCH SOCIETY

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Podium Presentation Abstracts

Presentation #1

Effect of Cervical Decompression Surgery on Gait in Cervical Spondylotic Myelopathy Patients

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Raj Arakal, MD, Dallas, TX
Akwasi Boah, MD, Denton, TX
Theodore Belanger, MD, Sasche, TX
Kevin L. Ju, MD, Dallas, TX

Introduction: Gait imbalance is a frequent symptom of cervical spondylotic myelopathy (CSM), and has been reported to be improved by surgical intervention. Clinical studies have determined that individuals with CSM have a slower gait speed, prolonged double support duration and reduced cadence compared to healthy controls. Previous studies also identified reduced knee flexion during in the early stages of the disease and in more severe cases, decreased ankle plantar flexion. The purpose of this study was to evaluate the effect of cervical decompression surgery on the biomechanics of the lower extremities and spine during gait in patients with CSM before and after surgical intervention.

Materials / Methods: A non-randomized, prospective, concurrent control cohort study. Fourteen subjects with CSM who have been deemed appropriate surgical candidates performed gait analysis a week before (Pre) and 3 months after the surgery (Post3). Twenty-five healthy volunteers served as a control group. The patient walked at his / her self-selected speed along a 10 m walkway. Spine and lower extremity kinematics were measured and recorded using a video system. One-way ANOVA with Bonferroni Post Hoc analyses was used.

Results: After cervical decompression surgery, CSM patients had significantly faster walking speed (Pre: 0.82 vs. Post3: 1.03 m/s, p=0.050), longer step (Pre: 0.48 vs. Post3: 0.60 m, p=0.013) and stride length (Pre: 0.98 vs. Post3: 1.14 m, p=0.050). A significantly smaller ankle plantar flexion ROM (Pre: 29.46 vs. Post3: 20.87 deg, p=0.033) was seen during the stance phase. In comparison to the control group, CSM patients preoperatively presented with a significantly slower gait speed (0.24 m/sec; p=0.037), decreased step length (0.11 m; p=0.014), stride length (0.20 m; p=0.019) and increased step width (0.05 m; p=0.001). Moreover, CSM patients presented with a longer double support time (0.01 s; p=0.050). Furthermore, CSM patients showed a significantly larger ankle (5º; p=0.024) ROM and smaller knee (15º; p=0.050) ROM in the sagittal plane, along with greater ankle (2º; p=0.050) ROM in the coronal plane. Minor differences in gait found between the post-surgical CSM patients in comparison to the control group. CSM patients showed a significantly larger hip (4º; p=0.038) and smaller pelvis (5º; p=0.015) ROM in the coronal plane.

Conclusions: Cervical decompression surgery improved the gait pattern in patients with CSM. Based on our results, surgical decompression resulted in faster walking speeds with longer steps with increase in spine and lower extremity function and efficiency. Cervical spondylotic myelopathy patients walk slower with reduced trunk and lower extremity function and efficiency in comparison to an asymptomatic group. Post-operative CSM patients actually had similar walking patterns in comparison to an asymptomatic group. Formal gait and motion analysis can provide an objective method to assess the impact of spinal cord compression on a patient's gait and lower extremity function and also monitor the subsequent improvement postoperatively.

Presentation #2

Surgical Outcome of Elderly Patients Over 80 Years with Cervical Spondylotic Myelopathy

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Kazuya Kitamura, Tokyo, Japan
Yuta Shiono, MD, Tokyo, Japan
Ken Ishii, MD, Tokyo, Japan
Masaya Nakamura, MD, Tokyo, Japan
Morio Matsumoto, MD, Tokyo, Japan
Narihito Nagoshi, Tokyo, Japan

Introduction: Surgical therapy for cervical spondylotic myelopathy (CSM) in elderly patients has been increasing in recent year. The aim of this study was to assess the surgical outcomes of posterior cervical decompression in elderly patients more than 80 years.

Methods: From 2012 to 2014, 628 patients who underwent posterior cervical decompression for CSM at 17 high-volume institutions were enrolled in this study. All patients were observed for more than 1-years post-surgery. The mean age at the time of surgery was 67.0 (ranged from 27 to 93) years old. The patients were divided into two groups: a younger group (<80 y/o) and an elderly group (>80 y/o). Gender, height, weight, operating time, estimated blood loss, medical history, perioperative complications, Japanese Orthopaedic Association (JOA) score, visual analog scale (VAS), sagittal cobb angle of C2-5, C5-7, C2-7 and C2-7 sagittal vertical axis (SVA) on the lateral radiographs and the most stenotic level on MRI were compared between two groups. To evaluate statistical differences, an independent t-test and chi-square test were used and p value of less than 0.05 was considered as significant.

See Disclosure Index pages 41 – 95.

Presentation #2 (cont.)

Results: Of 628 patients, 551 patients (87.7%) and 77 (12.3%) were classified as a younger group (average: 64.5 y/o) and as an elderly group (average: 83.8 y/o), respectively. The female / male ratio in the elderly group was higher than those in the younger group (elderly: 1.03, younger: 0.41, $p<0.001$). The elderly patients had lower height (elderly: 1.52±0.09 m, younger: 1.62±0.10 m, $p<0.001$) and body mass index (elderly: 22.3±3.4 kg/m2, younger: 24.4±4.5 kg/m2, $p<0.001$) than younger patients. Hypertension (elderly: 57%, younger: 41%), ischemic heart disease (elderly: 12%, younger: 5%) and malignant tumor (elderly: 12%, younger: 4%) were frequently observed in the elderly group ($p<0.05$). JOA score significantly improved in elderly group (preoperative: 9.6±2.4 pts, final: 12.6±2.4 pts, $p<0.0001$) and younger group (preoperative: 11.0±2.8 pts, final: 14.0±2.2 pts, $p<0.0001$). The elderly group revealed lower preoperative ($p<0.0001$) and final JOA scores ($p<0.00001$) and recovery rate (elderly: 42±25 %, younger: 51±28 %, $p<0.01$). There was no significant difference in operating duration (elderly: 107±45 min, younger: 110±47 min, $p=0.28$), estimated blood loss (elderly: 56±67 ml, younger: 50±86 ml, $p=0.26$) and perioperative complications. There was no statistical difference in VAS (elderly: 20±21 mm, younger: 21±23 mm, $p=0.42$) and sagittal Cobb angle of C2-C7 (elderly: 12.2±16.00, younger: 12.2±14.20 ,$p=0.48$), C2-C5 (elderly: 11.1±14.00, younger: 9.5±11.80, $p=0.18$) and C5-C7 (elderly: 3.0±8.50, younger: 3.5±7.60, $p=0.31$) between two groups at final follow-up.

Conclusion: Our study demonstrated that although the surgical outcomes of geriatric patients with CSM was worse than those of younger patients, significant improvement was observed at final follow-up even in the elderly group. Therefore, posterior decompression surgery for CSM is an effective procedure for patients over 80 years.

Presentation #3

What is the Role of Gait Analysis in the Evaluation of Walking Disturbance in the Cervical Myelopathy Patients? A Comparison between Pre- and Post-Operative Data in Surgically Treated Cervical Myelopathy Patients

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Jae Hwan Cho, MD, Seoul, Republic of Korea
Jung-Ki Ha, MD, Gangwon-Do, Republic of Korea
Chang Ju Hwang, MD, PhD, Seoul, Republic of Korea
Choon Sung Lee, MD, PhD, Seoul, Republic of Korea
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Introduction: Gait impairment is known to constitute the most prominent clinical manifestation of cervical myelopathy (CM). Gait analysis has the advantages of providing detailed and quantifiable information regarding gait parameters, which may contribute to the detection of any subtle preoperative impairment and postoperative improvement. The purpose of this study is to evaluate the role of gait analysis as a tool for measuring subclinical gait abnormalities, and to investigate which parameters will improve after decompressive surgery in CM patients.

Materials / Methods: This is a retrospective review of prospectively collected data. 62 consecutive patients (male 46, female 16, age 58.6±12.9 years)who underwent decompressive surgery for CM at a single institution and could accomplish gait analysis before and 6 months after surgery by using a computerized three-dimensional analysis system were included. Among them, 40 patients received anterior decompression and fusion, 11 patients received posterior laminoplasty, and 11 patients received posterior laminectomy and fusion. Data was collected from both extremities for each patient, and thus a total of 124 cases were analyzed. Since gait analysis was impossible for patients who could not walk independently, all included patients had a Japanese Orthopedic Association (JOA) lower limb motor dysfunction grade between 2-4. "Normal (grade 4)" patients were classified as Group A (60 cases), and "Able to walk unaided, but slowly (grade 3)" or "Needs walking aid only on stairs (grade 4)" were classified as Group B (64 cases).

See Disclosure Index pages 41 – 95.

Presentation #3 (cont.)

Results: Significant changes frequently detected after surgery in both groups were increased stride length, decreased maximal hip extension angle, and increased maximal knee flexion angle in swing phase. Although the group A patients had no subjective gait difficulties preoperatively, they showed significant improvements in decreased step width, increased stride length, decreased double limb support time, increased ankle plantar flexion angle at push off, and decreased maximal ankle dorsiflexion angle in mid-stance phase after surgery. In group B (the patients with subjective gait difficulty), there were significant changes in the increased maximal hip flexion angle, decreased maximal hip extension angle, increased maximal knee flexion angle in swing phase, and increased maximal ankle flexion moment. A comparison between preoperative results of group A and B showed that group B had significantly poorer stride length, velocity, standing phase time, and double limb support time than Group A, and lower maximal knee flexion angle in swing phase, and a higher maximal knee extension angle at mid-stance phase (Table 1 and 2).

Conclusion: In our study, decompressive surgery improved stride length, maximal hip extension angle, and maximal knee flexion angle (more stable stance and more comfortable foot clearance) prominently in CM patients. Interestingly, even in patients without subjective gait abnormality, subtle changes were detected, which manifested through difficulties in foot clearance and push-off. These parameters could be utilized for early detection and diagnosis of mild gait abnormalities. Patients with subjective preoperative gait difficulty showed significant improvements in hip and knee flexion angle (more powerful and comfortable hip and knee motions) as well as ankle flexion moment (more powerful push-off).

Table 1 : Comparison between Group A and B preoperative linear parameter.

Variable	Group A(60 cases)		Group B (64 cases)		Difference		95% confidence intervals		P-value
	Mean	SD	Mean	SD	Mean	SD			
Step Width (cm)	17.20	3.39	17.38	2.37	0.18	0.53	-0.87	1.23	0.737
Stride length (cm)	105.23	11.52	94.16	23.37	-11.07	3.39	-17.81	-4.34	0.000
Cadence (steps/min)	107.73	13.29	104.95	25.29	-2.78	3.66	-10.04	4.47	0.449
Velocity (cm/s)	93.93	13.59	81.49	24.90	-12.44	3.57	-19.54	-5.36	0.001
Standing phase duration (% GC)	61.76	4.57	64.18	5.66	2.42	0.93	0.59	4.26	0.010
Double limb support duration (% GC)	13.43	3.67	16.10	7.34	2.67	1.03	0.91	4.72	0.011

Means, standard deviation(SD), confidence intervals are reported in degrees.

Table 2 : Comparison between Group A and B preoperative kinematics, kinetics.

Variable	Group A (60 cases)		Group B (64 cases)		Difference		95% confidence intervals		P-value
	Mean	SD	Mean	SD	Mean	SD			
Maximal hip flexion angle	35.01	10.56	33.09	10.18	-1.92	1.86	-5.60	1.77	0.305
Maximal hip extension angle	4.08	14.49	2.95	13.99	-1.13	2.56	-6.19	3.93	0.660
Maximal knee flexion angle in stance phase	15.99	8.34	15.85	7.92	-0.14	1.46	-3.03	2.75	0.924
Maximal knee extension angle in mid-stance phase	-6.32	6.23	-3.38	8.02	2.94	1.29	0.38	5.51	0.025
Maximal knee flexion angle in swing phase	60.50	6.35	54.78	9.49	-5.72	1.44	-8.58	-2.86	0.000
Maximal ankle dorsiflexion angle in mid-stance phase*	17.30	17.28	11.33	5.79	-5.97	2.34	-10.64	-1.29	0.013
Maximal ankle plantar flexion angle in push-off	6.51	21.60	8.33	14.39	1.81	3.27	-4.67	8.30	0.581
Maximal ankle moment	0.91	0.38	0.85	0.36	-0.16	0.07	-0.19	0.08	0.398
Maximal ankle power generation	1.10	0.67	1.29	3.05	0.19	0.40	-0.60	0.98	0.637

• The FDA has not cleared the drug and / or medical device for the use described (i.e., the drug and / or medical device noted with an • is being discussed for an "off label" use). See inside back cover for information.

Presentation #4

Two-Year Surgical Outcomes of Patients with Cervical Myelopathy: An Analysis of the Impact of Patient Characteristics, Operative Data, and Preoperative Nonoperative Treatment Modalities

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Introduction: The treatment of spinal disorders is rapidly evolving in an era of advancing technology and concern over cost effectiveness. While surgery for cervical myelopathy is common, surgical indications, clinical characteristics, surgical approaches and outcomes are frequent topics of debate and scrutiny. This study uses a prospective multi-center database to study baseline clinical characteristics, use of non-operative treatment modalities prior to surgery, operative data, and surgical procedures, to study surgical outcomes for patients with cervical myelopathy.

Materials / Methods: therapy, steriod injections, oral steroids, traction, other modalities), operative data (previous cervical spine A retrospective review of a multi-center prospectively-collected database was performed. Inclusion criteria were patients with cervical myelopathy requiring 1-2 levels of surgical correction and less than or equal to Grade 1 Spondylolisthesis. Data collected included baseline patient demographics, comorbidities, clinical information (neck / arm pain, motor / sensory / reflex deficit, fine motor movement, duration of symptoms), non-operative treatment modalities (analgesics, bed rest, chiropractic, collar, muscle relaxants, narcotics, NSAIDs, pain management, physical surgery, revision, length of stay, length of surgery, estimated blood loss [EBL]), and surgical procedures (decompression / discectomy / fusion, discectomy / decompression levels, instrumentation, and bone graft). Primary outcomes measures were changes in health-related quality of life (HRQOL) questionnaires from baseline to 2 years post-operatively, measured by SF-36 physical component score (PCS) and mental component score (MCS), as well as Neck Disability Index (NDI) score.

Results: The study population included 203 patients who underwent surgical intervention for cervical myelopathy (43% female). Average age was 57.7 years and average BMI was 29.6 kg/m2. At baseline, 51% of patients presented with neck pain, 45% with arm pain, 22% with motor deficit, 25% with sensory deficit, 17% with reflex deficit, and 28% with fine motor movement difficulties. Of the study population, 59% underwent a decompression, 64% underwent a discectomy, and 97% underwent a fusion procedure. Furthermore, 64% of patients had an anterior approach. Multiple non-operative treatment modalities were used prior to surgery (Table 1). The average HRQOL scores of the study population significantly improved for SF-36 PCS, SF-36 MCS, and NDI scores, from baseline to two years post-operatively (Table 2).

See Disclosure Index pages 41–95.

Presentation #4 (cont.)

Conclusion: This study reports outcomes from a multi-center experience in the treatment of cervical myelopathy. Baseline patient characteristics, comorbidities, clinical information, and non-operative treatment modalities used prior to surgery are presented in the context of prospective HRQOL data. Despite the broad distribution of preoperative clinical presentations, the heterogenous use of non-operative modalities and the wide spectrum of surgical techniques, patients with cervical myelopathy are found to have improvement in HRQOL scores from baseline to 2 years post-operatively. A heightened awareness of the diverse clinical presentations of this disorder should be considered when planning intervention.

Table 1. Percentage of patients undergoing various types of non-operative treatment modalities prior to surgery.

Non-operative treatment modalities	Percentage of Study Population
Analgesics	32%
Bed rest	11%
Chiropractic	11%
Collar	8%
Muscle relaxants	18%
Narcotics	25%
NSAIDS	34%
Pain management	5%
Physical therapy	26%
Steroid injection (epidural)	15%
Steroids (oral)	7%
Traction	7%
Other	6%
None from this list	8%

Table 2. Paired sample t-tests comparing SF-36 PCS, SF-36 MCS, and NDI from baseline to two years.

	Baseline		2 Years Post-Op.		P-value
	Mean	SD	Mean	SD	
SF-36 PCS	35.54	8.42	37.12	9.69	0.046
SF-36 MCS	40.02	13.28	43.36	12.82	0.003
NDI	20.75	10.77	16.36	9.24	0.001

Presentation #5

Facet Joint Osteoarthritis Progress After Insertion of Artificial Disc Replacement: A Five-Year Follow-Up of a Prospective Randomized Controlled Study

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Introduction: Artificial disc replacement (ADR) is an optional treatment to fusion after anterior decompression for cervical degenerative disc disease (DDD). Preserved motion of ADR aims to prevent immobilization side effects such as stiffness, dysphagia and adjacent segment pathology. Several IDE studies have been performed with good clinical outcome for ADR. In hip arthroplasty all joint surfaces are replaced during surgery while in ADR the facet joints on the index level are left without action. Hence, the consequence of preserved motion might be continuance of degeneration in the facet joints due to intrinsic joint aging processes. The aims of this study were to evaluate MRI at five-years of follow-up in patients with ADR regarding progression of Facet Joint Osteoarthritis (FJO).

Patients / Methods: A prospective randomized controlled study with 151 patients undergoing surgery for cervical radiculopathy due to DDD was performed. The patients were randomized to either anterior decompression and fusion or anterior decompression and insertion of an ADR. Facet joint osteoarthritis was classified on Magnetic Resonance Imaging (MRI), not Computer Tomography (CT), preoperatively and after five years of follow-up, to save the patients from excessive radiation. Classification was done by a neuroradiologist according to the five level grading system by Walraevens et al. The proportion of FJO at baseline and five years was compared with a paired t-test.

Results: Included were 81 patients, 41 females and 40 males, randomized to ADR. The 70 patients randomized to fusion were excluded. Nine preoperative MRIs and 16 five-year MRIs were either missing or not readable due to artifacts or bad quality. There were 64 patients with complete and good quality preoperative MRIs and five-year MRIs. The distribution of preoperative FJO-grades was: grade 0=39 (61%); grade 1=14 (22%); grade 2=7 (11%); grade 3=4 (6%); grade 4=0. The distribution of five-year FJO-grades was: grade 0=25 (39%); grade 1=15 (23%); grade 2=15 (23%); grade 3=8 (13%); grade 4=1 (2%). The FJO progressed 0.5 grades (95% CI, 0.3 to 0.7; $P<0.001$) in five years after insertion of the ADR.

Conclusion: Preserved motion on the index level in patients with cervical ADR is followed by progressed degeneration in the facet joints five years after surgery. Long-term follow-up, ten years or more, is needed to investigate if there are associations to clinical symptoms.

See Disclosure Index pages 41 – 95.

Presentation #6

Long-Term Outcomes of Arthroplasty for Cervical Myelopathy vs. Radiculopathy, and Arthroplasty vs. Arthrodesis for Cervical Myelopathy

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Introduction: While cervical disc arthroplasty (CDA) has been used for the treatment of cervical disc disease with radiculopathy or myelopathy, concerns remain about the appropriateness of CDA to treat patients with myelopathy.

Materials / Methods: The objective of this study was to compare long-term safety and effectiveness outcomes after CDA in patients with myelopathy versus radiculopathy. Retrospective analysis of prospectively collected 84-month outcomes data from an FDA IDE clinical trial comparing CDA to ACDF for the treatment of cervical disc disease at 2 adjacent levels. A total of 397 patients were enrolled with a diagnosis of radiculopathy, myelopathy, or both: 287 radiculopathy alone, and 110 myelopathy alone or myelopathy with radiculopathy. 84-month safety and effectiveness outcomes: NDI, neck and arm pain (0-20 scale), SF-36 PCS, neurological status, adverse events, secondary surgeries at index and adjacent levels. Two comparisons were performed. First, CDA outcomes were compared between myelopathy (including myelopathy only and both myelopathy and radiculopathy) and radiculopathy patients. Second, the outcomes of CDA and ACDF were compared for myelopathy patients (including myelopathy only and both myelopathy and radiculopathy).

Results: There were no preoperative differences for the first comparison and the second comparison for NDI, neck and arm pain, and SF-36 PCS scores. All patient groups significantly improved for NDI, neck and arm pain, and PCS scores from preoperative to 84 months.

First Comparison: At 84 months the myelopathy and radiculopathy groups showed similar improvement for NDI (37.8 vs. 35.8, p=0.352; myelopathy vs. radiculopathy, respectively), neck pain (12.0 vs. 12.1, p=0.477), arm pain (11.6 vs. 9.6, p=0.480), and PCS (14.1 vs. 13.7, p=0.863). The two groups had similar proportions of patients who maintained or improved their neurological status (87.2% vs. 93.5%, p=0.218), similar rates of serious adverse events (AEs) (54.5% vs. 57.5%, p=0.291) and similar rates of secondary surgeries at index (3.7% vs. 4.4%, p=0.839) and adjacent levels (3.7% vs. 7.6%, p=0.367).

Presentation #6

Second Comparison: The CDA and ACDF groups showed similar improvement for NDI (37.8 vs. 31.1, p=0.147; CDA vs. ACDF, respectively), neck pain (12.0 vs. 10.4, p=0.337), and arm pain (11.6 vs. 11.4, p=0.791), PCS (14.1 vs. 11.2, p=0.363). The two groups had similar proportions of patients who maintained or improved their neurological status (87.2% vs. 96.2%, p=0.409) and similar overall rates of secondary surgeries at the index levels (3.7% vs. 9.4%, p=0.374), and similar rates of secondary surgeries at adjacent levels (3.7% vs. 15.4%, p=0.088). Compared to ACDF, the CDA group demonstrated lower rates of serious AEs (54.5% vs. 65.9%, p=0.019).

Conclusions: Long-term results show that CDA is safe and effective for the treatment of myelopathy. Myelopathy patients gain similar improvement from CDA to patients with radiculopathy only. Furthermore, myelopathy patients report similar levels of improvement from CDA compared with ACDF, but suffer fewer serious AEs.

See Disclosure Index pages 41 – 95.

Presentation #7

Comparison of 7-Year Results of One-Level vs. Two-Level Cervical Disc Arthroplasty and Anterior Cervical Fusion

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Introduction: Two independent clinical trials have concluded that cervical disc arthroplasty (CDA) is as safe and effective as anterior cervical discectomy and fusion (ACDF) for treating symptomatic cervical disc disease (SCDD) at one and two levels. The objective of this study was to compare the safety and effectiveness at 7-year follow-up for the subjects treated with 1-level and 2-level respectively using CDA and ACDF.

Material / Methods: Retrospective analysis of prospectively collected, combined data of 1 and 2-level FDA IDE clinical trials of a titanium ceramic composite cervical artificial disc. A total of 545 and 397 patients were studied in the 1-level and 2-level trials, respectively: CDA (n= 280 & 209), ACDF (n=265 & 188). 84-month safety and effectiveness outcomes were compared between 1-level and 2-level CDA and ACDF, specifically: NDI, neck and arm pain (0-20 scale), SF-36 PCS, neurological status, adverse events, and secondary surgeries at index and adjacent levels. The 1-level vs. 2-level comparisons were done across studies, and a propensity score method was used to adjust for potential confounding effects and adjusted means were reported.

Results: There were no preoperative differences between 1 and 2-level respectively for CDA and ACDF patients for NDI, neck and arm pain, and SF-36 PCS scores. All patient groups significantly improved for NDI, neck and arm pain, and PCS scores from preoperative to 84-month. **Comparison of 1 vs. 2-level CDA:** there were no significant differences between 1 and 2-level CDA for NDI improvement (38.2 vs. 39.0, p=0.768), neck pain (11.7 vs. 12.3, p=0.374), arm pain (11.3 vs. 11.0, p=0.736), SF-36 PCS (12.6 vs. 14.5, p=0.220), or proportions of patients who maintained neurological status (92.8% vs. 91.6%, p=0.867). The rate of secondary surgeries was numerically (but not significantly) higher for 1-than 2-level CDA at the index and adjacent levels (7.3 vs. 4.2%, p=0.566) and (11.6% vs. 6.5%, p=0.056) respectively. The rate of serious AEs was significantly higher for 1 than 2-level CDA (67.8% vs. 56.7%, p=0.004).

Comparison of 1 vs. 2-level ACDF: there were no significant differences between 1 and 2-level ACDF for NDI improvement (31.1 vs. 31.6, p=0.859), neck pain (9.7 vs. 9.9, p=0.796), arm pain (9.9 vs. 10.1, p=0.848), SF-36 PCS (10.8 vs. 12.1, p=0.424), proportions of patients maintaining or improving neurological status (79.7% vs. 82.1%, p=0.421), or rates of secondary surgeries at index levels (13.6% vs. 14.7%, p=0.631) or adjacent levels (10.9% vs. 12.5%, p=0.366). The rates of serious AEs were similar for 1 and 2-level ACDF (61.8% vs. 68.2%, p=0.200) but the rates of all AEs (94.5% vs. 98.2%, p<0.001) and device-related AEs (18.9% vs. 27.7%, p=0.036) were significantly lower for 1-level than 2-level ACDF.

Conclusions: One and 2-level CDA appear to be equally safe and effective in the treatment of SCDD at 7-years. Two-level ACDF was equally effective as 1-level, but 2-level ACDF had a higher rate of device-related AEs.

Presentation #8

Single-Level Cervical Arthrodesis Increases Adjacent Segment Midrange Motion

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Introduction: Our group has previously reported that maximum adjacent segment motion during dynamic movements does not increase 2 years after single-level cervical arthrodesis. However, the majority of activities of daily living do not occur at the end range of motion. Clinically, adjacent segment motion after cervical arthrodesis is routinely assessed at full flexion and full extension positions, neglecting the more common midrange positions. The purpose of this longitudinal study was to determine if adjacent segment motion during the midrange of head motion increases after single-level anterior cervical discectomy and fusion (ACDF). It was hypothesized that midrange adjacent segment motion would increase with time post-surgery, and that midrange adjacent segment motion 2 years post-surgery would be significantly greater than at corresponding motion segments in similar-aged controls.

Methods: Eight C5/C6 ACDF patients (1 M, 7 F; Age=45±9 yrs., tested 7±1 months and 28±6 months post-surgery) and 6 asymptomatic controls (0 M, 6 F; Age=47±6 yrs., tested twice 56±6 months apart) performed full range of motion (ROM) head flexion / extension and axial rotation while biplane radiographs were collected at 30 images per second. Bone motion was tracked with sub-millimeter accuracy using a validated tracking technique that matched subject-specific bone models (obtained from CT) to the biplane radiographs. Biplane radiographs were also collected in the static neutral position. Six degree-of-freedom kinematics (3 translations and 3 rotations) were calculated for motion segments from C4 to C7. Global head motion was determined using 8 reflective markers placed on the head and torso. The intervertebral ROM that occurred during the midrange of head motion (defined as±20° of head flexion / extension or rotation from the neutral orientation[1]) was determined for each dynamic movement trial. The control and ACDF groups were compared at each test session as well as changes over time within the ACDF group. Significance was set at p<.05.

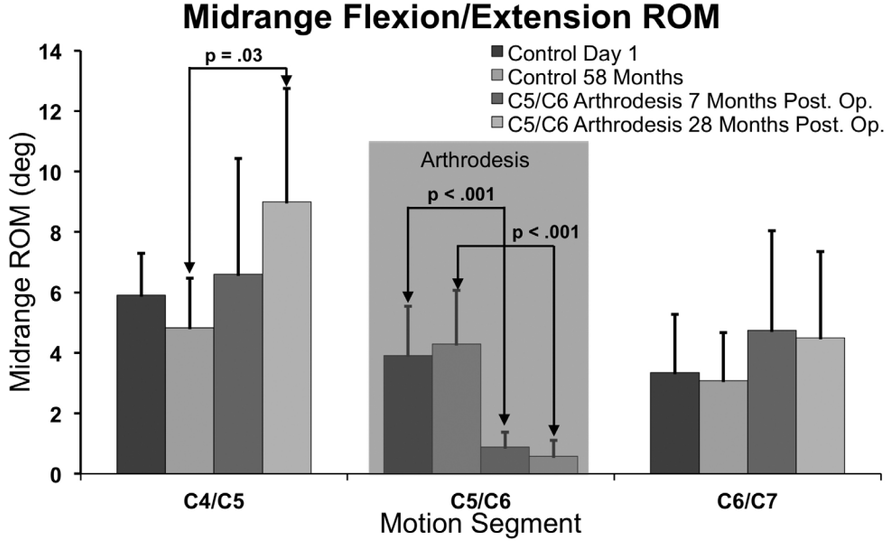
See Disclosure Index pages 41 – 95.

Presentation #8 (cont.)

Results: Adjacent segment midrange flexion/extension was greater in the arthrodesis group than in controls on both test dates, with the differences reaching statistical significance on the second test date for the superior (C4/C5) adjacent segment (p=.03) (Figure 1). During midrange head rotation, superior adjacent segment rotation was greater in the C5/C6 arthrodesis group than in controls on both test dates, with the differences reaching statistical significance on the second test date (p=.05) (Figure 2). Similar results were found in the coupled lateral bend motion during rotation, with significantly greater lateral bend motion at C6/C7 in the arthrodesis group (p=.048).

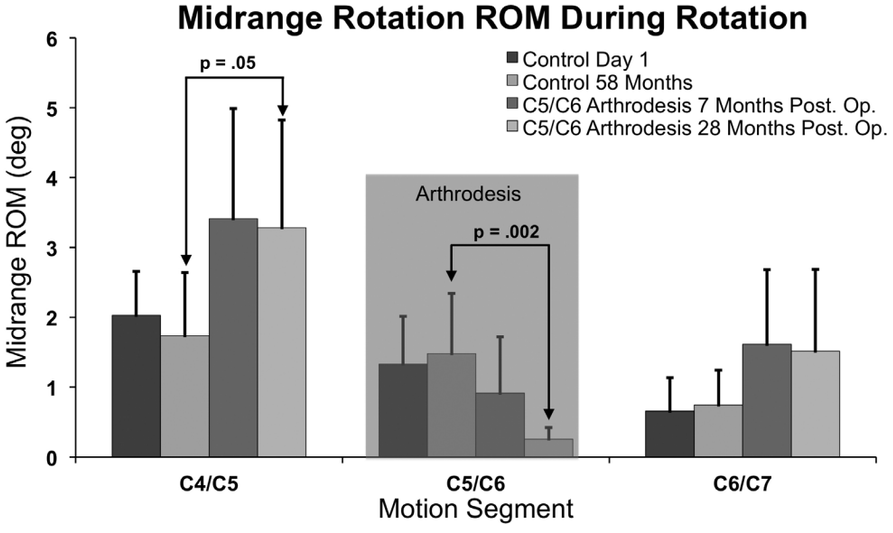
Conclusion: In spite of the small sample size, increased adjacent segment motion during midrange flexion/extension and rotation was identified. This contradicts previous results from this cohort that failed to identify any increase in end range adjacent segment ROM after arthrodesis. Midrange motions are functionally important and may provide more relevant information regarding the mechanical etiology of adjacent segment degeneration than end range measurements due to the fact that the majority of daily activities are performed while the head is within 20° of the neutral position1-3.

Figure 1. Midrange intervertebral flexion/extension range of motion (ROM) during head flexion/extension. Intervertebral motion was greater in motion segments adjacent to the arthrodesis than in corresponding motion segments of controls. These differences were significant at the C4/C5 motion segment. Error bars represent +1 standard deviation.



Presentation #8

Figure 2. Midrange intervertebral rotation range of motion (ROM) during head rotation. Intervertebral motion was greater in motion segments adjacent to the arthrodesis than in corresponding motion segments of controls. These differences were significant at the C4/C5 motion segment. Error bars represent +1 standard deviation.



See Disclosure Index pages 41–95.

Presentation #9

Cervical Mismatch: The Normative Value of T1S-CL and its Ability to Predict Ideal Cervical Lordosis

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Introduction: Numerous studies have attempted to delineate the normative value for the T1S-CL to serve as a marker for both cervical spinal deformity and as a goal for correction similar to how PI-LL mismatch informs decision making in thoracolumbar adult spinal deformities.

Methods: A prospective multicenter database of surgical adult spinal deformity (ASD) patients was retrospectively reviewed to identify subjects with the following criteria: no cervical fusion, McGregor's Slope (MGS) between -5 and 15° pre and postoperatively, and change in T1 Slope (T1S) and cervical lordosis proportional to each other between preop and postop to prove normal compensatory cervical motion. Correlation analysis across sagittal parameters was performed. Linear regression analysis was based on T1S. Findings were validated using the post-op alignment and a separate cohort of normative subjects. The range of normal alignment associated with horizontal gaze was derived from a multilinear regression on asymptomatic patients.

Results: 103 patients (mean age=54.7) met inclusion criteria from 837 patients in the database. Analysis revealed a strong correlation between T1S and C0-C7 lordosis (R=0.886), C2-7 lordosis (R=0.815), and C0-C2 lordosis (R=0.732). There was a moderate correlation between T1S and cSVA (R=0.470). There was no significant correlation between T1S and TS-CL. Linear regression analysis revealed that TS-CL assumed a constant value of 16.5° (R-square=0.664, Std Error=2°). These findings were then validated on the patients' post-thoracolumbar deformity correction imaging using the new T1S to predict the CL resulting in a mean absolute error of 5.9°. On a normative population, when controlling for MGS between -5 and 15°, the mean absolute error was 6.7°. A multilinear regression between C2-7, T1S, and MGS demonstrated a range of T1S-CL between 14.5 and 26.5 was necessary to maintain horizontal gaze

Conclusion: There is no significant correlation between T1S and the mismatch between T1S and CL. This suggests that cervical mismatch is independent of thoracic input and is thus constant. Normative CL can be predicted via the formula CL=TS–16.5±2. This implies a threshold of deformity and aids in providing a goal for surgical correction. This formula also implies that a kyphotic cervical alignment is to be expected for subject with a T1 slope<16.5.

Presentation #10

Analysis of Prospective Collection of 374 Osteotomies in 99 Patients with Adult Cervical Deformity

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Introduction: Operative adult cervical deformities represent a complex set of pathologies associated with poor Health-Related Quality of Life (HRQL) scores, pain and disability. Surgical intervention for complex adult cervical deformity (ACD) frequently employs a variety of osteotomies to correct sagittal malalignment. Few studies have reported segmental and global corrections for various osteotomies in cervical deformity surgery and none to date have utilized a prospective multicenter design. The purpose of this study was to define the corrections obtained from different osteotomy grades and varying osteotomy combinations.

Materials / Methods: Retrospective review of a prospectively collected, consecutive multicenter cervical deformity database of operative adult cervical deformity patients. Inclusion criteria were cervical kyphosis>10°, cSVA>4cm, or CBVA>25°. Osteotomy grading was performed in agreement with the Ames-ISSG Osteotomy Classification: partial facet resection (Grade 1), Ponte / complete facet resection (Grade 2), partial or complete corpectomy (Grade 3), uncovertebral joint resection (Grade 4), opening wedge (Grade 5) closing wedge (Grade 6), vertebral column resection (Grade 7). Segmental, global angular and translational corrections were evaluated by individual osteotomy and by osteotomy category. 3-column osteotomy (3CO) were assessed by the magnitude of correction and factors associated with better correction were explored.

See Disclosure Index pages 41–95.

Presentation #10 (cont.)

Results: 374 osteotomies were performed in 99 CD patients (mean age 61.6±10.8 yrs, 64.9% female, 44.8% revisions). Primary deformity drivers were as follows: 51.5% cervical, 40.2% cervicothoracic junction or upper thoracic spine, and 8.3% cervical scoliosis. When looking at the data by individual osteotomy type, the largest segmental corrections were seen in grade 7 osteotomies (VCR: 30.1°). The most common levels for 3CO were T1 (36%), T2 (41%), T3 (18%). 3CO with better corrections (>15°) had more preoperative kyphosis at the osteotomy site (26.5° vs. 6.35°, p=.01) and a trend towards 3CO location below T2 (40% vs. 8.3%, p=.07). When looking at the data by patient osteotomy category, cSVA corrections were greatest in the PSO/VCR group (-13.7mm, Table2). EBL was greatest in the PSO group (1.37L). OR time was longest for patients in combined anterior / posterior group (464.1min). There were 25.3% major complications, 31.3% minor complications, 20.2% neurologic deficits and 12.1% distal junctional kyphosis (DJK). There were 14.9% reoperations including 3 with neurologic deficits.

Table 1: Segmental angular correction by osteotomy type. There were no Grade 4 or 5 osteotomies in this cohort

Osteotomy Grade	Segmental Correction per level	Number of each osteotomy
Grade 1 Anterior Alone (ACDF)	11.9 ± 11.9	138
Grade 1 Posterior Alone (Partial Facet Resection	5.5 ± 10.4	66
Grade 2 Alone (Ponte Complete Facet Resection)	9.4 ± 12.8	86
Grade 3 Alone (Anterior Corpectomy)	13.0 ± 14.9	15
Grade 6 (PSO)	9.7 ± 7.8	21
Grade 7 (VCR)	28.3 ± 14.6	9
Grade 1 Anterior + 1 or 2 Posterior	12.9 ± 14.8	31
Grade 3 Anterior + 1 or 2 Posterior	15.4 ± 10.6	5

Table 2: Radiographic changes, demographic and operative parameters by patient osteotomy category

	3CO (Grade 6,7) (n=27)	Anterior/Posterior (n=31)	Anterior only (Grade 1, 3,4) (n=12)	Ponte Osteotomy (grade 2) (n=15)	Grade I or 0 (n=14)	p
C2-C7 SVA (mm)	-13.7 ± 13.9	-5.9 ± 13.6	-1.5 ± 8.1	-6.8 ± 15.0	-5.6 ± 11.3	0.06
TS-CL	-15.9 ± 17.4	-16.6 ± 13.0	-7.7 ± 11.6	-8.9 ± 23.4	-5.2 ± 17.3	0.21
C2 Slope	-19.3 ± 19.0	-18.6 ± 15.6	-8.6 ± 13.8	-9.9 ± 23.5	-6.6 ± 18.8	0.16
T1 Slope	-4.2 ± 14.5	-8.2 ± 10.9	+4.5 ± 6.0	-0.2 ± 12.7	-0.1 ± 13.0	0.004*
C2-T3 SVA (mm)	-30.9 ± 23.4	+0.6 ± 22.3	+4.3 ± 17.3	-10.4 ± 23.8	-4.2 ± 20.7	0.0001*
C2-T10 Angle	-8.1 ± 8.4	-2.3 ± 6.1	-1.0 ± 5.8	-0.2 ± 8.9	-5.9 ± 7.6	0.01*
% DJK	7.4	22.6	0	6.7	14.3	0.2
Mean # levels fused	11.7 ± 3.86	7.0 ± 2.24	3.3 ± 0.9	10.0 ± 5.4	9.2 ± 4.3	0.0001*
EBL (L)	1.33 ± 0.86	0.80 ± 0.72	0.065 ± 0.066	1.00± 1.07	0.88 ± 1.21	0.0017*
OR Time (min)	365.6 ± 153.5	464.1 ± 213.6	209.7 ± 54.6	312.7 ± 159.5	324.9 ± 193.0	0.0006*

• The FDA has not cleared the drug and / or medical device for the use described (i.e., the drug and / or medical device noted with an • is being discussed for an "off label" use). See inside back cover for information.

Presentation #11

Prospective Multicenter Analysis of Clinical and Radiographic Outcomes Following Surgical Correction of Patients with Moderate to Severe Cervical Deformities and Horizontal Gaze Disruption

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Introduction: Patients with severe cervical deformity (CD) endure disability, pain, and poor HRQL, which can persist following corrective surgery. Horizontal gaze, as measured by Chin Brow Vertical Angle (CBVA) is a marker of cervical deformity that has been correlated to poor quality of life. CBVA is typically less accessible than other cranial or cervical measurements due to the technical requirements of the radiograph. The slope of McGregor's line (McGS) is widely considered a surrogate measure and a proxy for CBVA. A post-operative C2-C7 Sagittal Vertical Axis (cSVA) greater than 4cm is representative of forward sagittal deformity of the cervical spine and a larger cSVA has been correlated with greater disability. The present study hypothesized that horizontal gaze disruption (measured by McGS) and severe forward cervical malalignment after corrective surgery are associated with worse post-operative patient-reported outcomes.

Methods: Retrospective review of a prospective, multi-center CD database was conducted. Database inclusion criteria were cervical kyphosis (CK) >10°, cervical scoliosis (CS)>10°, C2-7 SVA>4cm or CBVA>25°. Patients were categorized by high (>10°) and low (<10°) McGS and severe preoperative sagittal deformity (cSVA>4cm). The demographic, surgical, and radiographic parameters were compared. Relative visibility of CBVA and McGS on x-ray was assessed. 1-year post-operative health status was examined using the Neck Disability Index (NDI), EQ-5D and (NSR) neck and arm. Established radiographic parameters were analyzed by paired and independent samples t-tests.

See Disclosure Index pages 41 – 95.

Presentation #11 (cont.)

Results: 115 CD patients over age 18 (56% female, mean age 62, 41% revisions) were studied. CBVA was visible on x-ray in 17% of CD patients as compared to 90% visibility of McGS. High McGS was associated with poorer cSVA (58.6 vs. 33.0 cm, p<.001) and TS-CL (58.2 vs. 31.8°, p <.001). High McGS patients had more consecutive kyphotic levels in the upper cervical spine (64% vs. 37%, p <.001) and below C5 (68% vs. 26%, p=.012). Both cohorts' NDI, EQ-5D, and NRS-neck scores improved at 1 year post-op (both p<.01), along with NRS neck rating (p<.01). However, in horizontal gaze disrupted patients, 1-year post-op McGS was associated with poorer NDI (r=.302, p=.012). Among those with post-operative cSVA >4cm, post-operative C2 slope was positively correlated with worse NDI (R=0.32, p=0.03) and EQ5D (R=-0.43, p=0.004), and cSVA was positively correlated with NSR neck (R=0.3, p=0.05).

Conclusion: These findings underscore the importance of correcting forward cervical alignment to improve pain and quality of life measures in patients with severe CD. Specifically, restoration of horizontal gaze, C2 slope and cSVA are critical in improving HRQL. Corrective surgery for CD improved HRQL in all patients. However, a greater post-operative McGS is indicative of pain and disability in CD patients. McGS is more visible, and easily assessed, on spinal x-rays than CBVA. Correcting patients' McGS, cSVA, and C2 slope to within normal ranges should be a priority in surgical treatment for CD patients.

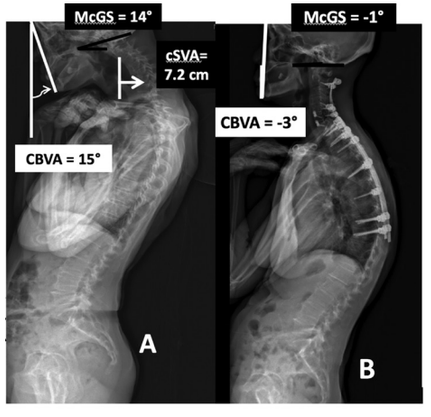

Figure: Preoperative (A) X-rays of a patient with severe cervical deformity (cSVA>4cm) with loss of horizontal gaze. Chin Brow Vertical Angle (CBVA) is 15° and the surrogate measure, McGregor's Line Slope (McGS) is 14°. Postoperatively (B) the deformity is corrected and horizontal gaze is restored.

Presentation #12

Assessment of Cervical Spine Deformity Flexibility Using Supine Advanced Imaging

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Introduction: Preoperative planning for cervical deformity correction must involve assessment of deformity flexibility as this has implications on the surgical technique chosen. No universally accepted method exists for assessing the flexibility of cervical deformities. Dynamic radiographs are often used for this purpose but have limitations, particularly in patients with extensor muscle dysfunction. Supine advanced imaging (SAI), as in cervical MRI or CT, eliminates the effect of the extensor musculature on generating lordosis and allows a more realistic assessment of cervical alignment in such patients. SAI is routinely performed in the preoperative evaluation of patients with cervical deformity and offers excellent visualization of the landmarks necessary to measure cervical sagittal alignment. The purpose of this study is to investigate the utility of SAI versus flexion/extension x-rays in assessing cervical flexibility in patients with cervical deformity.

Materials/Methods: Adult patients (age>18) with cervical deformity were studied. Radiographic inclusion criteria were any one of the following: cervical kyphosis (C2-7 Lordosis > 10°), cervical scoliosis (coronal Cobb >10°), C2-C7 sagittal vertical axis (cSVA) >4cm and/or chin-brow vertical angle (CBVA)>25°. Patients had upright neutral, flexion and extension X-rays as well as SAI (cervical MRI or CT). The sagittal parameters of C2-C7 lordosis (C2-C7L) and the Occiput-C2 angle (O-C2) were compared on the neutral radiograph, extension radiograph, and SAI. A novel sagittal parameter formed between T1 and the C2 centroid was also compared between studies (Figure 1). A subanalysis of sagittal alignment parameters compared SAI to extension radiograph alignment in patients with and without extensor dysfunction (patients with <15° increase in C2-C7L from neutral to extension). Paired samples t-tests were used where appropriate.

O-C2 was more lordotic on extension radiographs compared to SAI (-37.1°±10.4 vs. -22.8°±12.2, p<0.001). There were trends for the C2-T1 tilt to be more lordotic (0.72°±12.4 vs. 7.4°±19.2 degrees, p=0.56) and for C2-C7L to be greater (-6.1°±20.1 vs. -0.9°±33.4, p=0.36) on SAI than extension radiographs.

Eleven patients met criteria for extensor dysfunction. These patients had more lordotic C2-T1 tilt (6.6°±8.3 vs. 18.2°±16.6, p=0.02) and C2-C7L (-0.3°±14.1 vs. 14.9°±30.0, p=0.05) on SAI than extension radiographs. Patients without extensor dysfunction did not demonstrate such increases in lordosis on SAI (Figure 2).

Presentation #12 (cont.)

Results: Eighteen patients were included with a mean age of 61.2 years. Among all patients, the neutral X-ray mean cSVA=54.0 mm±25.4, C2-C7L=12.4°±28.7, 0-C2=-30.5°±10.4 and C2-T1 tilt =11.1°±16.7. cSVA demonstrated moderate correlation with C2-T1 tilt (r=0.43) whereas cSVA had a weaker correlation with C2-C7L (r=0.21).

Conclusion: Extension radiographs may underestimate achievable cervical lordosis in cervical deformity patients when extensor muscle dysfunction is present. Supine advanced imaging, performed during standard preoperative assessment of cervical deformity patients, should be utilized to judge deformity flexibility when patients are unable to generate additional cervical lordosis on upright extension imaging. C2-T1-Tilt can be utilized in standard radiographs and also supine imaging as a surrogate for cSVA.

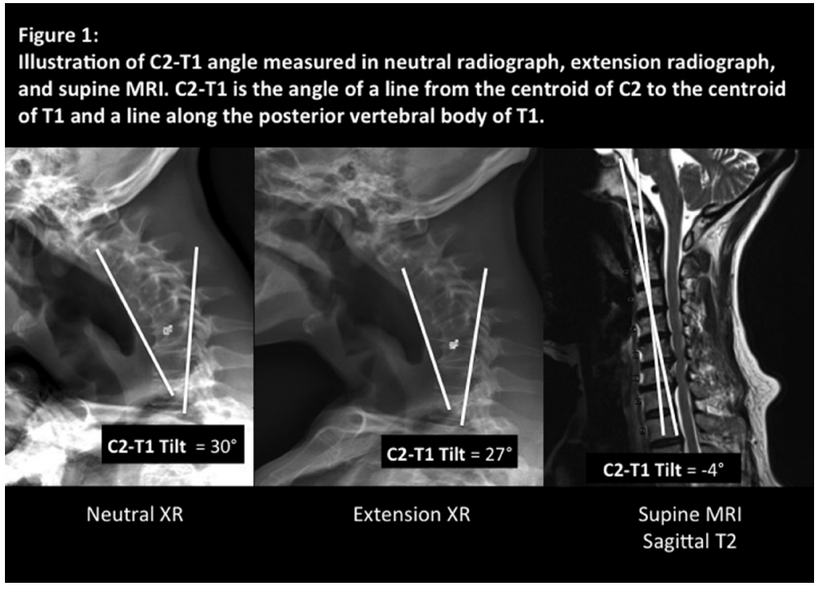

Figure 1:
Illustration of C2-T1 angle measured in neutral radiograph, extension radiograph, and supine MRI. C2-T1 is the angle of a line from the centroid of C2 to the centroid of T1 and a line along the posterior vertebral body of T1.

Figure 2:
Sagittal Alignment Parameters of Patients with and without Extensor Dysfunction on Extension Radiograph and Supine Advanced Imaging

with extensor dysfunction (n = 11)	Extension XR	SAI	*p-value*
C2-C7 Lordosis (°)	14.8 ± 30.0	-0.3 ± 14.2	0.05*
Occiput-C2 angle (°)	-38.7 ± 11.0	-25.2 ± 12.3	0.01*
C2-T1 Tilt (°)	18.2 ± 16.6	6.6 ± 8.4	0.02*
without extensor dysfunction (n = 7)	**Extension XR**	**SAI**	***p-value***
C2-C7 Lordosis (°)	-25.7 ± 21.9	-15.3 ± 27.2	0.12
Occiput-C2 angle (°)	-34.5 ± 9.8	-19.0 ± 11.8	0.01*
C2-T1 Tilt (°)	-9.4 ± 6.3	-8.6 ± 12.5	0.85

Presentation #13

The Role of CT Angiography in Changing Management in Patients with Cervical Fractures

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Introduction: Specific cervical fractures in the trauma patient or neurologic deficits found on physical exam have been shown to be associated with vertebral artery injuries (VAIs). The role of CT Angiography in these patients has been described by the prevalence of VAIs but not by the change in clinical management of these patients. In the interest of reducing the risk inferred upon the patient from CT Angiography, cost savings and lifting time constraints for patients who are indicated for operative procedures, it is imperative to examine the role of CT Angiography in the change of clinical management of the trauma patient with a cervical fracture.

Materials / Methods: A retrospective review analyzed all patients with cervical spine fractures diagnosed on CT of the neck who underwent CT Angiography between 2013 and 2016 at a single institution. CT Angiography reports along with operative notes and all medical records of these patients were thoroughly reviewed. Those with positive findings of traumatic nature on CT Angiogrpahy report who underwent change in clinical management were described and compared to those with negative findings. Patients who did not survive their hospital course were exlcuded from the study. Of those patients who had positive findings on CT Angiography examination, we described those whose clinical management was changed by the diagnosis.

Results: Between 2013 and 2016, 111 patients underwent a CT Angiography following CT of the head and neck demonstrating a cervical fracture. Of those 111, 21 (18.9%) reports included positive findings of traumatic nature. Three (2.7%) of those patients underwent surgical intervention secondary to these findings to address the VAIs. One patient had a comminuted fracture of C2, was found to have a dissection of the vertebral artery and underwent surgical intervention with stent placement. One patient had left C6 through T1 Facet and Transverse Process fractures, was found to have left vertebral artery laceration and underwent selective cathertization of the origin of the left vertebral artery. The final patient had fractures of the left C6-T1 Transverse Processes and left arm weakness on exam, was found to have a left vertebral artery lacteration and underwent an open exploration and cathertization of the left vertebral artery. No patients had their medical management changed by positive finding on CT Angiography.

Conclusion: Despite its common use in the work-up of the trauma patient with a cervical fracture, CT Angiography rarely plays a role in changning the management of these patients. In this study, we found that only 3 (2.7%) of the CT Angiographys performed on patients with a cervical fracture changed the clinical management of the patient. All three patients met previous literatures recommendation to obtain CT Angiography by either fracture pattern of neurologic deficit. These findings further suggest that, in the setting of the trauma patient with a cervical fracture, it is only necessary to obtain a CT Angiography in those patients who have a neurologic deficit or fracture pattern previously described as high risk for VAIs.

See Disclosure Index pages 41–95.

Presentation #14

Early vs. Delayed Reduction of Cervical Spine Dislocation with Complete Motor Paralysis–A Multicenter Study

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Introduction: Reduction of cervical facet dislocation should be performed to depressurize neuron cells as soon as possible, as recommended in the guidelines published in 2013. Although some basic studies have argued that early reduction should be defined as within 6 h of dislocation, some randomized control studies defined early reduction as over 24 hours after trauma. Moreover, there were some associated risks of reduction including vertebral artery injuries (VAI) and neurological deterioration. The purpose of this study was to define the actual time limit for early reduction in patients with complete motor paralysis.

Materials / Methods: Patients with cervical spine dislocation associated with complete motor paralysis admitted between April 2007 and December 2014 were analyzed in this retrospective cohort study. The inclusion criteria of our study were 1) American Spinal Injury Association Impairment Scale (AIS) grades A or B at admission; 2) minute-by-minute recordings available for both injury time and reduction time; 3) age over 15 years; and 4) dislocation level between C3 and T1. The exclusion criteria were 1) physical examination not performed by board-certified spine surgeons; 2) details of injury not documented; and 3) proceeding paralysis. Patients were stratified into 3 groups based on the number of hours elapsed since trauma at the time of reduction within 4 hours (very early group); >4 to 6 hours (early group); and >6 hours (delayed group). Patterns of injury, the arrival time at the hospital, the injury severity score (ISS), neurological outcomes, and VAI were compared.

Results: Thirty patients (28 men, 2 women) qualified the inclusion criteria. The median age was 54 years (range 15–80 years old). Eight (27 %) patients recovered to AIS Grades C-E. Four patients underwent open reduction and posterior fixation owing to failure of reduction by craniocervical traction. Neurological outcomes in the delayed group were poorer than those in the very early and early groups; however, no significant differences were noted in the recovery rate between the very early and the early groups. The injury pattern, arrival time, and ISS were not found to be associated with neurological outcomes. Two patients died while in the unit because of VAI and aspiration pneumonia, respectively.

Conclusion: Our data suggests that early reduction of cervical spine dislocation (≤6 hours of injury) might facilitate motor function improvement even in patients with complete motor paralysis. Reduction of cervical spine dislocation >6 hours after trauma may lead to adverse outcomes. Reduction should be performed with sufficient attention to complications, such as VAI.

Presentation #15

Cervical Spine Trauma in Children: Analysis of Changes in Incidence, Etiology, and Concurrent Injuries Among 11,323 Pediatric Patients Over a Ten-Year Period

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Introduction: Cervical fracture in pediatric patients is a rare event, but is frequently associated with major long-term disability. Recently there has been an increased societal awareness of prevention of trauma. Heightened awareness has manifested in greater enforcement of seat belt and bicycle helmet laws, adaptation of playgrounds towards child safety, and outreach programs focusing on traffic safety. Data shows decreasing rates of certain traumatic injuries. However cervical traumatic fractures, despite being one of the most significant traumatic accidents, is not studied thoroughly in the literature. Understanding the changing epidemiologic patterns is an important step in local and national efforts on injury prevention.

Methods: To identify the trauma cases, the KID database was queried for HCUP-supplied ICD-9 External Cause of Injury codes (E-Codes), which also identified cause of injury (Falls, Motor Vehicle, Assault, etc.). National estimate for the annual incidence of cervical trauma using hospital and year adjusted trend weights and dividing the frequency of cervical fractures by the overall number of trauma cases occurring that year. Secondary fractures (Femur, clavicle, radius etc.), level of fracture, and cord injuries were queried using ICD-9 codes and analyzed by t test.

See Disclosure Index pages 41–95.

Presentation #15 (cont.)

Results: 11,323 pediatric patients (average age: 16.6 years; male: 65.9%) sustained cervical fractures in 2003 (incidence: 2.3% of trauma patients), 2006 (2.9%), 2009 (2.9%), and 2012 (2.9%). Motor vehicle accidents were the most common etiology, responsible for 50.0% of cervical fractures, followed by falls (10.0%). Closed fractures most frequently occurred at C2 (20.5%) or C7 (23.9%). Open fractures occurred most frequently at C1 (32.7%) and C7 (19.1%). Non-cervical concurrent fractures were common: 15.2% fracture of ribs; 14.5% skull; 7.15% pelvis. In upper cervical spine, injury to the spinal cord was less common (6.39%). The most common cord injury diagnosis in the upper cervical region was complete transection (1.58%, $p<0.001$). The rate of cord injury occurred more frequently in the lower cervical spine (10.83%, $p<0.001$), and, aside from unspecified injury to the cord (7.05%), the most common injury was complete transection (2.95%). 0.94% of patients were diagnosed with quadriplegia, 2.44% with Cauda Equina Syndrome, and 3.82% with bowel complications.

Conclusion: Incidence of cervical trauma remains stagnant over the past decade. However, concurrent cord injury and neurological complications occur at a high incidence.

Presentation #17

Incidence of Cervical Spine Injuries Sustained During Sporting Activities

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Introduction: Several investigations have examined the epidemiology of head and neck injuries in individual sports, however, there is little data reporting the nationwide incidence of cervical spine injuries for all age groups in multiple sports and activities.

Methods: The National Electronic Injury Surveillance System (NEISS) database, which collects information on patients presenting to the emergency department at 100 hospitals across the United States, was queried for neck sprains and cervical fractures associated with sporting activities from 2000 – 2015. Weighted estimates of each injury were calculated and compared by sport. Incidence rates were calculated by age and sex utilizing U.S. census data.

Results: In total, 21,063 patients with neck injuries sustained during sport were identified representing 20,181 neck sprains and 828 fractures, representing a weighted estimate of 718,179 neck sprains and 27,101 fractures. The estimated injury incidence was 148.5 (123.3 – 173.8) neck sprains and 5.6 (4.1 – 7.1) fractures per million person-years. Compared to females, the incidence for injuries in males was 1.9 times greater for neck sprains and 3.5 times greater for fractures ($p<0.0001$ for both). Football was the most common cause of cervical sprains in males, followed by cycling and basketball (Figure 1). Females sustained most neck sprains in aerobics, cheerleading, and cycling (Figure 1). From 2000 to 2015, the incidence of neck sprains from aerobics increased from 5.6 to 15.6 per million person-years ($p<0.0001$). Similarly, the incidence of cervical fractures from sport increased from 4.9 to 7.1 per million ($p=0.048$), and the incidence of fractures from cycling increased from 0.47 to 2.55 per million ($p<0.0001$) over the same interval (Figure 2). For males, cycling was the most common cause of fracture, followed by football and horseback riding. For females, horseback riding was most common, followed by cycling and cheerleading.

Conclusions: Football is the leading cause of cervical injury in the United States, although the majority of injuries are sprains. The most common cause of cervical fracture in men is cycling, while the most common cause of fractures in women is horseback riding. The incidence of sporting-related cervical fractures has increased by 45% from 2000 to 2015, which has primarily occurred due to an increase in cycling-related injuries.

See Disclosure Index pages 41 – 95.

Presentation #17 (cont.)

Figure 1. Most Common Causes of Neck Sprains in Males and Females

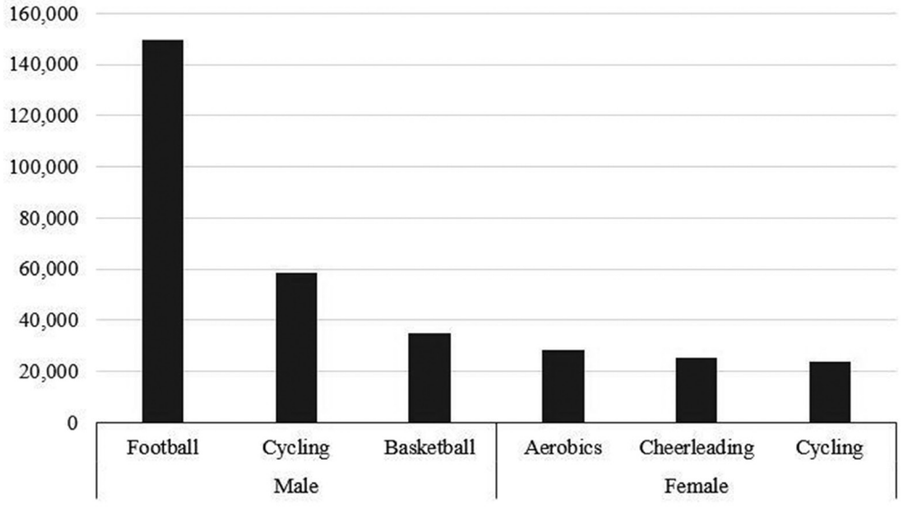
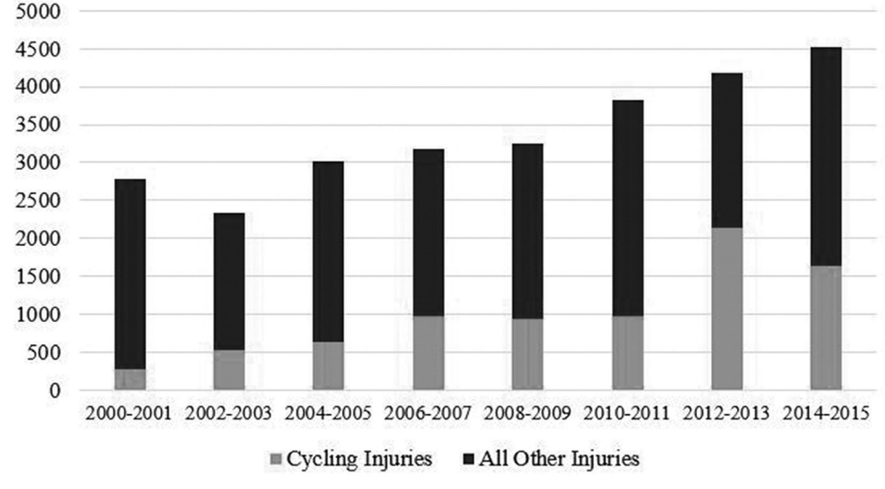


Figure 2. Cervical Spine Fractures from Cycling and All Other Causes from 2000-2015



• **The FDA has not cleared the drug and/or medical device for the use described (i.e., the drug and/or medical device noted with an • is being discussed for an "off label" use). See inside back cover for information.**

Presentation #18

Return to Play After Anterior Cervical Disectomy and Fusion in Professional Athletes

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Introduction: The purpose of this study is to analyze the return to play of professional athletes after anterior cervical discectomy and fusion (ACDF). Literature in this distinct group of patients is limited, with the largest previous study containing 15 subjects.

Methods: This study is a Clinical Quality Improvement (CQI)

The earliest return to play is when a player is symptom-free with normal exam at around 6 months postoperative, has completed the rehabilitation program, and has radiographic evidence of fusion and stability (preferably CT scan). If the radiographic images suggest a delayed union and/or the player is still symptomatic, then return to play may be prolonged.

Results: Twenty-six professional athletes underwent 27 ACDFs by one of the two senior authors. Average age was 28.1 years (18.7-35.5). By sport: 13 NFL, 5 NHL, 5 MLB, 3 NBA, and 1 MLS. By level: 3 C3-C4, 2 C4-C5, 17 C5-C6, and 5 C6-C7. Primary pathology for surgery: 25 were acute disc herniation and the other 2 were persistent radiculopathy after posterior foraminotomy. Primary preoperative symptom: 18 players with radiculopathy and 9 players with myelopathy.

Twenty-six out of 27 (96.3%) showed clinical and radiographic evidence of fusion. Twenty out of 25 eligible players returned to play (80%). Two players out of the 27 reported on are still awaiting the start of the next NFL season. Four out of 5 players that did not return to play were NFL players.

Average time to return to play in a professional game was 9.5 months (5.0–20.2mo). Eleven of the 19 players returned to play at the first possible game in the next season. Earlier in the study, players tended to have a longer time until return to play. Excluding the four players with the longest return to play, which we were all before 2005, the average return to play was 8.0 months.

Of the 15 players that returned to play but had retired by the time of this study, the average career length after fusion was 3.2 years (0.1–8.0). Of this group, the 2 NBA players averaged 5.6 years and the 7 NFL players averaged 2.3 years. Of the 5 players that were still playing at the time this study, the average career length after fusion to that point was 3.0 years (1.0–6.0). Adjacent level herniations after ACDF: one NBA player at 6.2 years and one NFL player at 1.7 years.

Conclusion: After single-level ACDF, 80% of professional athletes are able to return to sport at about 9 months.

See Disclosure Index pages 41–95.

Presentation #19

Does Local Intraoperative Corticosteroids Delivered in a Gel-Matrix Minimize Dysphagia Following Anterior Discectomy and Fusion (ACDF)? A Preliminary Analysis of an Ongoing Double Blinded Randomize Controlled Trial (RCT)

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Introduction: Dysphagia is a common complication in the setting of ACDF surgery. There is controversy in the literature regarding the effectiveness of Local Intraoperative Corticosteroids (LIC) in reducing post-operative dysphagia. This study aims to evaluate the effectiveness of LIC in decreasing the severity of swallowing difficulty following ACDF.

Methods: Adult patients undergoing primary multi-level ACDF (2 – 4 levels) were enrolled at a single institution, and randomized (double blinded) to two arms. Arm S (Steroid) received 1ml (40mg) of methylprednisolone delivered with an absorbable gel matrix (vehicle) to the retro-esophageal space prior to closure. The control arm (C) only received the vehicle prior to closure. Dysphagia specific PROs (SWAL-QOL, Eat-10, Bazaz) were collected pre-operatively, and at day-1 (POD1), day-2 (POD2), and 1 month (M1) post-operatively. A Mann-Whitney U test was performed to compare the group median PRO scores (S vs. C) for each time point, as well as the median change in the PRO scores from baseline to each post-op time point.

Results: A total of 59 patients were consecutively enrolled: 30 patients in the S Arm (37% with >2 level fusion; 57% male), and 29 patients in the C Arm (52% with >2 level fusion, 2 Corpectomy; 66% male). The C arm population had a higher BMI (31.7±6 vs. 28.4±5.6, p=.03), longer OR time (158±42 vs. 132.6±40, p=.02), and rated their baseline neck (5.9±2.5 vs. 3.77±2.8, p<0.01) and right arm (3.82±3.2 vs. 1.48±2.2, p=.002) pain higher on visual pain scales. At baseline, patients in the S and C arm had similar dysphagia outcome scores. A comparison of the median scores of the SWAL-QOL domains found that patients in the C group had worse scores for Burden at POD2, Fear at POD1 and POD2, Mental Health at POD1, Food selection at POD2, and Eating Duration at M1 (Table 1). These findings were confirmed with the pre to post comparison (larger decline in domain scores for the C group); in addition, C arm patients also exhibited a worsening of the mental health domain at POD2 and fear domain at M1 (Table 2).

The Pre-post op comparison of the Eat-10 measure found that C arm patients had a larger increase in a modified inpatient Eat-10 score at POD1, and total Eat-10 score at M1 (Table 2). A comparison of the group medians mirrored the results at M1, but only found that the difference was trending significance for the modified inpatient Eat-10 score at POD1 (Table 1). There was no difference between groups on the Bazaz-Dysphagia score at any time point. Furthermore there was no difference in documentation rate for leukocytosis, hyperglycemia, or blood loss anemia in the early post-operative period.

Presentation #19

Conclusion: Our study shows a promising potential for the application of LIC with this delivery method to prophylactically reduce dysphagia following ACDFs

Table 1: Dysphagia Specific Patient Reported Outcome Scores

SWAL- QOL		Pre-Op (C N=29, S N=30)			POD1 (C N=28, S N=28)			POD2 (C N=25, S N=24)			M1 (C N=27, S N=28)		
		Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P
Burden	C	100	(100–100)	0.309	62.5	(25–87.5)	0.117	**62.5**	**(25–87.5)**	0.049	87.5	(62.5–100)	0.106
	S	100	(100–100)		81.25	(50–100)		**81.25**	**(53.1–100)**		100	(78.1–100)	
Fear	C	100	(100–100)	0.313	**87.5**	**(68.8–100)**	0.049	**87.5**	**(50–96.8)**	0.032	93.8	(87.5–100)	0.062
	S	100	(100–100)		**100**	**(82.8–100)**		**100**	**(76.6–100)**		100	(90.6–100)	
Mental Health	C	100	(100–100)	0.309	**70**	**(50–100)**	0.026	70	(37.5–97.5)	0.054	100	(75–100)	0.337
	S	100	(100–100)		**100**	**(81.3–100)**		95	(77.5–100)		100	(82.5–100)	
Food Section	C	100	(100–100)	0.583	75	(28.1–87.5)	0.06	**50**	**(25–100)**	0.034	100	(75–100)	0.298
	S	100	(100–100)		93.8	(50–100)		**100**	**(53.1–100)**		100	(100–100)	
Eating Duration	C	100	(100–100)	0.273	75	(25–100)	0.842	50	(18.8–87.5)	0.435	**87.5**	**(50–100)**	0.012
	S	100	(100–100)		75	(37.5–100)		75	(28.8–100)		**100**	**(87.5–100)**	
EAT-10		Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P
Standard	C	0	(0–0)	0.415	18	(7.25–24.5)	0.067	17	(7.5–25.5)	0.214	**5**	**(0–10)**	0.03
	S	0	(0–.25)		8	(4–20.75)		15	(8–25)		**0**	**(0–4.5)**	
Modified For Inpatient Stay	C	N/A			15.5	(7.25–24)	0.055	15.5	(7.3–25)	0.099	N/A		
	S				7.5	(4–17.5)		15	(8–20)				

Eat-10: 0= best score, SWAL-QOL: 100= best score
Modified for Inpatient Stay Eat-10: Sum of questions (8 out of 10) determined to be relevant for inpatient stay
IQR: Interquartile range

Table 2: Change in Dysphagia Specific Patient Reported Outcome Scores from Baseline (Pre-op)

SWAL- QOL		POD1 (C N=28, S N=28)			POD2 (C N=25, S N=24)			M1 (C N=27, S N=28)		
		Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P
Burden	C	-31.3	(-75—12.5)	0.128	**-37.5**	**(-75—12.5)**	0.049	-12.5	(-37.5–0)	0.147
	S	-18.8	(-50–0)		**-18.8**	**(-46.9–0)**		0	(-21.9–0)	
Fear	C	**-9.4**	**(-29.7–0)**	0.05	**-12.5**	**(-43.8—3.1)**	0.032	**-6.3**	**(-12.5–0)**	0.046
	S	**0**	**(-17.2–0)**		**0**	**(-18.8–0)**		**0**	**(0–0)**	
Mental Health	C	**-30**	**(-50–0)**	0.027	**-30**	**(-60—2.5)**	0.054	0	(-25–0)	0.435
	S	**0**	**(-18.8–0)**		**-5**	**(-22.5–0)**		0	(-17.5–0)	
Food Section	C	-25	(-59.4—3.1)	0.098	**-50**	**(-75–0)**	0.034	0	(-25–0)	0.056
	S	-6.3	(-50–0)		**0**	**(-46.9–0)**		0	(0–0)	
Eating Duration	C	-25	(-71.9–0)	0.967	-50	(-75—12.5)	0.435	**-12.5**	**(-25–0)**	0.001
	S	-25	(-62.5–0)		-25	(-71.9–0)		**0**	**(-12.5–0)**	
EAT-10		Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P	Median	IQR (Q1-Q3)	P
Standard	C	18	(7.25–20.5)	0.052	17	(7.5–25.5)	0.19	**5**	**(0–10)**	0.021
	S	8	(3.25–19)		8	(4.25–19.75)		**0**	**(0–4.25)**	
Modified For Inpatient Stay	C	**15.5**	**(7.25–20)**	0.043	15	(7.3–20)	0.074	N/A		
	S	**7.5**	**(3.25–15)**		7	(3.5–16)				

Eat-10: 0= best score, SWAL-QOL: 100= best score
Modified for Inpatient Stay Eat-10: Sum of questions (8 out of 10) determined to be relevant for inpatient stay
IQR: Interquartile range

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Presentation #20

Preliminary Results: Cervical Degenerative Disc Disease and Subclinical Discitis: Cause or Contaminant?

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Introduction: The presence and potential effect of low-virulent bacteria residing within intervertebral discs remains a controversial topic surrounding degenerative disc disease (DDD). Recent studies have demonstrated a correlation between lumbar degenerative disc disease and culture positive disc space infection. The authors hypothesize that degenerative disc disease in the cervical spine is correlated with culture positive disc space infection.

Methods: Following IRB approval, a prospective study evaluating disc culture compared to degenerative disc disease was undertaken. Beginning in February 2017, consecutive patients undergoing an elective ACDF for DDD were enrolled and had a portion of their diseased disc sent for bacterial culture. During anterior exposure dissection, a biopsy of the longus colli muscle was taken as a control specimen prior to discectomies. Study samples were obtained following the initial antibiotic dose for surgical prophylaxis. All study samples were obtained with an unused sterile instrument. Samples were homogenized, gram stained and cultured in both aerobic and anaerobic medium for 5 and 14 days respectively.

Results: For preliminary analysis, 18 patients (mean age 54 yrs, 50% male, mean BMI 31.5 kg/m2) had sufficient data available for review. In total, 66.7% (12 of 18, 30 total disc specimens) of patients had at least one positive disc culture, with Proprionibacterium acnes (P. acnes) accounting for 84.2%. Three disc specimens contained Streptococcus, two coagulase negative Staphylococcus, and one Peptostreptococcus. Control specimens were positive in 44.4% (8 of 18) with P. acnes accounting for 75%. One Strep and one Staph accounted for the other two positive specimens. There was no significant difference in culture positive rates between our control specimens and patients with at least one positive disc (44.4% vs. 66.7%, p=0.15). In patients with at least one positive disc culture (n=12) vs. sterile disc culture (n=6), there was a significant disparity in BMI (mean 28.4 vs. 37.7 kg/m2, p=0.006).

Conclusion: Compared to previously reported rates, our preliminary culture positive rate is considerably higher at 66.7% but with the same skin organism, P.acnes, leading the way. While our control specimen positive rate of 44.4% reveals contamination may play the majority role, the difference between control and disc specimens is trending towards significance (p=0.15). With further enrollment, increased power and similar rates, we may expect to see a significant difference between contaminant control and disc specimen culture positive rates, potentially supporting the possibility of subclinical infection in DDD.

Presentation #21

Surgical Management of Unilateral Multi-Level Cervical Spondylotic Radiculopathy: A Comparative Study of Clinical and Radiological Outcomes of Posterior Foraminotomy vs. Anterior Cervical Discectomy and Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) has been considered the standard surgical treatment for cervical radiculopathy. However, it has many disadvantages such as the loss of motion, adjacent segment disease, and pseudarthrosis. Posterior cervical foraminotomy (PCF) is another surgical option that could avoid those complications. If PCF is applied for unilateral multi-level neural foraminal stenosis with spondylosis, it could not only minimize injuries to dorsal musculature and ligament structures, but also prevent unnecessary loss of motion segments. Nevertheless, multi-level PCF still has concerns about aggravation of neck pain, kyphosis, and late recurrence. The purpose of this study is to elucidate the efficacy of unilateral multi-level PCF performed for cervical spondylotic radiculopathy patients by comparing its clinical and radiological outcomes with those of ACDF.

Methods: We retrospectively reviewed medical records and radiographic data of 121 consecutive patients who underwent multi-level (≥2 levels) ACDF or PCF with unilateral radiculopathy symptoms occurring from spondylotic neural foraminal stenosis. In this study, PCF was selected as a more favorable procedure than ACDF in patients without severe neck pain (VAS>4), segmental instability and / or kyphosis, or central cord compression. A total of 97 patients were followed up for more than 2 years with appropriate data. These patients were divided into two groups according to the surgical procedure: PCF group (n=25) vs. ACDF group (n=72). Clinical outcomes were compared between both groups by using VAS scores of arm pain / neck pain, neck disability index (NDI), and reoperation rates. To investigate changes of segmental stability and cervical alignment, we analyzed segmental kyphosis, anterolisthesis >2mm, and sagittal range of motion (ROM) between C2 and C7.

Results: There were no baseline group differences in age, gender, or follow-up periods. Arm pain scores were similar in both groups pre- and postoperatively. Mean neck pain score was significantly worse in the ACDF group preoperatively (p=0.044), but it improved to a similar degree as that of the PCF group after surgery (p=0.637). Similarly, there were no significant differences in mean postoperative NDI score between the two groups (5.7±4.4 vs. 4.0±4.0, p=0.916). Mean C2-7 ROM was reduced by 9.6° in the ACDF group, but increased by 3.2° in the PCF group (p<0.001). Significant segmental kyphotic change or anterolisthesis were not detected in any patients. Revision surgeries were performed for 1 patient in the PCF group and for 2 patients in the ACDF group because of relapsed or persistent radicular symptoms (p=0.999) (Table 1).

See Disclosure Index pages 41 – 95.

Presentation #21 (cont.)

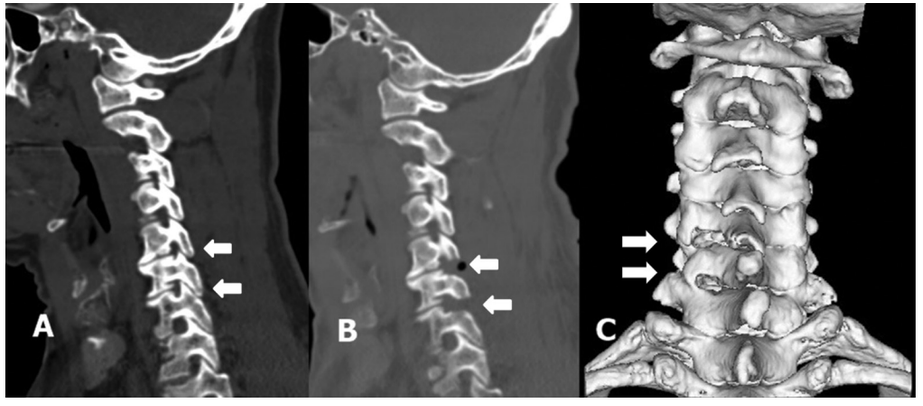
Conclusion: ACDF performed for multi-level radiculopathy patients may cause various worrisome complications such as loss of motion, adjacent segment disease, or pseudarthrosis. For these reasons, PCF could be a better option for patients with unilateral multi-level radiculopathy, as it can be performed more easily without muscle, ligament, or bony structure injuries on the contralateral side (Figure 1). Our results support that unilateral multi-level PCF would provide satisfactory outcomes in terms of improvements in arm pain, postoperative NDI, and reoperation rates without aggravation of neck pain. Also, it could maintain sagittal ROM, which is markedly reduced after ACDF.

Table 1.

		ACDF (n=72) (Mean±SD)	PCF (n=25) (Mean±SD)	P values
Gender	M:F	45: 27	19: 6	0.107
Age (years)		59.1±11.3	62.0±10.7	0.265
Follow-up (months)		31.5± 4.9	33.6± 5.6	0.179
	2 level	67	15	
No. of surgery levels	3 level	5	8	
	4 level	0	2	
Neck pain-pre		4.8±2.6	3.6±2.6	0.044
Neck pain-post		1.6 ±1.5	1.8±2.3	0.637
NP improvement		-3.2± 2.6	-1.8±2.8	**0.027**
Arm pain-pre		5.4±2.5	6.1±2.6	0.211
Arm pain-post		1.4±1.2	1.9± 1.5	0.065
AP improvement		-4±2.3	-4.2±2.4	0.728
NDI-pre		32.5±4.7	29.8±5.7	**0.045**
NDI-post		5.7±4.4	4.0±4.0	0.916
NDI improvement		26.8±4.9	25.8±3.8	0.311
ROM-pre		40.9± 12.4	39.0±10.1	0.503
ROM-post		31.2± 11.6	42.1± 10.2	**<0.001**
ROM decrease		-9.6±12.9	3.1±10.1	**<0.001**
Revision surgery		2 (3%)	1 (4%)	>0.999

Presentation #21

Figure 1. (A) Pre-op CT sagittal image (B) Post-op CT sagittal image (C) Post-op CT 3D image



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Presentation #22

CT Scan: Always Necessary for the Preoperative Planning in the Cervical Spine Surgery?

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Introduction: Cervical spine CT scan is widely used for evaluation of patients before surgery, because it provides high resolution images of the bony architecture including 2 dimensional (2D) and 3D images. Therefore, surgeons can understand more about the lesions and can plan successfully on the operation. However a single CT scan subjects the human body between 150 to 1100 times the radiation of a conventional x-ray, or around a year's worth of exposure to radiation from both natural and artificial sources in the environment. This study was performed prospectively to see the possibility of eliminating CT scan as a routine exam before cervical spine surgeries.

Methods: 115 patients who took x-ray, 3 dimensional CT scan, and MRI (Siemens 1.5 tesla) before surgery were included in this prospective study. This study was performed in 2 steps. The first step was to evaluate the accuracy of size measurement by different three observers. Anterior height of C3 body on x-ray, mid sagittal images of 2D CT scan, and T1 weighted MRI (using GE centricity enterprise web version 3.0 software) was measured twice. We measured on original resolution x-ray image before compression and 2 times magnified views of CT and MR images. Paired sample t-test was performed to evaluate the inter- and intra-observer reliability and correlation of each imaging study. The second step is to evaluate the decision making of the surgery. Senior author reviewed medical records, x-ray, and MR images without seeing CT scan and decide the surgical method and levels. After the decision was made, he reviewed CT scan and made new decision. We analyzed the accuracy of decision.

Results: Both inter- and intra-observer reliability were high (x-ray: pearson correlation coefficient=0.607–0.800, CT scan: 0.671–0.790, MRI: 0.618–0.838). Mean anterior height of C3 body was 16.38mm on x-ray, 14.60mm on CT scan, 14.58mm on MRI. Magnification ratio of x-ray to CT scan and MRI to CT scan were 112.16% and 99.86%. CT scan and MR images were highly correlated (Correlation coefficient =0.972, p=0.000). MRI was as accurate as CT scan in measurement without significant differences (mean difference= 0.01983mm, p=0.517). Surgical decision making by senior author coincided in 97.4% (112/115). In three patients there were difficulties in exact diagnosis and surgical planning.

Conclusion: T1 weighted MR image was as accurate as CT scan in measuring the size of bony structure. Without CT images, we could make right diagnosis and right treatment plan in most of the patients (97.4%). Routine preoperative evaluation of patients using CT scan might not be necessary.

Presentation #23

Prevalence, Progression, Clinical Implications, and Risk Factors of Heterotopic Ossification After Cervical Total Disc Replacement at 7 Years

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Introduction: Heterotopic ossification (HO) is a known risk following cervical total disc replacement (CTDR) surgery, however the cause and effect of HO are not well understood. The reported HO rates vary, and few studies are specifically designed to report HO. The effects on outcomes, and the potential risk factors for development of HO have been hypothesized and reported in small population, retrospective analyses, using univariate statistics. This study was designed to report HO prevalence, progression, clinical implications, and risk factors following CTDR surgery.

Materials/Methods: A post-hoc, multiple phase analysis of radiographic, clinical and demographic data for CTDR as it relates to HO. HO was radiographically graded for 164 one-level and 225 two-level CTDR patients using the McAfee and Mehren system with grades 3 and 4 considered clinically relevant. Analysis was performed to correlate HO grades to clinical outcomes and evaluate potential risk factors for development of HO using demographics, baseline clinical measures and operative measures.

Results: At 7 years, HO date was available for 65.9% (108/164) of one-level patients and 70.2% (148/225) of two-level patients. One-level clinically relevant HO grades were 17.6% grade 3 and 11.1% grade 4. Two-level clinically relevant HO grades, evaluated using the highest patient grade, were 26.6% grade 3 and 10.8% grade 4. Interaction between HO and time revealed significance for NDI (p=0.04) and VAS neck pain (p=0.02). When analyzed at each timepoint NDI was significant at 48–84 months ($p<0.05$) and VAS neck at 60 months ($p<0.05$). For predictors two analyses were run. The odds ratio analysis indicated follow-up visit, male gender and pre-op VAS neck pain are related to HO development. A hazards ratios analysis indicated male gender, obesity, endplate coverage, levels treated and pre-op VAS neck pain are related to HO development.

Conclusion: This is the largest study to report HO rates, and related outcomes and risk factors. To develop an accurate predictive model, further large scale analyses need to be performed. Based on the results reported here, clinically relevant HO should be more accurately described as motion-restricting HO until a definitive link to outcomes has been established.

See Disclosure Index pages 41–95.

Presentation #24

Comparison of Anterior and Posterior Surgery for Degenerative Cervical Myelopathy – An MRI-Based Propensity Score-Matched Analysis Using Data from the Prospective Multicenter AOSpine CSM North America and International Studies

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Introduction: Surgeons often choose between 2 different approaches (anterior and posterior) for surgical treatment of degenerative cervical myelopathy on the basis of imaging features of spinal cord compression, the number of levels affected, and the spinal alignment. However, each surgical approach has its pros and cons in terms of complication rates, spinal alignment and there is lack of consensus on which approach is preferable. Comparative studies are limited with mixed conclusions due to selection biases. Designing a randomized controlled trial for surgical decision making is challenging due to ethical constraints. The objective of the present study was to use magnetic resonance imaging (MRI)-based propensity-score-matched analysis to compare postoperative outcomes between the anterior and posterior surgical approaches for degenerative cervical myelopathy.

Materials / Methods: A total of 757 patients were enrolled in 2 prospective multicenter AOSpine studies, which involved 26 international sites. Preoperative MRIs were reviewed to characterize the causes of the cord compression, including single-level disc disease, multilevel disc disease, ossification of the posterior longitudinal ligament, enlargement of the ligamentum flavum, vertebral subluxation / spondylolisthesis, congenital fusion, number of compressed levels, or kyphosis. The propensity to choose anterior decompression was calculated using demographic data, preoperative MRI findings, and the modified Japanese Orthopaedic Association (mJOA) scores in a logistic regression model. We then performed 1-to-1 matching of patients who had received anterior decompression with those who had the same propensity score but had received posterior decompression to compare 2-year postoperative outcomes and 30-day perioperative complication rates between the 2 groups after adjustment for background characteristics.

Results: A total of 435 cases were included in the propensity score calculation, and 1-to-1 matching resulted in 80 pairs of anterior and posterior surgical cases; 99% of these matched patients had multilevel compression. The anterior and posterior groups did not differ significantly in terms of the postoperative mJOA score (15.1 vs. 15.3, p=0.53), Neck Disability Index (20.5 vs. 24.1, p=0.44), or Short Form-36 (SF-36) Physical Component Summary (PCS) score (41.9 vs. 40.9, p=0.30). The overall rates of perioperative complications were similar between the 2 groups (16% versus 11%, p=0.48); however, dysphagia / dysphonia was reported only in the anterior group whereas surgical site infection and C5 radiculopathy were reported only in the posterior group.

Conclusion: Anterior and posterior decompression for degenerative cervical myelopathy resulted in similar postoperative outcomes and rates of complications.

Presentation #25

Do Laminoplasty Conducted by Junior Surgeons Affect Clinical Outcomes for the Treatment of Cervical Spondylotic Myelopathy? Comparison between Board- and Non-Board-Certified Spine Surgeons

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Introduction: Several studies have evaluated the impact of unexperienced junior surgeon's participation on spinal surgical outcomes. However, it remains elusive whether this situation influences the outcomes in patients with cervical spondylotic myelopathy (CSM). The purpose of this study is to evaluate the surgical outcomes for CSM patients who underwent laminoplasty performed by board-certified spine surgeons (BSS) or non-BSS (NBSS) in Japan.

Methods: This is a retrospective multicenter study. Six hundred and seventy-five patients diagnosed as CSM were enrolled at 17 high-volume institutions in Japan. Patients were followed up at least one year after surgery. Preoperatively and at final follow-up, patients were evaluated using the Japanese Orthopedic Association scale (JOA) and the Visual Analog Scale (VAS). Radiographic images were used to evaluate cervical alignment by intermittent C2-C7 angles and range of motion (ROM) by extension minus flexion C2-C7angles. The BSS is qualified if the surgeon meets the following requirements: 1) authorization for Spine Specialist Approved by the JOA, 2) surgical experience in spine and spinal cord surgery for more than 300 cases, and 3) at least five clinical papers related to spine and spinal cord disorders. The parameters were compared between the two groups using unpaired t-test for continuous variables or a chi-square test for categorical variables.

See Disclosure Index pages 41 – 95.

Presentation #25 (cont.)

Results: Four hundred and thirty-two patients underwent laminoplasty by BSS, and 243 by NBSS as primary surgeons. In the NBSS group, 187 surgeries (76.95%) were performed under instruction of BSS. In BSS group, surgical time was significantly shorter (97.99±39.49 mins vs. 108.07±49.71 mins; $P<0.01$), and number of operated laminae was significantly larger (4.08±1.20 vs. 3.84±1.18; $P=0.01$). The rate of perioperative complications showed no significant difference between the groups. Recovery rate of JOA scores (47.60±26.58% vs. 46.66±29.06%; $P=0.85$) and differences in the VAS as pre- and postoperative changes (-1.45±2.91 vs. -1.43±2.50; $P=0.96$) were comparable between the groups. Lordotic cervical alignment was maintained postoperatively, and ROM was also preserved in both groups without statistical significance (29.86±12.33° vs. 31.05±13.33°; $P=0.28$).

Conclusions: The current study revealed that surgical time was longer in NBSS group despite smaller number of operated laminae. However, surgical outcomes such as functional recovery, perioperative complication rates and cervical dynamics were comparable with those in BSS group. Therefore, the laminoplasty is a safe and effective procedure even conducted by young surgeons who underwent appropriate practice under supervision of experienced spine surgeons.

Presentation #26

A Comparative Study for Cervical Spondylotic Myelopathy with One- or Two-Level Lesions – Anterior Cervical Discectomy with Fusion vs. Selective Laminoplasty

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Introduction: Since conventional laminoplasty (LAMP) sometimes causes postoperative kyphotic deformity or persistent axial pain, we have previously performed anterior cervical discectomy with fusion (ACDF) for cervical spondylotic myelopathy (CSM) patient with 1 or 2 level lesions. However, in recent years, it was reported that selective LAMP (S-LAMP) at the spinal cord compression level could maintain the cervical alignment and alleviate the axial pain. Therefore, we started to perform S-LAMP in parallel with ACDF. The purpose of this study is to compare surgical outcomes after ACDF and S-LAMP for CSM patient with 1 or 2 level lesions.

Materials / Methods: This study included a total of 47 consecutive CSM patients with 1 or 2 level lesions (30 male, 17 female; mean age 69.4 years) who underwent ACDF or S-LAMP from 2014 and completed at least 1 year of follow-up. Twenty-five patients in the ADF group and 22 patients in the S-LAMP group were evaluated. The average follow-up period was 2.0 years. The radiographic measurements included the following: (1) CL (C2-7 lordotic angle), (2) CSVA (CGH-C7 SVA), (3) C7 slope and (4) Local angle (lordotic cobb angle at operative level). Clinical results were evaluated by the Japanese Orthopedic Association scoring system for cervical myelopathy (C-JOA score), visual analog scale of neck pain and neck disability index (NDI).

Results: There were no significant differences in patients' demographics between the 2 groups prior to surgery. At the final follow-up period, postoperative CL, CSVA, C7 slope, neck pain and NDI were not significantly differences between the 2 groups; however, the recovery rate of C-JOA score in the ADF group (57.6%) was superior to that in the S-LAMP group (39.8%). Additionally, we divided patients into two subgroups based on the preoperative local angle: Local Lordosis (≥ 0) and Local Kyphosis (< 0) subgroups. The recovery rate of C-JOA score in the Local Lordosis subgroup showed no significant differences between the 2 groups; however, in the Local Kyphosis subgroup, S-LAMP resulted in worse recovery rate of the C-JOA score (20.4%) than ACDF (57.9%) (Figure 1), and S-LAMP worsened the local angle postoperatively (Figure 2).

See Disclosure Index pages 41 – 95.

Presentation #26 (cont.)

Conclusion: Selective laminoplasty is not suitable for CSM patients with local kyphosis at operative level.

Figure 1.

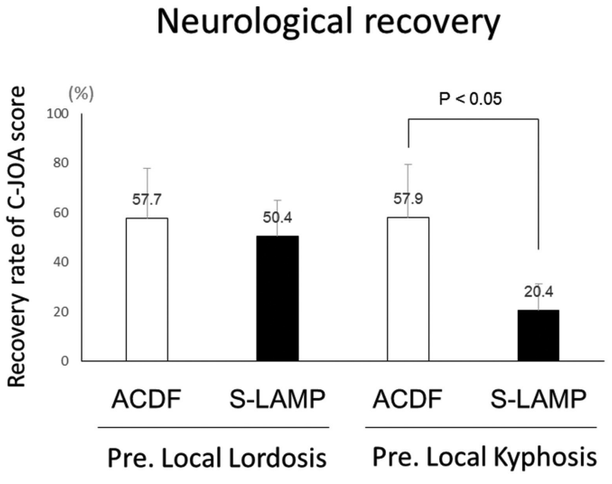
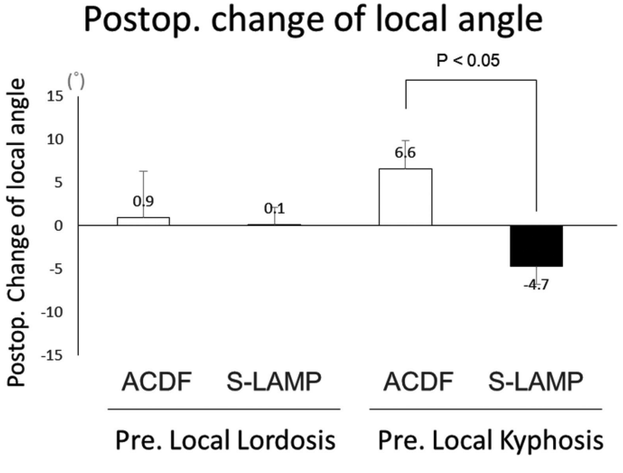


Figure 2.



Presentation #27

Comparison of Surgical Outcomes between Open-Door, Double-Door Laminoplasty, and Selective Laminectomy with Muscle Preservation for Cervical Spondylotic Myelopathy: A Multicenter Study of 881 Cases

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Introduction: Although there are several posterior decompression surgeries for cervical spondylotic myelopathy (CSM), such as open-door laminoplasty, double-door laminoplasty and selective laminectomy with muscle preservation, no comparative study of these three methods has previously reported. The aim of this study was to evaluate among three posterior decompression surgeries for CSM.

Materials / Methods: Between 2012 and 2014, 881 patients who underwent posterior cervical decompression surgeries for CSM at multi-centers in Japan were enrolled in this series. All subjects were observed with more than 2 years post-surgery. All patients were divided into three groups, open-door laminoplasty group (OD group), double door laminoplasty group (DD group) and selective laminectomy with muscle preservation group (SL group). Gender, height, body weight, body mass index (BMI), operating time, intra-operating blood loss, Japanese Orthopedic Association (JOA) score, and perioperative complications including C5 palsy were evaluated. Flexion-extension range of motion (ROM), sagittal Cobb angle of C2-7, C2-5, C5-7, and C2-7 sagittal vertical axis (SVA) on the lateral radiographs and the most stenotic level on MR imaging were evaluated. To evaluate statistical differences, an independent t-test and chi-square test were used and p value of less than 0.05 was considered as significant.

See Disclosure Index pages 41 – 95.

Presentation #27 (cont.)

Results: Of the 881 participants, 282 were classified as OD group, 213 as DD group and 217 as SL group. Male ratios were 67.7% in OD group, 66.8% in DD group and 64.4% in SL group, respectively. Height/body weight/ BMI were 160cm/60kg/23.5 in OD group, 159cm/61kg/24.2 in DD group, 161cm/61kg/23.3 SL group. Operating times were 100min in OD group, 88min in DD group and 133min in SL group. Operating time of SL group was significantly longer than other groups. Intra-operating blood losses were 77ml in OD group, 46ml in DD group and 18ml in SL group. Intra-operating blood loss of SL group is significantly smaller than other groups. The average pre-operative JOA scores/JOA scores at final follow up were 10.7/14.0 in OD group, 11.0/14.0 in DD group, and 11.0/13.8 in SL group. Incidences of C5 palsy were 3.2% in OD group, 1.9% in DD group, and 0.9% in SL group, respectively. There were no significant differences among three groups. Pre-operative ROM/ post-operative ROM/ residual rate of ROM were 33.7 degree/28.2 degree/83.7% in OD group, 37.8 degree/30.4 degree/80.4% in DD group, 35.1 degree/32.1 degree/91.4% in SL group, respectively. Residual rate of ROM in SL group is better than in DD group. C4/5 and C5/6 are the most frequent levels of severest stenosis on MRI.

Conclusion: There are several methods of posterior decompression surgeries for CSM, and each method has both merits and demerits. Although selective laminectomy which use operating microscope take longer operating time than other methods, it could reduce intra-operative blood loss and preserve neck ROM. In all procedures, recovery rates of JOA score were approximately 45–55% and incidences of C5 palsy were less than 3.2%, which were not significantly differences. All posterior decompression surgeries would be therefore safe and reliable treatment option for CSM.

Presentation #28

Investigating the Utility of Intra-Operative Neurophysiological Monitoring for Anterior Cervical Discectomy and Fusion: Analysis of Over 140,000 Cases from a National Inpatient Dataset

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Introduction: Although intra-operative neurophysiological monitoring (IONM) improves the safety of scoliosis surgery, its utility in more routine procedures, such as ACDF, is debated. Proponents advocate for routine use of multimodal monitoring, including SSEPs and tceMEPs, during ACDF. However, there are few head-to-head comparisons, leaving the benefit to outcomes unclear. Using an administrative database, we sought to determine whether use of IONM impacted the incidence of neurological complications in ACDF.

Methods: From the Healthcare Cost and Utilization Project (HCUP) National/Nationwide Inpatient Sample (NIS) (2009–2013), we identified inpatient discharges with a primary procedure code for ACDF (ICD-9-CM 81.02). The first five procedure codes were searched to separate ACDF operations that used IONM (ICD-9-CM 00.94). Diagnosis codes were searched to identify cases with post-operative neurological complication (ICD-9-CM 997.0, 997.00, 997.01, 997.02, 997.09).

We performed univariate and multivariate logistic regression analyses for the dichotomous outcome of post-operative neurological complication with use of IONM as the independent variable; cofactors evaluated included age, sex, surgical indication, multilevel fusion, Charlson Comorbidity Index, and admission type. We performed propensity matching in a one-to-one ratio with use of IONM as the treatment indicator and the above variables as cofactors. In the propensity-matched cohort, we compared neurological complication, length of stay (LOS), and hospital charges. We evaluated the impact of IONM on neurological complication in subgroups of patients defined by our cofactors of interest.

The threshold for statistical significance was p£0.05. Statistical tests were performed using STATA 13.1.

See Disclosure Index pages 41–95.

Presentation #28 (cont.)

Results: 141,007 ACDF operations were identified. Mean age was 54.0±0.03 years. There were 73,048 (51.8%) females. IONM was used in 9,540 (6.8%) cases. No significant association was found between neurological complication and use of IONM on univariate (OR 0.80, p=0.39) or multivariate regression (OR 0.82, p=0.45) (Table 1). By contrast, age³65 years, multilevel fusion, Charlson Comorbidity Index>0, and non-elective admission were associated with greater neurological complication.

The propensity-matched cohort consisted of 18,760 patients who underwent ACDF with (n=9,380) or without IONM (n=9,380). Rates of neurological complication were comparable between IONM and non-IONM groups (0.17% vs. 0.22%, p=0.41) (Table 2). IONM and non-IONM groups had a comparable proportion of patients with LOS³2 days (19% vs. 18%, p=0.15). Use of IONM was associated with an additional $6,843 (p< 0.01) in hospital charges.

We did not identify a subgroup of patients defined by age, sex, surgical indication, number of levels fused, Charlson Comorbidity Index, or admission type where IONM was associated with a significant difference in neurological complication.

Conclusion: We sought to determine if use of IONM improves the safety of ACDF. We used data from over 140,000 patients from an administrative dataset, making this the largest study to address this question. With growing costs, there is an evolving need for us, as physicians and managers of health care resources, to minimize expenses that do not enhance quality of patient care. The results of our study would suggest routine use of IONM for ACDF provides little to no benefit to patients at extra cost to the health care system.

Presentation #28

Table 1. Univariate and multivariate logistic regression analyses for post-operative neurological outcome in the study population

	Neurological complication (%)	Univariate regression OR (95% CI)	*p*	Multivariate regression OR (95% CI)	*p*
Age (yrs.)					
0–64	194 (0.17)	reference		reference	
³65	97 (0.33)	1.91 (1.50 to 2.44)	< 0.01*	1.35 (1.05 to 1.75)	0.02*
Sex					
Male	153 (0.23)	reference		reference	
Female	138 (0.19)	0.84 (0.67 to 1.06)	0.13	0.92 (0.73 to 1.16)	0.48
Surgical indication					
Infection	3 (0.72)	1.82 (0.43 to 7.67)	0.41	1.61 (0.38 to 6.80)	0.52
Neoplasm	4 (1.26)	3.20 (0.85 to 11.99)	0.08	1.51 (0.40 to 5.70)	0.54
Degenerative	239 (0.18)	0.46 (0.19 to 1.11)	0.08	0.92 (0.37 to 2.28)	0.86
Trauma	34 (0.51)	1.28 (0.50 to 3.27)	0.61	2.03 (0.78 to 5.27)	0.15
Deformity	6 (0.57)	1.44 (0.44 to 4.73)	0.55	2.53 (0.76 to 8.46)	0.13
Other	5 (0.40)	reference		reference	
No. of levels fused					
1–2	233 (0.19)	reference		reference	
³3	58 (0.30)	1.58 (1.18 to 2.11)	< 0.01*	1.47 (1.10 to 1.97)	< 0.01*
Charlson Comorbidity Index					
0	117 (0.13)	reference		reference	
1	91 (0.27)	2.12 (1.61 to 2.79)	< 0.01*	2.06 (1.56 to 2.71)	< 0.01*
2	36 (0.39)	3.11 (2.14 to 4.52)	< 0.01*	2.79 (1.91 to 4.08)	< 0.01*
³3	47 (0.94)	7.47 (5.32 to 10.50)	< 0.01*	5.71 (3.94 to 8.27)	< 0.01*
Admission type					
Elective	72 (0.41)	reference		reference	
Non-elective	219 (0.18)	2.29 (1.75 to 2.99)	< 0.01*	1.50 (1.10 to 2.06)	0.01*
IONM					
No	275 (0.21)	reference		reference	
Yes	16 (0.17)	0.80 (0.48 to 1.33)	0.39	0.82 (0.50 to 1.36)	0.45

Table 2. Outcomes in the propensity-matched cohort (n=18,760)

	No IONM (n=9,380)	IONM (n=9,380)	OR (95% CI) or MD (95% CI)	*p*
Neurological complication	21 (0.22)	16 (0.17)	0.76 (0.40 to 1.46)	0.41
Hospital charges	$59,173±612	$66,016±489	$6,843 (5,308 to 8,378)	< 0.01*
LOS>2 days	1,666 (17.8)	1,742 (18.6)	1.06 (0.98 to 1.14)	0.15

See Disclosure Index pages 41–95.

Presentation #29

Comparison of Preoperative and Postoperative Cervical Lordosis in Patients Undergoing Cervical Laminoplasty–Effect of C3 Laminectomy

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Introduction: Laminoplasty is an effective technique for the treatment of multilevel cervical stenosis and was developed in response to the high rate of complications associated with cervical laminectomy. The causes of post-laminoplasty kyphosis are not fully known. Previous studies have demonstrated that intervention at C3 may result in loss of cervical lordosis. The purpose of this study is to investigate the 1-year cervical lordosis following cervical laminoplasty in patients who had a C3 laminectomy versus preservation of C3.

Materials / Methods: A retrospective case-control study of patients at a single academic institution treated by four surgeons with multi-level open-door laminoplasty for myelopathy was performed. All patients treated from 2006 to 2015 were included. Patients with incomplete radiographs, or previous cervical fusions were excluded. Patients were divided into two groups based on the intervention at the C3 level. Group 1 underwent C3 laminectomy (C3 full or partial laminectomy), and Group 2 had preservation of C3 with laminoplasty performed caudally. The C2-C7 Cobb angle, the Cobb angle of the decompressed levels (segmental lordosis), and C2-7 Sagittal Vertical Axis (SVA) were measured on preoperative, 6-week postoperative and 1-year postoperative films. Pre-operative neutral, flexion, and extension radiographs were additionally measured for T1 slope, listhesis, spondylosis, and maximal C2-7 Cobb angles in flexion and extension. Change from baseline to one year follow-up in C2-7 Cobb, segmental lordosis, C2-7 SVA were analyzed with paired and unpaired t-test, and T1 slope, listhesis, maximal C2-7 flexion and extension Cobb angles were compared with unpaired T test. To determine the effects of pre-operative radiographic measurements and operative interventions on postoperative lordosis, a multi-variate regression analysis was performed. The dependent variable was postoperative C2-7 Cobb angle. Significance was defined as p-value <0.05.

Results: There were 233 patients who underwent laminoplasty from 2006–2015. 37 were excluded for incomplete radiographs, 6 had previous surgical fusions, 5 had autofusions or congenital fusions, =and 66 were lost to follow-up. Analysis of patients lost to follow-up cohort demonstrated no difference to the study patients. There were 95 patients who underwent C3 laminectomy and 24 patients with preservation of C3. There was no difference in pre-operative C2-7 Cobb, segmental lordosis, maximum flexion or extension, T1 slope or C2-7 SVA (Table 1). At one year, when a C3 laminectomy was performed, the change of C2-7 lordosis averaged -4.95°, with a change in segmental lordosis of -3.69°. When C3 was preserved, the change of C2-7 lordosis averaged -2.98°, with a change in segmental lordosis of -1.65° (p=0.32 and 0.13 respectively) (Table 2). Regression analysis demonstrated that pre-operative segmental lordosis was the only significant factor in determining one-year postoperative cervical lordosis (B=0.95, $p<0.001$).

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Conclusion: Our results indicate that laminectomy at C3 does not alter the loss of cervical lordosis compared to preservation of C3. We recommend complete or partial C3 laminectomy over C3 laminoplasty at the cranial segment to preserve cervical lordosis. Additionally, our results suggest that the patient's baseline segmental lordosis ultimately drives the postoperative cervical lordosis.

Table 1. Pre-Operative Characteristics

	C3 Laminectomy (N=95)	C3 Preserved (N=24)	p Value
Age	60.68±1.31	68.04±1.79	0.009
Sex (M-F)	58–37	15–9	0.99
C2-7 Cobb	8.41±1.42	10.28±2.92	0.56
Segmental Lordosis	0.80±1.00	2.88±1.21	0.32
Maximum Flexion	-14.68±1.67	-11.81±2.48	0.42
Maximum Extension	20.46±1.42	22.9±3.19	0.45
T1 Slope	32.96±0.97	35.86±2.15	0.19
C2-7 SVA	3.12±0.15	3.34±0.27	0.5
# Levels compressed	3.82±0.10	3.26±0.24	0.018
T2 Hyperintensity	46/68	11/19	0.43

Table 2. Radiographic Change

	C3 Laminectomy (N=95)	C3 Preserved (N=24)	p Value
C2-7 Pre-Op	8.41±1.42	10.28±2.92	0.56
C2-7 6 weeks	1.56±1.46	4.85±3.31	0.32
C2-7 1 year	4.09±1.53	7.30±3.26	0.35
Change in C2-7	-4.95±8.7	-2.98±8.66	0.32
Seg Lordosis Pre-Op	0.80±1.00	2.88±1.21	0.32
Seg Lordosis 6 weeks	-3.91±1.12	0.23±1.26	0.07
Seg Lordosis 1 year	-2.81±1.17	1.22±1.3	0.094
Change in Seg Lordosis	-3.69±6.10	-1.65±4.92	0.13
SVA Pre-Op	3.12±0.15	3.34±0.27	0.5
SVA 6 weeks	4.01±0.17	4.26±0.40	0.53
SVA 1 year	3.93±0.17	4.17±0.37	0.53
Change in SVA	0.83±1.03	0.83±1.08	0.99

See Disclosure Index pages 41–95.

Presentation #30

A Comparative Study between Two Types of Cervical Laminoplasty on the Deep-Extensor Volume and Axial Neck Pain-Minimum Two-Year Follow-Up Results

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Introduction: Cervical laminoplasty is one of the classic surgical options for the treatment of degenerative cervical myelopathy. However, traditional open door laminoplasty is hard to avoid the extensive detachment of the paraspinal muscles and posterior ligaments. Our previous study on the modified open door laminoplasty with the preservation of the unilateral posterior muscular-ligament complex showed less axial pain at the early postoperative follow-up compared to the conventional laminoplasty. The aim of this study is to evaluate the medium-term clinical outcomes and the volume of deep extensor muscles after modified cervical laminoplasty with the preservation of unilateral posterior muscular-ligament complex.

Materials / Methods: A retrospective review was performed on 116 patients who underwent open door laminoplasty from C3 to C7 by a single group within one institution between 06/2007 and 10/2013. Traditional laminoplasty was performed in 61 patients (T group), and the other 55 patients underwent modified laminoplasty with the preservation of posterior muscular-ligament complex (P group). All patients had at least 2 years of clinical follow-up. The volume of deep extensor muscles was calculated as the sum of cross-sectional areas (CA) from C2/3 to C6/7 on cervical MRI T2 image by Photoshop software. C2-7 alignment and range of motion (ROM) were measured on the cervical lateral and flexion-extension x-rays. Clinical outcomes such as modified Japanese Orthopaedic Association (mJOA) score for neurologic function and Visual Analogue Scale (VAS) for axial neck pain were collected pre- and post-operatively and then compared between groups. VAS score > 3 was defined as the obvious axial neck pain.

Results: The study patients had an average age of 57 years, with a mean follow-up of 27.6 months. There is no significant difference in the baseline demographics in age, gender, cervical alignment, range of motion, follow-up time, CA in each level, mJOA score and VAS-neck. Clinical outcomes at final follow-up were significantly improved for both T group ($p=0.02$) and P group ($p=0.01$) patients by the two patient-reported measures. Despite decreased C2-7 ROM in both groups at the final follow-up ($p<0.01$), patients in P group had a better cervical alignment and mobility than those in T group ($p<0.01$). Notably, patients in P group had a higher CA in each level from C2/3 to C6/7 than those in T group at final follow-up ($p<0.01$). Similarly, 14 patients in P group and 29 patients in T group complained of obvious axial neck pain ($p=0.014$).

Conclusion: Modified cervical laminoplasty with preserving of unilateral posterior muscular-ligament complex had the advantage of maintaining the volume of deep extensor muscle, cervical alignment, range of motion and reducing the axial neck pain compared to the conventional open door laminoplasty based on a minimum 2-year follow-up.

Presentation #31

The Correlation between Cervical Alignment and Posterior Cervical Muscle Fatty Infiltration at Baseline in Cervical Deformity Patients

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Introduction: Degenerative changes in the cervical spine often develop insidiously and spinal cord impairment, malalignment, and muscle impairment frequently co-occur. Cervical extensor musculature is known to play an important role in the physical support of the neck buts its role in the disease history of degenerative cervical disease and surgical correction of degenerative changes is poorly researched in the literature. Muscle fatty infiltration may have an effect on cervical deformity, including success of surgical intervention. The purpose of the present study is to examine the relationship between cervical muscle area and fatty infiltration on baseline kyphosis in surgical cervical deformity patients.

Methods: Consecutive patients undergoing multi-level posterior fusions for cervical deformity were prospectively enrolled by two surgeons. Preoperative cervical extensor musculature (multifidus, semispinalis cervicis, semispinalis capitis, and splenius capitis) were quantitatively measured from the T2-weighted axial MR images of the intervertebral disc levels from C2-C3 to C6-C7 using ImageJ imaging software. These measurements included total cross sectional area, functional area (fat free area; FFA), and a ratio of FFA to total area as an indication of fatty infiltration. T-tests and Pearson correlation tests were used to examine how mal-alignment (cervical lordosis / kyphosis [C2-C7], cervical Sagittal Vertical Angle [C2-C7 cSVA], and Cervical Lordosis minus T1 Slope [TS-CL]) correlated to fatty infiltration and total muscle area. Secondary analysis examined baseline predictors of fatty infiltration and total area.

Results: 20 patients underwent surgical correction for cervical deformity (Average age: 55.8 years, 70% female). Fatty infiltration increased in the inferior aspect of the cervical spine (C2-C3: 0.51 to C6-C7: 0.64, $p<0.001$). Gender, age, and BMI did not show any significant relationship with fatty infiltration or total muscle area. However, total muscle area was significantly lower in smokers (smoker: 532.3 cm^2 vs. non-smokers: 954.0 cm^2, $p=0.031$). While fatty infiltration showed a significant relationship with cervical kyphosis ($r^2=0.529$, $p=0.016$) and TSCL ($r^2=0.659$, p-0.028), total muscle area had no significant correlation with radiographic sagittal alignment in this cervical deformity population (C2-C7, cSVA, and TS-CL all $p>0.05$). In analyzing disability and pain scores, fatty infiltration and total muscle area did not correlate with lower mJOA scores, NDI scores, NSR back pain, or NSR neck pain scores (all $p>0.05$).

Conclusions: In this study of preoperative cervical deformity patients, there was a significant relationship between cervical sagittal alignment and posterior muscle fatty infiltration. Fatty infiltration was associated with positive sagittal balance. Patient factors including gender, age and BMI did not correlate with muscle area or fatty infiltration, while smoking had a substantial negative correlation with muscle area.

See Disclosure Index pages 41–95.

Presentation #32

Increase in Cervical Lordosis Decreases Postoperative Neck Pain After Laminectomy and Fusion

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Object: Degenerative disease of the cervical spine is associated with a loss of cervical lordosis. Surgeons will often try to restore this. The effect of loss of cervical lordosis on postoperative neck pain after posterior cervical procedures is examined here.

Methods: Data from patients in the Quality Outcomes Database (QOD) undergoing cervical laminectomy & fusion (lami-fus) or laminoplasty was reviewed. Clinical outcomes and radiographs were compared. Subgroup analysis on patients who had pre and postoperative neck pain was performed.

Results: 182 patients were reviewed (61 lami-fus and 121 laminoplasty). Preoperative cervical lordosis and percentage of patients with baseline neck pain was similar between the groups. The laminoplasty group had significantly lower preoperative VAS neck pain scores (4.89 vs. 6.38, p=.014). Baseline cervical lordosis (CL), T1 slope (T1s), cervical sagittal vertical alignment (cSVA) and T1s-CL mismatch (TCM) were similar between the groups.

Average follow up is 15.6 months. Return to OR rates were similar between the groups. The lami-fus group had a significant reduction in VAS neck pain at follow up (6.15 to 3.95, p=.004) but the laminoplasty group did not (3.68 vs. 3.26, p=.556). Cervical lordosis significantly decreased in the laminoplasty group at follow up (10.94° to 8.98°, p=.012). Cervical SVA increased in the lami-fus group (27.12mm vs. 32.43mm, p=.004) and not in the laminoplasty group (32.65 vs. 35.03, p=.302). T1s and TCM were unchanged (Table 1).

Subgroup analysis comparing patients with and without neck pain at follow up was examined. Patients in the lami-fus group with neck pain on follow up had a decrease in cervical lordosis of 3.32° while patients who did not have neck pain had an increase in lordosis of 3.46° (p=.033). The differences in the laminoplasty group were not statistically significant. Change in cervical SVA was not associated with postoperative neck pain (Table 2).

Binomial regression modeling was performed with preoperative neck pain as a cofactor. This found that an increase cervical lordosis significantly decreased the chances that a patient would have postoperative neck pain in the entire cohort (OR .960, p=.034).

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Conclusion: Loss of cervical lordosis is associated with an increased chance of having neck pain after a cervical laminectomy and fusion. Laminectomy with fusion tends to worsen cervical sagittal vertical alignment, but this wasn't associated with a worse outcome. Patients who have neck pain on follow up after a laminectomy and fusion showed a decrease in cervical lordosis while patients without neck pain showed an increase in lordosis. Regression modeling shows that increasing cervical lordosis decreases the chances that a patient will have neck pain.

Table 1. Differences between preoperative and postoperative values. Continuous values compared using paired samples t-tests and categorical values with McNemar test. T1s: T1 slope. CL: cervical lordosis.

	Preop	Postop	p
Pain incidence entire cohort	127 (69.8%)	74 (42.8%)	**<.001**
Pain incidence laminoplasty	79 (65.4%)	43 (38.4%)	**<.001**
Pain incidence lami-fusion	48 (78.7%)	31 (50.8%)	**<.001**
VAS entire cohort	4.95	3.62	**.011**
VAS laminoplasty	3.68	3.26	.556
VAS lami-fusion	6.15	3.95	**.004**
Lordosis entire cohort	9.44	8.65	.092
Lordosis laminoplasty	10.94	8.98	**.012**
Lordosis lami-fusion	8.18	8.08	.950
C2 SVA entire cohort	29.81	33.69	**.008**
C2 SVA laminoplasty	32.65	35.03	.302
C2 SVA lami-fusion	27.12	32.43	**.004**
T1s-CL mismatch entire cohort	17.23	19.96	.054
T1s-CL mismatch laminoplasty	17.45	20.18	.080
T1s-CL mismatch lami-fusion	17.03	19.73	.254

SVA: Sagittal vertical alignment. VAS: visual analog scale.

See Disclosure Index pages 41–95.

Presentation #32 (cont.)

Table 2. Differences in radiographic parameters among patients with and without postoperative neck pain. Independent samples t-tests were used to compare groups. SVA: Sagittal vertical alignment.

	Patients with postop pain	Patients without postop pain	*p*
Entire cohort			
Preop lordosis	11.50±11.00	8.81±11.58	.144
Postop lordosis	8.10±9.62	9.11±12.50	.584
Change in lordosis	-3.34±10.90	0.41±8.65	**.022**
Preop C2 SVA	27.71±13.69	33.23±16.69	.123
Postop C2 SVA	32.37±13.30	34.90±18.90	.513
Change in C2 SVA	-4.32±11.04	-1.77±13.02	.399
Laminoplasty			
Preop lordosis	12.34±7.90	10.07±11.01	.286
Postop lordosis	8.86±8.34	9.14±12.45	.905
Change in lordosis	-3.37±7.79	-0.95±7.93	.149
Preop C2 SVA	30.40±15.63	34.27±15.60	.474
Postop C2 SVA	32.00±14.98	37.53±18.22	.345
Change in C2 SVA	-1.00±11.05	-2.71±16.16	.724
Lami fusion			
Preop lordosis	10.55±13.77	6.07±12.50	.193
Postop lordosis	7.22±11.01	9.03±12.84	.562
Change in lordosis	-3.32±13.74	3.46±9.53	**.033**
Preop C2 SVA	25.37±11.59	32.25±18.10	.193
Postop C2 SVA	32.66±12.17	32.07±19.89	.911
Change in C2 SVA	-7.17±10.47	-0.67±8.61	.078

SVA: Sagittal vertical alignment.

Presentation #33

A Prospective Cohort Study of Postoperative Spinal Epidural Hematoma after Cervical Laminoplasty

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Introduction: It has been documented that postoperative cervical spinal epidural hematoma (SEH) sometimes requires re-operation. However, there is no prospective report reporting the epidemiology. We therefore conducted a prospective study that tracks patients with SEH following cervical laminoplasty.

Materials / Methods: Two hundred thirty seven consecutive patients (mean age 68.8 years) who received double-door laminoplasty for cervical compressive myelopathy at our hospital from 2008 to 2013 and were followed up for at least 1 year were enrolled. Cervical MRI was evaluated before and within 1-week after surgery. Spinal cord area (SCA) on axial T2-weighted MRI was measured and categorized 3 grades as follows; Grade 0 (G0): the spinal cord was expanded with the presence of cerebrospinal fluid; Grade 1 (G1): spinal cord was compressed by SEH whereas the SCA increased after operation; Grade 2 (G2): spinal cord was compressed by SEH and the SCA decreased after surgery (Figure 1). Cervical Japanese Orthopedic Association (C-JOA) score was used as clinical result.

Results: One hundred seventy five cases were categorized as G0 group. The spinal cord compressions by SEH was detected in 62 cases (26.2%). We could classify 48 cases (20.3%) for G1 group, and 14 cases (5.9%) for G2 group. The rate of preoperative use of anticoagulant in G0 group was lower than those in G1 and 2 groups. Re-operation was performed to 1 case (0.4%) with neurological deterioration in G2 group. In 236 cases without neurological deterioration, the mean recovery rate of the C-JOA score at 1-month follow-up in G2 was inferior to that in G0; however that at 1-year follow-up did not show a significant difference among the three groups (Figure 2).

Conclusion: As results of prospective study, spinal cord compression by SEH after cervical lamonoplasty was observed in 26.2%, severe spinal cord compression in 5.9%, and neurological deterioration in 0.4%. In case without neurological deterioration, spinal cord compression by SHE affected neurological recovery at early stage, but not at 1-year follow-up period.

See Disclosure Index pages 41–95.

Presentation #33 (cont.)

Figure 1.

Grading of SEH

	Spinal cord compression by SEH	SCA (spinal cord area)
G0	-	Postop. SCA > Preop. SCA
G1	+	Postop. SCA > Preop. SCA
G2	+	Postop. SCA < Preop. SCA

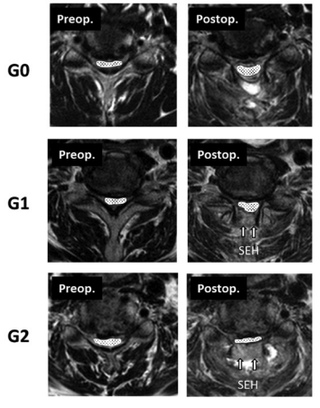
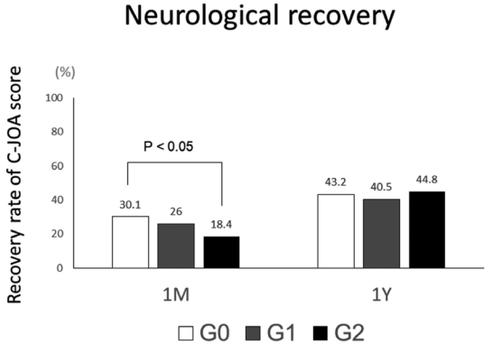


Figure 2.



Presentation #34

Long-Term Fate of C3-7 Arthrodesis: 4-Level ACDF vs. Cervical Laminectomy and Fusion

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Introduction: Multilevel cervical spondylotic myelopathy (CSM) or ossification of the posterior longitudinal ligament (OPLL) is successfully treated surgically by mulitlevel anterior cervical discectomy and fusion (ACDF) or cervical laminectomy and fusion (CLF). While various investigations have described differences with respect to outcomes and incidence of complications, no procedure has been clearly shown to be superior. Most prior investigations comparing approaches, however, are limited by marked heterogeneity in the composition of the study groups, particularly that posterior surgery groups tend to treat a greater number of spinal levels and that different surgical approaches, such as discectomy and corpectomy as well as laminoplasty and CLF, are grouped together making direct comparisons problematic. In addition, the overwhelming majority of patients surgically treated for CSM and OPLL have disease within the C3-7 levels; but incidence of symptomatic adjacent segment degeneration (ASD) and long-term neurologic outcome in those patients needing fusion of all these levels is not fully characterized.

Methods: A retrospective review of cases over a twelve-year period of surgeries to treat CSM or OPLL identified patients undergoing ACDF or CLF at the C3-7 levels. Demographic and clinical data was recorded, the pre and post-operative modified Japanese orthopedic association scores (mJOA) were calculated, and any complications were noted. Minimum follow up was 12 months.

Results: Of 781 patients undergoing cervical decompressive surgery, 64 met study criteria, 15 undergoing C3-7 ACDF and 49 CLF. There were no differences in age, sex, diabetes and smoking status, BMI, and pre/postoperative mJOA scores. Mean follow-up for anterior and posterior groups were 52 and 44 weeks respectively. A complication occurred in 3/15 (21%) of the anterior and 14/49 (28%) of the posterior group. One ACDF patient required reoperation 3 weeks postop for anterior plate dislodgement, another had moderate dysphagia that resolved by 6 weeks, and a third had C5 paresis that resolved over 8 months. In the CLF group, two CLF patients developed deep vein thrombosis, another had a perioperative myocardial infarction, and another was readmitted within 30 days with pneumonia. There were no infections in the ACDF patients but three CLF patients had superficial wound infections. Solid fusion was seen in 96 percent of ACDF levels with two patients having no bridging bone evident at C6/7 not associated with symptoms. Fusion in the CLF group was 95% with four asymptomatic pseudoarthroses at C6/7 and three at C3/4; and two had reoperation for symptomatic kyphotic deformity at the inferior level. Two CLF patients had symptomatic disc herniation at the C7/T1 level successfully managed conservatively (Table 1).

Conclusion: Long-term neurological improvement is seen following surgical management of myelopathy from C3-7 cord compression with either 4-level ACDF or CLF with comparable change in mJOA scores. While not statistically significant, fewer complications, particularly medical, were noted in the patients treated with ACDF. The absence of symptomatic ASD in the ACDF group raises as a question for further study whether the statistical likelihood of ASD following anterior fusion may be lower than currently published data once the C3-7 levels are already fused.

See Disclosure Index pages 41–95.

Presentation #34 (cont.)

Table 1. Summary of patient data C3-7 ACDF versus cervical laminectomy and fusion

	ACDF n=15	CLF n=49
age (years)	56.8 (37–70)	60.8 (35–83)
gender (M/F)	6/9	20/29
smoker	3 (20%)	11 (22%)
diabetes	4 (27%)	10 (20%)
Mean BMI	29 (25–36)	29 (17–46)
BMI≥30	6 (40%)	7 (14%)
Preop mJOA	11.6 (8–14)	11.4 (6–15)
Postop mJOA	15.4 (13–17)	15.5 (13–18)
Follow-up (months)	52.0 (14–141)	43.8 (12–130)
Preoperative symptoms (%)		
gait difficulty	67	78
hand numbness	100	96
motor deficit	100	90
Babinski sign	33	41
Hoffmann sign	67	75
hyperreflexia	73	71
T2 cord change (%)	60	70
Any complication	3 (21%)	14 (28%)
myocardial infarction	0	1 (2%)
Deep vein thrombosis	0	2 (4%)
pneumonia	0	1 (2%)
C5 nerve palsy	1 (7%)	3 (6%)
transient dysphagia	1 (7%)	0
wound infection	0	3 (6%)
reoperation at adjacent level	0	2 (4%)
Symptomatic adjacent segment deg	0	4 (8%)
fusion rate per level (%)	96	95

Presentation #35

What is a Right Distal Fusion Level for Prevention of Sagittal Imbalance in Multilevel Posterior Cervical Spine Surgery; C7 or T1?

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Introduction: The sagittal balance of the cervical spine is known to be affected by cervical lordosis and T1 slope. But T1 slope is not a constant parameter that can be frequently changed after the surgery. Therefore, postoperative sagittal alignment may be unpredictable. And in multilevel posterior cervical fusion, there is debate among surgeons regarding the most appropriate distal extent of fusion. Purpose of this study was to see the sagittal alignment and T1 slope after the multilevel posterior cervical spine surgery depending on distal fusion level; C7 or T1.

Materials / Methods: Consecutive 50 patients with cervical myelopathy who had undergone multilevel posterior cervical fusion were evaluated and followed more than 2 years (mean follow up duration: 39 months). Group 1 consisted of 29 patients whose distal fusion level was C7. Group 2 was consisted of 21 patients whose distal fusion level was T1. Mean age was 63.1 years in group 1 and 62.1 years in group 2. Gender distribution was similar between the two groups. Number of fusion level was 4.20 in group 1 and 5.19 in group 2.

C1-2 lordosis, C2-7 lordosis, C2-7 sagittal vertical axis (SVA), and T1 slope were measured on preoperative and last follow up cervical spine lateral radiographs by three spine fellows twice. Inter- and intra-observer reliability test was performed. Statistical analysis was performed by independent sample T-test to compare the two groups and, paired sample T-test to compare the preoperative and last follow up measurement in each group

Results: Cronbach's alpha was 0.784–0.822 for intra- and inter-observer reliability. There were no significant differences between the two groups in preoperative measurements (Table 1). C1-2 lordosis was significantly decreased and C2-7 lordosis was significantly increased after the surgery in both groups (Table 2). C2-7 SVA (23.1mm→30.4mm) worsened significantly, and T1 slope (22.3º→32.9º) was significantly increased after the surgery in group 1 (Figure 1). C2-7 SVA was not changed significantly after the surgery in group 2. Last follow up T1 slope (22.7º) was similar with preoperative T1 (21.8º) slope in group 2 (Table 2, Figure 2).

Conclusion: Sagittal alignment became worse after the surgery in C7 fusion group due to increased T1 slope. However, in T1 fusion group, T1 slope was not changed after the surgery. Therefore, sagittal alignment was maintained after the surgery. Based on the results of this study, we recommend distal fusion extends to T1.

See Disclosure Index pages 41–95.

Presentation #35 (cont.)

Table 1. Preoperative measurements in two groups

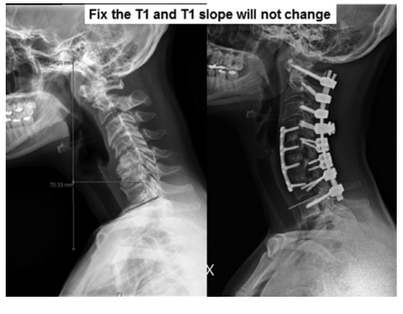
	Group 1 (Fusion to C7)	Group 2 (Fusion to T1)	P-value
C1-2 lordosis (degrees)	29.1	28.1	0.658
C2-7 lordosis (degrees)	7.2	6.2	0.807
C2-7 SVA (mm)	23.1	25.3	0.686
T1 slope (degrees)	22.3	21.8	0.832

Table 2. Paired sample t-test of preoperative and postoperative measurements in each group

	Group 1 (Fusion to C7)			Group 2 (Fusion to T1)		
	Preop	Last follow up	P-value	Preop	Last follow up	P-value
C1-2 lordosis (degrees)	29.1	24.7	0.022	28.1	21.0	0.036
C2-7 lordosis (degrees)	7.2	21.8	0.000	6.2	25.9	0.000
C2-7 SVA (mm)	**23.1**	**30.4**	**0.043**	25.3	23.6	0.648
T1 slope (degrees)	**22.3**	**32.9**	**0.000**	21.8	22.7	0.041

Figure 1. Sagittal vertical axis became worse after the surgery in C7 fusion group

Figure 2. T1 slope was not changed after the surgery and sagittal vertical axis was improved.



• The FDA has not cleared the drug and / or medical device for the use described (i.e., the drug and / or medical device noted with an • is being discussed for an "off label" use). See inside back cover for information.

Presentation #36

Distal Junctional Kyphosis (DJK) After Cervical Deformity Surgery: Analysis with In-Construct Measurements

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Introduction: Distal Junctional Kyphosis (DJK) and Distal Junctional Failure (DJF) are prevalent following cervical deformity surgery. However, surgeons currently have no intraoperative method of assessing a patient's eventual risk for developing DJK-related malalignment. This limits their ability to tailor their surgical alignment priorities to prevent post-operative loss of correction or failure of realignment. Established regional alignment measures such as C2-C7 SVA (cSVA) are useful to establish radiographic alignment targets, but they cannot be relied upon during surgery. Surgeons aim to optimize in-construct alignment to meet preoperative goals, while minimizing the risk of DJK or DJF. This study proposes a set of in-construct measures, which can be utilized intraoperatively to assess the adequacy of cervical realignment.

Materials / Methods: A prospective collection of operative cervical deformity patients was analyzed for DJK (change in kyphosis >10° in LIV to LIV-2). Inclusion criteria were cervical kyphosis>10°, cervical scoliosis>10°, C2-C7 SVA>4cm or CBVA>25°. Demographics, established radiographic parameters, new in-construct measures, and 1-year post-operative quality of life measures were assessed and compared between patients with DJK and without DJK (controls) by student's t-tests and Chi-squared analysis. Linear regression was conducted to determine the association between in-construct measures (C2-T1 tilt, C2-T10 tilt, and C2-LIV tilt) and 1-year post-operative cSVA.

See Disclosure Index pages 41–95.

Presentation #36 (cont.)

Results: 84 cervical deformity patients (mean age 61 years, 60% female, 8.3% revisions) were included. DJK occurred in 12 patients (14.3%), and 2/12 (18%) required revision. DJK patients had more baseline deformity by cSVA (52.6 vs. 36.9cm, p<.01) and TS-CL (47.9 vs. 36.4°, p<.05). Linear regression revealed that cSVA of 4cm corresponded to C2-T1-Tilt of 2.30°, C2-T10-Tilt of 25.8° and C2-LIV-Tilt of 38.0° (R>.51, p<.001). DJK patients did not differ significantly from controls in number of levels fused or frequency of osteoporosis diagnoses. There was a higher total osteotomy grade in controls (p<.003). DJK patients had worse post-operative alignment (cSVA: 48.3 vs. 31.6, p<.001; TSCL: 35.6 vs. 25.1, p=.008). The deformity correction was similar for DJK and controls by in-construct measures C2-LIV Tilt (p=.130), but post-operative alignment across fused segments was worse for DJK patients by in-construct measurement C2-T1-Tilt (.035 vs. -10.6, p<.01). Inclusion of the thoracic apex or the secondary, thoracolumbar driver of the deformity did not have an effect on DJK. There was no difference in 1-year HRQL between the groups.

Conclusion: DJK patients had worse baseline and post-operative alignment, despite similar intraoperative corrections; this implies that insufficient correction of the cervical deformities may be associated with the development of DJK. The proposed in-construct measures provide an intraoperative measurement tool that surgeons can use to prevent post-operative DJK, and failure of realignment. Because DJK is a common driver of deformity in cervical fusion patients, adoption of this in-construct measure has the potential to decrease the overall societal burden due to cervical fusion complications. Future studies should assess alignment intraoperatively within the fusion separate from unfused segments to identify thresholds above which DJK is more prevalent.

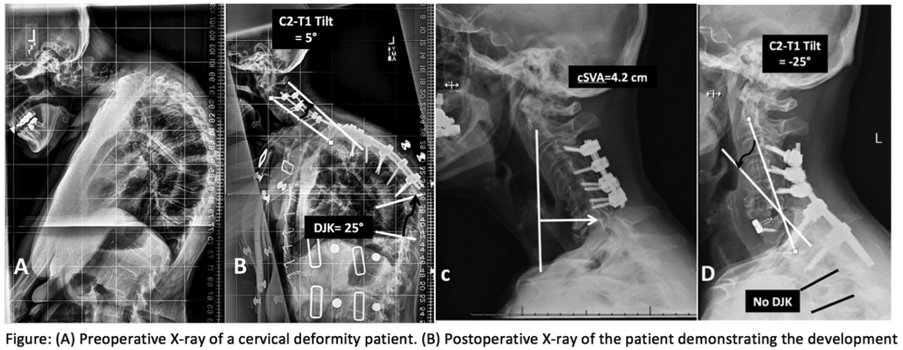

Figure: (A) Preoperative X-ray of a cervical deformity patient. (B) Postoperative X-ray of the patient demonstrating the development of Distal Junctional kyphosis (DJK). The in-construct measurement, C2-T1 Tilt (Angle of a line from the centroid of C2 to the centroid of T1 and a line parallel to the posterior vertebral body of T1) quantifies alignment in the fusion construct. (C) Preoperative X-ray of a different cervical deformity patient. (B) Postoperative X-ray demonstrating excellent correction with combined anterior/posterior osteotomies at C6-7. The in-construct measurement, C2-T1 Tilt = -25° and there is no DJK.

Presentation #37

Cervical vs. Thoracolumbar Spinal Deformities: A Comparison of Baseline Quality-of-Life Burden

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Introduction: Surgeons often must decide, in correcting deformities, the etiology of multiple curvatures in planning surgical intervention. The relative quality-of-life burden of cervical and thoracolumbar deformities has never been compared to each other. This may have significant implications in deciding treatment intervention on patients with both thoracolumbar and cervical deformities. The goal of this study was to determine the relative quality-of-life burden in patients with uncompensated cervical, thoracolumbar, or cervical and thoracolumbar deformities

Methods: Retrospective analysis of two prospectively collected multi-center databases. C2-C7 SVA>4cm defined cervical deformity and C7-S1 SVA>5cm defined thoracolumbar deformity. Patients with both SVA criteria were defined as "both", and were compared to pure cervical and pure thoracolumbar sagittal deformities. Primary analysis compared patients, keeping different region groups separate, by demographic, comorbidity data, and quality of life scores (EQ-5D) between groups using t-tests. A secondary analysis merged both treatment groups with propensity scores matching based on baseline EQ-5D scores according to cervical, thoracolumbar, and both malalignment. Differences in disease-specific metrics (ODI, NDI, mJOA) were analyzed using ANOVA tests.

See Disclosure Index pages 41 – 95.

Presentation #37 (cont.)

Results: 190 patients were included in our analysis. Gender (56.3%) and age (63.5 yrs) did not differ significantly by sagittal deformity category. BMI was significantly higher in patients with both cervical and thoracolumbar deformities (p=0.037). Baseline EQ-5D score was lower in patients with both deformities (p=0.022). In patients diagnosed and treated for cervical deformity, the "both" subgroup had a significantly higher comorbidity burden (p=0.017). Quality-of-life analysis between these subgroups revealed the lowest mJOA score in the "both" cohort (p=0.006). In patients diagnosed and treated for thoracolumbar deformity, the "both" cohort exhibited the highest comorbidities (p=0.014) and demonstrated the highest BMI (p=0.039). Matching patients from both databases based on baseline EQ-5D scores created deformity groups with similar quality of life burden. Cervical deformity patients had fewer comorbidities (p=0.000), while "both" patients had more baseline neurological impairment, as measured by the mJOA score (p=0.026). However, there were no significant differences in terms of ODI and NDI scoring (p=0.884 and p=0.496, respectively). Cervical deformity patients tended to be younger and had fewer posterior levels fused, although these values did not reach statistical significance (p=0.059 and p=0.062, respectively).

Conclusions: In this study, spinal deformity patients with both cervical and thoracolumbar malalignment were associated with the lowest quality-of-life scores. Additionally, patients who met criteria for cervical deformity tended to be younger with lower comorbidities despite similar baseline quality-of-life scores, possibly suggesting a significant impact of cervical malalignment on disability presenting at an earlier age. Collectively, these findings suggest an additive effect of cervical sagittal malalignment on thoracolumbar deformity resulting in increasing disability.

Presentation #38

High C2-T3 Sagittal Imbalance is an Independent Predictor of Recurrent Proximal Junctional Kyphosis

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Introduction: No prior studies have identified pre-operative radiographic parameters that predict recurrence of proximal junctional kyphosis (R-PJK). Identifying such predictors may facilitate surgical planning in PJK revision surgery. The purpose of this project is to determine which pre-op radiographic parameters can predict R-PJK in patients who underwent revision surgery for PJK.

Methods: Consecutive patients who underwent revision surgery for PJK at multiple institutions from 2005-2013 with at least 2 years follow-up were included in the study. Patients without instrumentation to the pelvis were excluded. R-PJK was defined as a PJK angle>10° as previously described by Glattes et al. Patient demographics and radiographic measurements including C2-T3 angle (CTA), C2-T3 SVA (CTS), and C7 SVA were compared between R-PJK patients and those without recurrent PJK (N-PJK). Univariate and multivariate analyses were used to determine R-PJK predictors.

Results: A total of 58 patients of 71 met inclusion/exclusion criteria. The mean age was 65.8 years old with an average follow-up of 2 years. R-PJK occurred in 28 patients (48%). All demographics, except female sex (p=0.03) and UIV implant types (p<0.01) were similar between the R-PJK and N-PJK groups. Pre-op UIV distribution was as follow: below T12 (n=11), T9-12 (n=30), T4-8 (n=15), C7-T3 (n=3) who were then revised up to C2-7 (n=5), T1-3 (n=7), T4-8 (n=28) and T9-12 (n=18). Pre-op CTA (p=0.03), CTS (p<0.01), and C7SVA (p=0.02) were significantly larger in the R-PJK group. PJK angle after revision showed a positive correlation with pre-op CTS (r=0.40, p<0.01) and C7SVA (r=0.34, p=0.01). Pre-op CTA >15° (p=0.03) and CTS>4cm (p=0.01) were associated with higher prevalence of R-PJK. Multivariate analysis revealed pre-op C2-T3 SVA>4cm (OR 4.96, p=0.01) was an independent predictor of R-PJK. In patients with a pre-op C2-T3 SVA>5.5cm, 100% developed R-PJK (n=5) and when <2.5cm 0% developed R-PJK (n=10).

Conclusion: Larger pre-op CTA and CTS were associated with higher risk of R-PJK. Pre-op CTS was an independent predictor of R-PJK. Care should be taken with PJK revision in patients with severe pre-op cervicothoracic malalignment and those with a CTS>5.5 cm should be considered very high risk.

See Disclosure Index pages 41–95.

Presentation #39

Improvement in Ames-ISSG Cervical Deformity Classification Modifier Grades Correlate to Clinical Improvement and Likelihood of Reaching MCID in Multiple Metrics: Series of 73 Patients with 1-Year Follow-Up

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Introduction: Prospective cervical deformity (PCD) patients have recently been assessed with ACD and adult spinal deformity (ASD) classifications with short follow-up. This study describes PCD patients with cervical (Ames) deformity scheme at baseline and 1-year post-operative and correlates modifier grades with outcomes. This study aims to utilize the Ames cervical classification to assess 1 year ACD outcomes.

Methods: Retrospective review of a prospectively collected cervical deformity database. Inclusion: PCD patiens≥18yrs with pre-/post-op (1Y) radiographs. Patients were classified with Ames (A-ACD) scheme. A-ACD primary deformity descriptors (C=cervical; CT=cervicothoracic junction; T=thoracic; S=coronal) and alignment modifiers (cSVA, TS-CL, mJOA, Horiz) were assigned. Baseline univariate description evaluated demographics, clinical intervention, and Ames deformity driver types. Outcome Measures: Distribution of patients groups according to the Ames deformity descriptors and alignment modifiers pre- and 1 year post-operatively. Health-related quality of life (HRQL) measures: Neck Disability Index (NDI), EuroQol-5, modified Japanese Orthopaedic Association (mJOA). Minimum clinically important difference (MCID) for HRQL measures were defined based on published values. Patients were evaluated for improvement and meeting MCID for mJOA, NDI, and EQ5D.

Presentation #39

Results: The 73 patients were categorized as: C=41 (56.2%), CT=18 (24.7%), T=9 (12.3%), S=5 (6.8%). By Ames modifier improvement at 1Y, 13 (17.8%) improved in mJOA score, 26 (35.6%) in cSVA grade, 19 (26.0%) in Horiz, and 15 (20.5%) in TS-CL (Figure 1). The distribution of patients without severe modifier grades at 1Y across all Ames descriptors were as follows: 100% cSVA, 27.4% TS-CL, 67.1% Horiz, 69.9% mJOA. At 1Y the highest mJOA modifier grade differed across types (C=26.3%, CT=15.4%, T=0.0%, S=0.0%, p=0.003). Higher PT was observed in patients with high (1+2) cSVA grades (58.3% vs. 28.0%, p=0.013) and high (2+3) mJOA (64.0% vs. 39.6%, p=0.041) scores at baseline. 1Y post-operatively, only S deformities differed in cSVA grade distribution (0=20.0%, 1=80.0%, 2=0.0%, p=0.048) and severe myelopathy (mJOA=3) prevalence differed between Ames-ACD deformity descriptors (C=26.3%, CT=15.4%, T=0.0%, S=0.0%, p=0.033). Improvement in the mJOA modifier correlated with reaching 1Y NDI MCID in the overall cohort (r=0.354, p=0.002). For type C, cSVA improvement correlated with reaching NDI MCID at 1Y (r=0.387, p=0.016). The number of Ames modifiers a patient improved in from baseline to 1Y correlated to reaching 1Y mJOA MCID (r=0.344, p=0.003). The number of Ames modifier improvements also correlated with reaching an increasing number of MCIDs for mJOA, NDI, and EQ-5D (r=0.272, p=0.020).

Conclusions: Ames ACD classification can effectively describe cervical deformity patients' alignment and outcomes at 1Y. Improvement in Ames modifier grades correlate to 1 year outcomes and alignment correction.

See Disclosure Index pages 41–95.

Presentation #40

Increased Signal Intensity of the Spinal Cord on T2-Weighted Magnetic Resonance Images and Correlation with Cervical Sagittal Alignment and the Severity of Spinal Cord Compression

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Introduction: Few studies have investigated the relationship between high signal intensity (SI) of the spinal cord on T2-weighted magnetic resonance images (T2W MRI) and cervical sagittal alignment. This study aimed to evaluate the correlation between cervical sagittal alignment, the severity of spinal cord compression and increased signal intensity (ISI) to identify the risk factors for the presence of high SI.

Materials / Methods: From June 2015 to March 2017, 124 patients (average age: 55.4 years, range, 36-80 years) with cervical spondylotic myelopathy (CSM) undergoing surgery in a single institution were enrolled. According to whether high SI of the spinal cord was observed on T2W MRI, patients were divided into two groups: group 1 (n=63), without high SI; group 2 (n=61), with high SI. C2-C7 angle, cervical curvature index (Ishihara), C2-C7 sagittal vertical axis (cSVA), the severity of spinal cord compression, the Japanese Orthopaedic Association (JOA) and Neck Disability Index (NDI) score were compared between the two groups. Parameters which were applied to evaluate the severity of spinal cord compression includes: 1) the ratio of sagittal diameter of spinal cord at the high SI level to that at C1 level; 2) the diameter of vertebral canal at the high SI level; 3) the cross-sectional area of spinal cord at the high SI level. Besides, for group 2, the regions of interest (ROIs) are taken by 0.05 cm^2 of the spinal cord at the level of ISI and ROIs are taken by 0.3 cm^2 of the normal spinal cord at C7-T1 disc level. Signal change ratio (SCR) was the ratio between the signal of the aforementioned two ROIs.

Results: Compared to group 1, significantly larger C2-C7 angle (cervical lordosis), smaller cSVA and higher Ishihara index were observed in group 2 ($P<0.05$). However, no significant difference was found in the severity of spinal cord compression, JOA and NDI score between the two groups ($P>0.05$). In addition, there was no obvious correlation between cervical sagittal parameters, the severity of spinal cord compression and SCR ($P>0.05$).

Conclusion: Large cervical lordosis and small cSVA may be the risk factors for high IS on T2W MRI in CSM patients. It is important to recognize these risk factors to facilitate preoperative counseling and risk stratification.

Presentation #41

Congenital Cervical Spine Stenosis in a Global Cohort of Patients with Degenerative Cervical Myelopathy: A Report Based on a MRI Diagnostic Criterion

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Introduction: Congenital Spinal Stenosis (CSS) is a known predisposing factor for Degenerative Cervical Myelopathy (DCM). However, current diagnostic criteria for CSS do not consider the size of the spinal cord, and methods to establish pre-existing CSS in patients with DCM do not presently exist. Using a global cohort of patients with DCM, MRI-based criteria were developed to diagnose pre-existing CSS and to evaluate differences between patients with and without CSS.

Materials / Methods: Study data (including 349 MRIs for quantitative analysis) were derived from two international prospective and multicenter studies collected between 2005–2011. Spinal canal and cord anteroposterior diameters were measured above and below the region of interest at non-compressed sites, and a spinal cord occupation ratio (SCOR) was calculated (Figure 1). A SCOR≥70% was used to diagnose patients with CSS. Torg-Pavlov ratios and spinal canal diameters from radiographs were correlated with SCOR. Clinical and MRI factors were compared between patients with and those without CSS using t-tests. Multiple linear regression was used to assess surgical outcome.

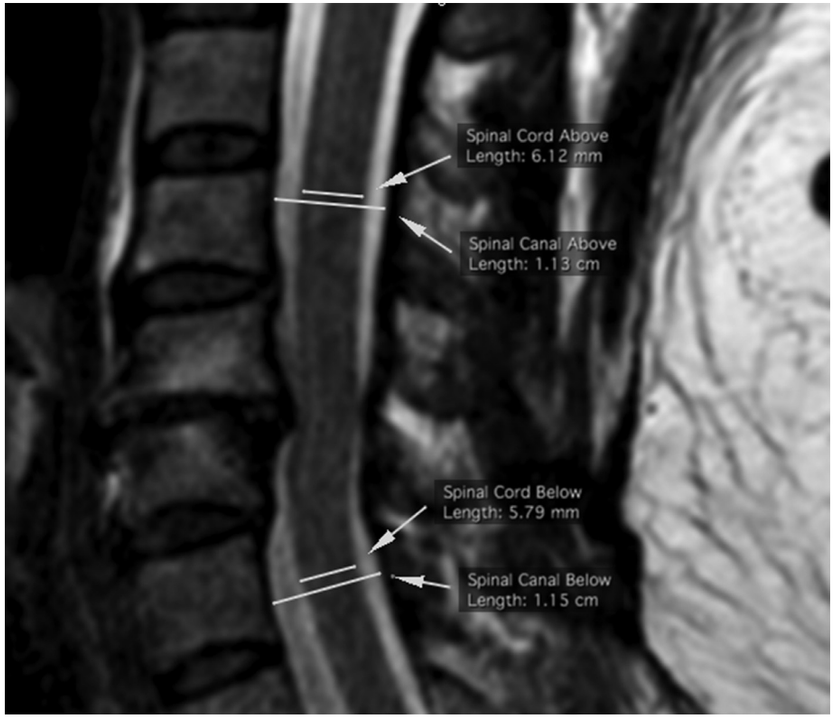
Results: Calculation of SCOR was feasible in 311 / 349 patients (89%). Twenty-six patients with CSS were identified (8.4%). Patients with CSS were younger than patients without CSS (50.8 vs. 56.3, p=0.03) and had worse baseline severity as measured by the mJOA (p=0.04), Nurick (p=0.05) and NDI (p<0.01) (Table 1). CSS patients also presented more commonly with T2 cord hyperintensity changes (p=0.09), and worse SF-36 Physical Component scores (p=0.06), though this did not reach statistical significance. SCOR was correlated with Torg-Pavlov ratio and spinal canal diameter at C3 but not C5. Patients with a SCOR≥65% were also younger but did not have differences in baseline severity.

Conclusions: CSS patients develop myelopathy at a younger age and have greater impairment and disability than other patients with DCM. Despite this, CSS patients have comparable duration of symptoms, MRI presentations, and surgical outcomes to DCM patients without CSS.

See Disclosure Index pages 41–95.

Presentation #41 (cont.)

Figure 1. A mid-sagittal T2WI MRI of a patient with DCM. SCOR is calculated by averaging the cord diameter (nearest normal adjacent levels above/below) and dividing this by the average canal diameter (nearest adjacent normal levels above/below). In this example, SCOR is 52.2% [(6.12+5.79)/(11.3+11.5)] x 100.



Presentation #41

Table 1. Baseline clinical factors and surgical outcome for DCM patients dichotomized by presence/absence of CSS.

Patient Characteristics	Congenital Stenosis *(SCOR≥70%)*	Non-congenital stenosis *(SCOR<70%)*	P-value
Baseline Clinical Factors			
Age	50.81±12.70	56.29±11.04	**0.034**
Duration of Symptoms (months)	28.65±34.12	29.68±37.61	0.85
mJOA	11.65±2.99	12.86±2.58	**0.040**
Nurick	3.50±0.86	3.14±1.03	**0.047**
SF-36 Mental	40.12±13.60	41.82±13.77	0.45
SF-36 Physical	31.74±9.54	35.58±9.74	0.061
NDI	49.60±21.11	36.02±19.90	**0.0076**
Baseline MRI Factors			
SCOR (%)	72.39±2.38	59.14±5.74	<0.0001
Torg-Pavlov Ratio at C5*	0.76±0.12	0.81±0.13	0.17
Torg-Pavlov Ratio at C3*	0.74±0.12	0.83±0.14	0.011
Canal Diameter at C5* (mm)	15.38±1.68	16.20±1.86	0.12
Canal Diameter at C3* (mm)	15.16±1.56	16.39±1.80	0.0035
T2WI signal hyperintensity	23 (88.46%)	206 (73.57%)	0.094
T1WI signal hypointensity	6 (24.00%)	61 (22.68%)	0.89
Number of cord compression levels	3.27±1.04	3.06±1.18	0.49
Source of compression–Anterior Only	10 (38.46%)	110 (38.73%)	0.98
Source of compression–Anterior -Posterior	16 (61.54%)	174 (61.27%)	0.98
Surgical Factors			
Anterior Approach	17 (65.38%)	171 (60.21%)	0.70
Number of levels operated	3.69±1.22	3.74±1.24	0.82
Surgical Outcome Measure (24-months)			
mJOA	2.91 (1.98, 3.83)	2.74 (2.47, 3.02)	0.74
Nurick	1.82 (1.28, 2.35)	1.48 (1.32, 1.64)	0.23
SF-36 Mental	6.40 (1.73, 11.08)	5.38 (3.97, 6.79)	0.68
SF-36 Physical	6.01 (2.08, 9.95)	5.40 (4.22, 6.59)	0.77
NDI	14.18 (6.87, 21.49)	11.50 (9.45, 13.54)	0.49

See Disclosure Index pages 41–95.

Presentation #42

A 20-Year Prospective Longitudinal Study on Degeneration of the Cervical Spine Using MRI in Volunteers

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Introduction: There have been very few studies investigating degenerative changes in the cervical spine during a long term. The purpose of this study was to evaluate degenerative changes of the cervical spine evolving over a period of 20 years in originally healthy volunteers, and to clarify relationship between progression of cervical degenerative changes and development of clinical symptoms.

Materials / Methods: Between 1993 and 1996, 497 originally asymptomatic volunteers underwent MRI to evaluate the prevalence of age-related changes in the cervical spine. 181 subjects (90 males and 91 females, mean age: 56.6 years) from the original cohort were recruited for this 20-year follow-up study. The mean duration between the initial and the present study was 21.6 years. Questionnaires regarding cervical spine-related symptoms were also obtained. Degenerative changes of the cervical spine were assessed by MRI using the original numerical grading systems for all intervertebral levels between C2 and T1. The evaluated parameters were 1) Decrease in signal intensity of the intervertebral disc (DSI), 2) Anterior compression of the dura and spinal cord (AC), 3) Posterior disc protrusion (PDP), 4) Disc space narrowing (DSN), and 5) Foraminal stenosis (FS). These parameters were graded blindly by a single experienced neuroradiologist. The relationship between the degenerative progression on MRI and the onset of clinical symptoms was evaluated by logistic regression analysis.

Results: Degenerative changes were seen in all the subjects over 60 years old at this study. The progression of degeneration of the cervical spine on MRI was found in 82.3% of the subjects. The degenerative progression of DSI, AC, PDP, DSN and FS was observed in 81.8%, 86.2%, 82.9%, 14.8%, and 18.7% of the subjects, respectively. The progression of the parameters of DSI, AC and PDP was found in relatively high ratio with more than 56% of the subjects in every age group, while the progression of DSN and FS had a tendency to be seen only in older subjects. Although the subjects were basically asymptomatic in the initial study, 65.2% of them in this study complained of at least one clinical symptom including neck pain, stiff shoulder, low back pain, numbness in the upper extremities and pain in the upper extremities. As a result of the statistically analysis, the degenerative progression on MRI was not related with the onset of each clinical symptom ($P>0.05$).

Presentation #42

Conclusion: This study revealed that progression of degenerative changes of the cervical spine on MRI occurred in 82.3% of the subjects during a 20-year period. The ratio of the subjects in whom the degenerative changes was seen on MRI was much larger than that of the subjects who complained of some clinical symptoms. In addition, the progression in each parameter of degeneration was not related with the development of the clinical symptoms concerning the cervical spine.

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Presentation #43

Does the Sagittal Alignment of the Cervical Spine Have an Impact on Disc Degeneration? 20-Year Follow-Up of Asymptomatic Volunteers

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Introduction: Few studies have investigated and clarified the association between sagittal alignment of the cervical spine and progression of degenerative changes of intervertebral discs.

Purpose: To longitudinally evaluate the association between sagittal alignment of the cervical spine and progression of degenerative changes of intervertebral discs and development of clinical symptoms in healthy subjects.

Materials and Methods: 90 volunteers (30 males and 60 females) who had undergone MRI and plain radiography of the cervical spine between 1994 and 1996 and had been originally asymptomatic were enrolled in this 20-year follow-up study. All subjects underwent second MRI at an average of 21.6 years after the initial study. The mean age at the time of the initial study was 35.5±13.4 years (11–65 years). The items assessed on MRI were 1) decrease in signal intensity of the intervertebral discs, 2) posterior disc protrusion, and 3) disc space narrowing from C2-3 to C7-T1. The subjects were divided into groups according to the age and sagittal alignment of the spine at baseline, i.e., subjects under or over the age of 40 years, and subjects with the lordosis type or the non-lordosis type of sagittal alignment of the cervical spine. The MRI findings and neck pain, stiff shoulders and numbness of the upper limbs at follow-up were evaluated.

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Results: During the 20-year period, progression of decrease in signal intensity of the disc, posterior disc protrusion, and disc space narrowing were observed in 84.4 %, 86.7% and 17.8% of the subjects, respectively. No significant associations were observed between sagittal alignment and progression of decrease in signal intensity, posterior disc protrusion or progression of disc space narrowing. Progression of the degenerative change at C7-T1 was significantly more frequent in the non-lordosis over 40 years group (90.9%) than those in older the lordosis group (54.2%) (p=0.032). No significant differences were observed between sagittal alignment and the onset of clinical symptom at follow-up.

Discussions and Conclusions: The present 20-year follow up study showed that non-lordotic cervical alignment may be related to progression of disc degeneration. However, cervical alignment had no impact on development of the clinical symptom in healthy subjects.

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Presentation #44

The Many Faces of the Japanese Orthopedic Association (JOA) Score: An Outcome Measure with Face Validity for Assessment of Patients with Cervical Spondylotic Myelopathy

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Introduction: Cervical spondylotic myelopathy (CSM) is the most common cause of non-traumatic spinal cord impairment and disability in the world. The so-called "JOA Score" is the most frequent outcome measure used in research and management of patients with CSM, which suggests its face validity. This systematic review comprehensively and critically evaluates the psychometric properties of the different versions ("faces") of the JOA Score.

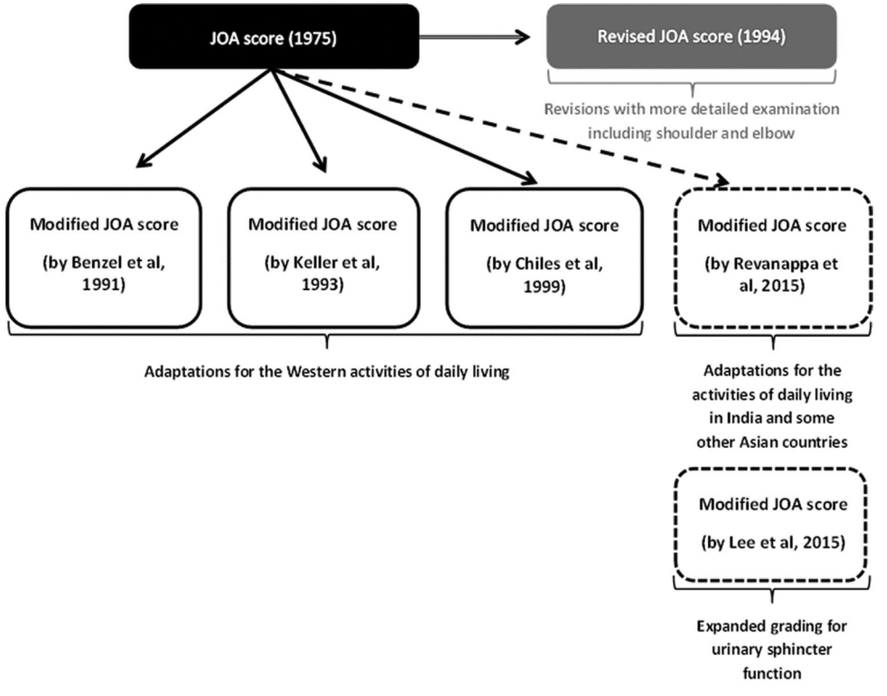
Materials / Methods: Papers, which reported the psychometric properties of the JOA Score (original, revised and modified versions), were obtained from Medline, PsycINFO, EMBASE, APC Journal Club and Cochrane databases (1975 to 2015). Additional papers were captured in a secondary search using the bibliographies from original articles and published reviews. The JOA Score were evaluated with regards to item generation and reduction, internal consistency, reliability, validity and responsiveness. This review included all versions of the JOA Score that had at least two publications reporting its psychometric properties.

Results: The primary search strategy identified 59 publications of which 9 fulfilled the inclusion and exclusion criteria. An additional 18 publications were captured in the secondary search. The key findings from the 27 studies examined indicate that: (a) the original JOA Score (1975) originated the Revised JOA Score (1994) and three modified versions with at least two publications (1991, 1993 and 1999 JOA Scores) (Figure 1); (b) the revised and modified versions of the JOA Score are markedly different from each other and, hence, each version of the JOA Score must be specifically evaluated regarding its psychometric properties prior routine use in research settings and clinical practice; (c) only the Revised JOA Score was validated using the original JOA Score; (d) while the 1975 JOA Score is the most appropriate instrument for Asian populations (especially, Japanese individuals), the 1991 JOA Score is the most appropriate version for use among Western populations based on its psychometric attributes.

Conclusions: The results of this systematic review suggest that the original, revised and modified versions of the JOA Score are substantially distinct from each other in terms of their content with culturally sensitive items and incompletely proven psychometric properties. In the literature, the commonly used term "modified JOA Score" includes substantially different versions of the JOA Score and, hence, a more specific designation should be used. While the 1975 JOA Score is the most appropriate version for assessment of Asian population (especially, those ones that eat with chopsticks), the 1991 JOA Score (modified by Benzel and colleagues) is the most suitable version for evaluation of Western population with CSM. Because of the content differences between the 1975 and 1991 JOA Scores, the effect size of each item needs to be comparatively analyzed prior to combining and generalizing the results. Further investigation of the psychometric properties of those versions of the JOA Score is recommended due to a paucity of studies describing their responsiveness.

Presentation #44

Figure 1. Different versions of the JOA Score. Dashed boxes indicate the modified versions of the JOA Score that were mentioned in only one publication and, hence, were excluded from this review.



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Presentation #45

The Effectiveness of Local Autogenous Bone Dust as an Implantation Filler in Anterior Cervical Discectomy and Fusion

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Objective: To investigate the effectiveness of using local auto bone dust obtained during Anterior cervical discectomy and fusion (ACDF) surgery as an implantation filler to improve fusion rate.

Summary of Background Data: ACDF is a common procedure in cervical spine surgery, used in the treatment of traumatic injuries, herniated discs and degenerative diseases. Materials such as autologous iliac bone grafts, allografts and demineralized bone matrixes (DBM) are widely applied as implantation fillers during ACDF. In the majority of cases, the removed bone fragments and bone dust that are generated during the operation are discarded without being used, and little is known about the prognosis of using these fragments as implants.

Methods: Medical records and radiographic data from 149 consecutive patients who received ACDF from a single experienced spine surgeon from April 2011 to December 2013 with a minimal follow-up period of 2 years were retrospectively reviewed. A plyetheretherketone (PEEK) cage and anterior metal plate were used in all patients. The patients in which removed bone fragments and bone dust to fill the cage and intervetebral space were classified as group 1, and patients whose autologous iliac bone was used as grafting material were classified as group 2. Follow-up CT was taken 1 year after surgery, and follow-up radiographs were obtained at the 6 months, 1 year, and 2 years intervals. The average value of three measurements taken by one examiner was used to determine Extra graft bone bridging (ExGBB) on CT and interspinous motion (ISM) on dynamic radiographs, respectively. In cases of multi-segmental (>2) surgery, nonunion in even one segment was classified as nonunion.

Results: Of the 149 patients, 70 patients were treated using bone fragments and bone dust

(Group 1), and a total of 105 cervical segments were treated. 79 patients and 129 cervical segments were treated using autologous iliac bone (Group 2. There was no statistically significant difference in the age and sex ratio between the two groups (P-value>0.5) (Table 1). Postoperative radiological findings of ExGBB on 1-year CT and ISM values on dynamic radiographs at 6, 12, and 24 months (Table 2) showed superior fusion rate with a statistically significant difference in group 1.

In ACDF, utilzing autologous iliac bone graft is associated with various complications such as chronic donor site pain, scarring, nerve damage, hematoma, and difficulties in early ambulation. Additionally, materials such as allograft and DBM have poorer fusion rates and higher risk of infection. Based on our findings, it is possible to reduce operating time and obtain a good fusion rate by using only bone dust obtained during surgery, while also avoiding the complications associated with iliac bone grafting.

Presentation #45

Table 1.

	Insertion (70 Patients / 105 Segments)	Non-insertion (79 Patients / 129 Segments)	P-value
Age at sugery	57.9 (35~83)	58.2 (37~82)	0.88
Male : Female	36:34	42:37	0.84

Table 2.

		Insertion Group (n=70)	Non-Insertion Group (n=79)	P-value
ExGBB(12 mo)	Fused	54	41	0.001378
	Pseudo	16	38	
ISM(6 mo)	Fused	36	43	0.005901
	Pseudo	34	36	
ISM (12 mo)	Fused	54	45	0.009222
	Pseudo	16	34	
ISM (24 mo)	Fused	58	47	0.000635
	Pseudo	12	32	

See Disclosure Index pages 41–95.

Presentation #46

Safety and Efficacy of a Novel Anterior Decompression Technique (Vertebral Body Sliding Osteotomy) for Ossification of Posterior Longitudinal Ligament of the Cervical Spine:

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Introduction: Anterior corpectomy and fusion (ACF) with or without the floating method for cervical ossification of the posterior longitudinal ligament (OPLL) is known to ensure better neurologic recovery over posterior surgery, especially in patients with OPLL with a high canal-occupying ratio or kyphosis. However, ACF is also associated with a higher incidence of surgery-related complications including cerebrospinal fluid (CSF) leak and neurologic deterioration. To avoid these complications, we have developed a novel anterior decompression technique (vertebral body sliding osteotomy; VBSO), the basic concept of which is to expand the spinal canal by anteriorly translating the involved vertebral bodies as well as ossified masses (Figure 1). The purpose of this study is to attest the efficacy and safety of VBSO by comparing its clinical and radiological outcomes with those of conventional ACF.

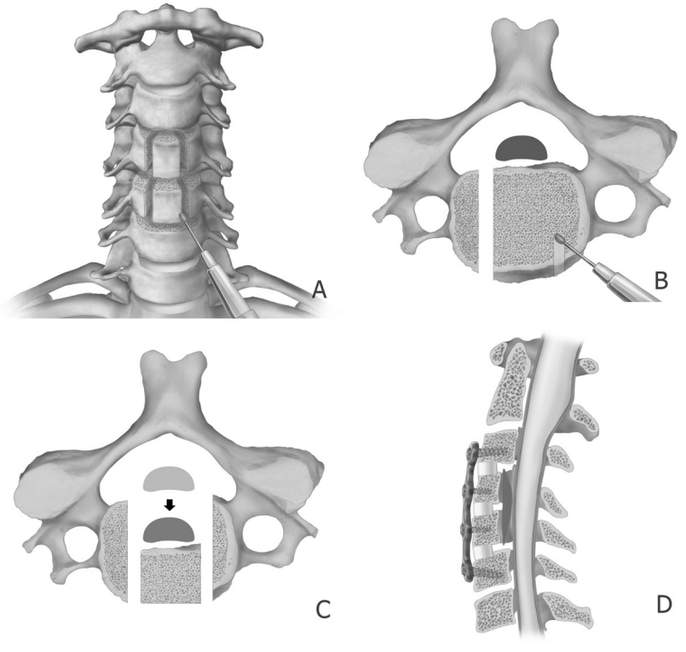
Materials / Methods: Twenty-four patients who needed anterior decompression for cervical OPLL underwent VBSO by a single surgeon. Other 38 patients underwent ACF by another single surgeon. In 16 out of 38 ACF patients, OPLL masses were partially remained by the floating method due to severe adhesion between ossified mass and dura mater. We investigated operation time, estimated blood loss (EBL), neurologic outcomes by Odom's criteria, and the incidence of surgery-related complications including CSF leak, neurologic deficit, graft migration, pseudarthrosis, and so on. Various radiographic parameters including the canal widening and C2-C7 sagittal angle were also measured.

Results: The mean operation time (130.7±21.0 min) and EBL (176.3±38.00 ml) in VBSO group were significantly smaller than those in ACF group (292.8±52.1 min and 367.9±251.1ml) ($p<0.01$). Sixteen patients in ACF group (42.1%) showed various surgery-related complications (neurologic deficit in 2 patients, CSF leak in 4, graft migration in 3, and pseudarthrosis in 7). On the contrary, there was no neurologic deterioration, no dural tear, and no graft migration except 2 pseudarthrosis (8.3%) in VBSO group. Neurologic improvements showed no significant difference between the two groups ($p>0.05$). On radiographic data, the mean canal widening was significantly greater in VBSO group than in ACF group (4.79±1.34mm vs. 3.21± 1.76mm, $p<0.05$). C2-C7 lordosis of VBSO group had been improved postoperatively much more than that of ACF group (-.9.83±7.50° vs. 3.27±4.56°).

Presentation #46

Conclusion: Our novel anterior decompression technique (VBSO) could provide similar neurologic outcomes with shorter operation time and less bleeding compared with the conventional corpectomy procedure. Since surgeons do not need to directly manipulate the OPLL mass or dissect the interspace between the OPLL and dura mater, this technique could significantly decrease the surgery-related complications. Furthermore, as VBSO is based on the multi-level discectomy and fusion technique, it would be more helpful to restore a physiologic lordosis.

Figure 1.



See Disclosure Index pages 41 – 95.

Presentation #46 (cont.)

Table 1.

	VBSO group	ACF group	P-value
Number of cases	24	38	
Age (years)	56.310.6 (36-75)	53.810.1 (35-79)	0.352
Operation time (min)	130.6621.02 (102-190)	292.7652.11 (200-385)	<0.01
Blood loss (g)	176.2537.97 (100-250)	367.89251.05 (200-1000)	<0.01
Complications (cases)	Neurologic deficits (0) CSF leakage (0) Graft migration (0) Pseudarthrosis (2)	Neurologic deficits (2) CSF leakage (4) Graft migration (3) Pseudarthrosis (7)	
Neurologic outcome (Odom's criteria)	Excellent (12) Good (8) Fair (3) Poor (1)	Excellent (11) Good (16) Fair (9) Poor (2)	>0.05
Number of surgery levels	1 level (2) 2 level (20) 3 level (1) 4 level (0)	1 level (18) 2 level (15) 3 level (3) 4 level (2)	
Preoperative canal occupying ratio (%)	5415 (25-78)	4710 (27-64)	<0.05
Postoperative canal widening (mm)	4.791.34 (2.70-8.07)	3.211.76 (0.00-6.50)	<0.05
Preoperative sagittal angle (C2-C7)(°)	-2.179.21	-9.56(°)10.36	<0.01
Postoperative sagittal angle (C2-C7)(°)	-10.789.07	-6.719.58	0.107
Preoperative sagittal angle (lesion)(°)	-1.396.72	-4.378.55	0.159
Postoperative sagittal angle (lesion)(°)	-11.657.84	-1.108.88	<0.01
Postoperative angle–preoperative angle (C2-C7)(°)	-9.837.50	3.274.56	<0.01

Presentation #47

Does Additional Uncinate Resection Increase Pseudarthrosis following Anterior Cervical Discectomy and Fusion?

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Introduction: Additional uncoforaminotomy (uncinate resection; UR) simultaneously performed with anterior cervical discectomy and fusion (ACDF) is known to facilitate better and accelerated improvement of patient's arm pain. However, the fact that this procedure might affect the fusion process by causing segmental instability is a point of concern, as uncovertebral joints are important for maintaining stability in the subaxial cervical spine. To our knowledge, no study to date has described the relationship between the fusion rate and UR with ACDF. The purpose of this study is to assess whether unilateral or bilateral UR along with ACDF for neural foramen decompression increases the risk of pseudarthrosis at long-term follow-up, and to compare the clinical outcomes between those who did and did not undergo UR.

Methods: We retrospectively reviewed 167 patients (89 men, 78 women; mean age, 58.4±10.5 years) who consecutively underwent single- or double-level ACDF and were followed up for more than 2 years. Among them, 46 patients did not undergo UR (N-UR group). In the other 121 patients, UR was performed in at least one foramen (UR group), unilaterally (U-UR group, n=89) or bilaterally (B-UR group, n=32). Demographic data, fusion rates, visual analog scale (VAS) scores for neck/arm pain, and Neck Disability Index (NDI) scores were compared between N-UR, U-UR, and B-UR groups. Additionally, the fusion rates after single- and double-level procedures were compared among the different groups. The criterion for solid fusion was interspinous distance (ISD) change of <1 mm on flexion/extension lateral X-rays magnified by ≥150%.

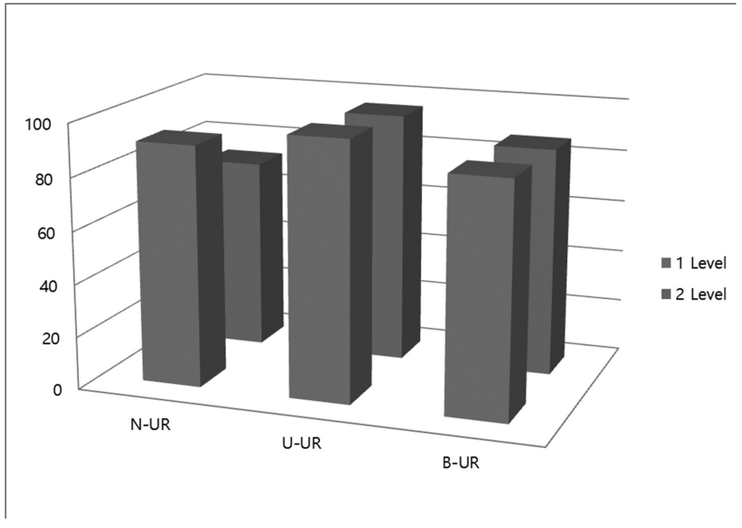
Results: There were no significant differences in gender, age, weight, height, BMI, and smoking history between the N-UR and UR groups. The fusion rates after single-level ACDF were not significantly different among the N-UR, U-UR, and B-UR groups (91.4% [32/35], 97.8% [44/45], and 88.2% [15/17]; p=0.290). Solid fusion was achieved in 72.7% (8/11) in the N-UR group, 95.5% (42/44) in the U-UR group, and 86.7% (13/15) in the B-UR group after double-level ACDF. There was no statistical difference of fusion rates among the three groups (p=0.071) (Figure 1). In logistic regression analysis, there were no statistically significant risk factors for nonunion or pseudarthrosis at 2-year follow-up. The improvement in VAS for arm pain was significantly higher in the UR group than the N-UR group at postoperative 2 weeks (4.9±2.7 vs. 2.7±2.4, p<0.001), and there was no significant difference until final follow-up (Figure 2).

Conclusion: One of the main concerns about uncoforaminotomy simultaneously performed with ACDF was that the unilateral or bilateral resection of uncinate processes might result in excessive segmental instability, which could increase the risk of pseudarthrosis following ACDF. However, in this study, unilateral or even bilateral UR did not affect the fusion rate, and enabled faster improvements in arm pain after single- or double-level ACDF for cervical radiculopathy patients. Hence, additional UR during ACDF can be applied, if necessary, without any concerns regarding nonunion.

See Disclosure Index pages 41–95.

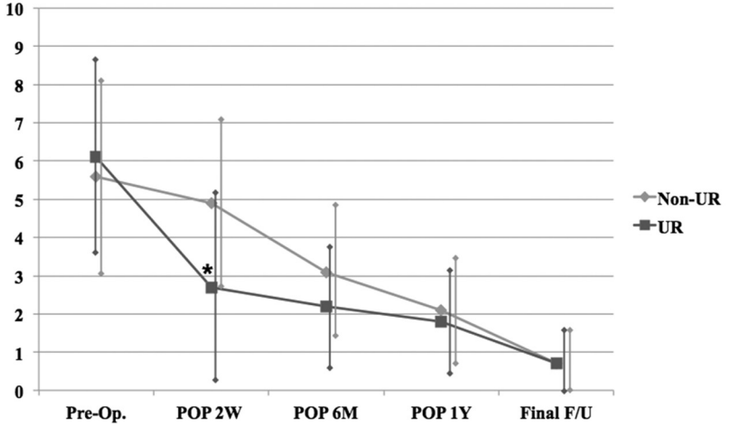
Presentation #47 (cont.)

Figure 1. Comparison of fusion rates among three groups after single- or double-level ACDF (p>0.05).



N-UR: Non Uncinate Resection
U-UR: Unilateral Uncinate Resection
B-UR, Bilateral Uncinate Resection

Figure 2. Visual analogue scale (VAS) of arm pain in the uncinate resection (UR) and non-uncinate resection (Non-UR) groups. (*p<0.05)



Presentation #48

Sulfated Glycopeptide Nanostructures Scaffold for Spinal Arthrodesis

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Introduction: Use of recombinant human BMP-2 (rhBMP-2) has decreased the rate of pseudarthrosis after spine fusion procedures. However, reported complications have provoked considerable interest in the development of novel scaffolds, such as self-assembling nanofiber peptide amphiphiles (PA), that allow for reduced concentrations of rhBMP-2 without compromising its therapeutic effects. Our lab has shown that PAs synthesized with a trisulfated monosaccharide (3,4,6S-GlcNAc PA or TriS-GPA) mimic natural glycosaminoglycans (GAGs) such as heparin and heparan sulfate that can bind to BMP-2. The aim of this study was to evaluate the efficacy of the TriS-GPA nanofiber scaffold in promoting spinal arthrodesis in a rat posterolateral fusion (PLF) model. We hypothesized that the TriS-GPA scaffold would increase lumbar fusion rates relative to non-sulfated GPA, non-glycosylated PA and ACS scaffold with equivalently-loaded rhBMP-2.

Materials / Methods: Female Sprague-Dawley rats underwent a L4-L5 PLF procedure with placement of one of four absorbable collagen sponge (ACS) scaffolds preloaded with 0.1 μg of rhBMP: (1) ACS+TriS-GPA, (2) ACS+GlcNAcPA (non-sulfated GPA), (3) ACS+PA (non-glycosylated PA) or (4) ACS alone (negative control). An animal group treated with ACS scaffolds pre-loaded with 10 μg rhBMP-2 (per animal) was used as a positive control. At eight weeks postsurgery, spines were evaluated for successful fusion and new bone formation via radiographs, manual palpation, microCT imaging, and histologic analysis. Fusion scores were determined by blinded palpation using an established scoring system: 0=no bridging bone, 1=unilateral bridging, and 2=bilateral bridging bone. Spines with an average score of ≥1.0 were considered successfully fused.

See Disclosure Index pages 41–95.

Presentation #48 (cont.)

Results: TriS-GPA elicited significantly higher fusion scores relative to ACS, control (non-sulfated) GPA, and non-glycosylated PA ($p<0.001$; Figure 1A) with equivalently preloaded 100 ng rhBMP-2. Animals treated with TriS-GPA preloaded with 100 ng rhBMP-2 elicited a fusion rate of 100%, which was also significantly higher than animals treated with ACS, non-glycosylated PA, and non-sulfated GPA (0%, 42%, 8%, respectively; $p<0.004$; Figure 1B). TriS-GPA treatment demonstrated statistically equivalent fusion scores and rates to the positive control group. MicroCT analysis highlighted significantly higher bone volume in the group treated with TriS-GPA compared to all other groups except the positive control (Figure 2). Histology demonstrated representative L4-L5 fusion in each group.

Conclusion: Our results suggest that PAs synthesized with a trisulfated monosaccharide (TriS-GPA) can effectively serve to bind and sequester BMP-2 at the site of bone formation. TriS-GPA on an ACS carrier was capable of eliciting lumbar spine fusion while utilizing a 100-fold lower dose of rhBMP-2 than the established positive control model. Reducing the amount of rhBMP-2 necessary for successful spine fusion through the development of novel carriers could decrease the rate of side effects observed with supraphysiologic dosing of rhBMP-2 currently used.

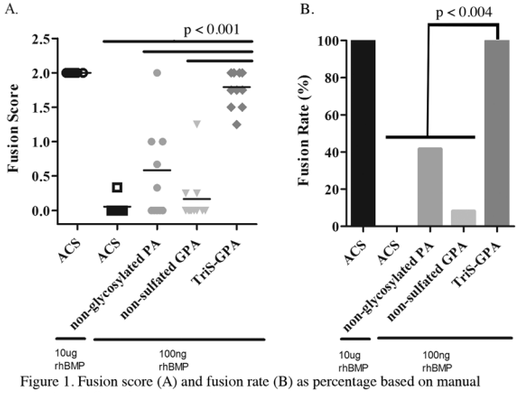

Figure 1. Fusion score (A) and fusion rate (B) as percentage based on manual palpation at 8 weeks post-operative.

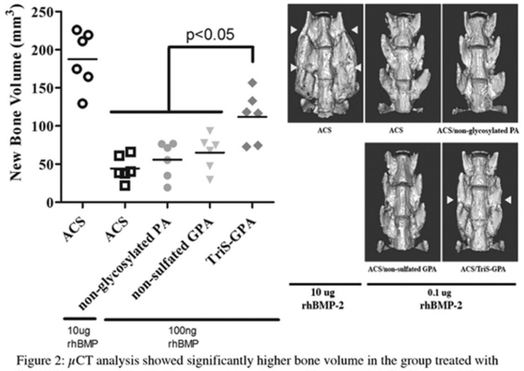

Figure 2: μCT analysis showed significantly higher bone volume in the group treated with TriS-GPA compared to all other groups except the positive control (left). Representative volume rendering from μCT. Yellow arrows indicate new bridging bone (right).

- **The FDA has not cleared the drug and / or medical device for the use described (i.e., the drug and / or medical device noted with an • is being discussed for an "off label" use). See inside back cover for information.**

Presentation #49

Surgical Site Drains and Postoperative Complications Following Posterior Cervical Spine Surgery: A Multicenter Retrospective Study

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Background: Use of surgical site drains following posterior cervical spine surgery is variable, and its impact on outcomes remains controversial. Studies of drain use in the lumbar spine suggest drains are not associated with reduction of reoperations for wound infection or hematoma. There is a paucity of studies examining this relationship in the cervical spine where hematomas and infections can have severe consequences.

Methods: This study is a multicenter retrospective review of 1,886 consecutive patients undergoing posterior cervical decompression with instrumentation at four tertiary care centers treated between 2004–2016. Demographic and perioperative data were analyzed for associations with drain placement and return to the operating room. Multivariable logistic regression was used to identify predictors of drain placement as well as the association between drain placement and reoperation for surgical site infection or hematoma.

Results: Of 1,886 patients, 1,232 (65.3%) had a drain placed. Elective surgery (OR 2.01, $P<0.001$), anterior with posterior approach (OR 0.44, $P=0.001$), number of operative levels (OR 1.34, $P<0.001$), and history of prior cervical spine surgery (OR 0.65, $P<0.001$) were significant predictors of drain placement. Rates of reoperation for any surgical site complication were not different between the drain and no-drain groups (4.2% vs. 4.3%, $P=0.95$). After adjusting for the number of operative levels, patients with drains had significantly lower odds of returning to the operating room for surgical site infection (OR 0.51, $P=0.028$) but not for hematoma (OR 1.21, $P=0.78$).

Conclusions: This large study characterizes current practice patterns in the utilization of surgical site drains during posterior cervical decompression and instrumentation. Patients with drains placed did not have lower odds of returning to the operating room for postoperative hematoma. However, our data suggests patients with drains are less likely to return to the operating room for surgical site infection.

See Disclosure Index pages 41–95.

Presentation #50

Cost-Utility Analysis of Cervical Deformity Surgeries Using One-Year Outcome

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Introduction: With advances in understanding of sagittal balance, osteotomy techniques, and improved patient safety, realignment procedures for correction of cervical spinal deformity has become more common. Complex correction of cervical deformity employs a large amount of resources, requiring personnel for many hours, and includes high cost, with many implants, devices, and medications used for a single patient. Given the important recent advances in surgical intervention for cervical deformity, it is necessary to measure its benefit in terms of resources used. Cost-utility analyses are increasingly popular with decision makers' increasing emphasis on patient-centric, and value per dollar data. Cost-utility studies compare subjective patient-defined description of utility, such as Quality-Adjusted Life Year (QALY), to cost. Medicare reimbursements are the most commonly employed cost-proxy in spine, allowing researchers to pinpoint the value of the actual procedures as determined by national consensus. The goal of this study is to define cost-utility of surgical cervical deformity correction in terms of reimbursement per QALY. This ratio will be an important step in evaluating cervical deformity surgeries, and it is the hope of the authors that others may compare these data to alternative interventions.

Methods: Patients undergoing surgical correction for cervical deformity were consecutively enrolled in a multi-center database undergoing. Cervical deformity was defined as one of the following: kyphosis (C2-7 Cobb angle >10°), cervical scoliosis (coronal Cobb angle >10°), positive cervical sagittal imbalance (C2-C7 sagittal vertical axis >4cm or T1-C6 >10 °), or horizontal gaze impairment (chin-brow vertical angle >25°). Quality adjusted life years were calculated by both EuroQol 5D (EQ5D) quality of life and NDI mapped to SF6D index. Costs were assigned using Medicare 1-year average reimbursement for: 9+ level posterior fusions (PF), 4–8 level PF, 4–8 level PF with anterior fusion (AF), 2-3 level PF with AF, 4–8 level AF, and 4–8 level posterior refusion. Reoperations and deaths were added to cost and subtracted from utility respectively. QALY per dollar spent was calculated using standardized methodology at 1-year time point and subsequent time-points relying on maintenance of 1-year utility.

Presentation #50

Results: 84 patients (average age: 61.2 years, 60% female, BMI: 30.1) were analyzed after cervical deformity correction (average levels fused: 7.2, osteotomy used: 50%. Costs associated with index procedures were: 9+ level PF ($76,617), 4–8 level PF ($40,596), 4–8 level PF with AF ($67,098), 4–8 level AF ($31,392) and 4–8 level posterior refusion ($35,371). Average 1-year reimbursement of surgery was $55,097 at 1-year with 8 revisions and 3 deaths accounted for. Cost per QALY gained to 1-year follow-up was $646,958 by eq5d and $477,316 by NDI SF6D.

Conclusions: Medicare 1-year average reimbursement compared to 1-year quality adjusted life year described $646,958 by eq5d and $477,316 by NDI SF6D. If 1-year benefit is sustained, upper threshold of cost-effectiveness is reached 3–4.5 years after intervention. Longer follow-up is needed for a more definitive cost-analysis, but this data is an important first step in justifying cost-utility ratio for cervical deformity correction.

See Disclosure Index pages 41–95.

Presentation #51

Preparing for Bundled Payments in Cervical Spine Surgery: Do We Understand the Influence of Patient, Hospital, and Procedural Factors on the Cost and Length of Stay?

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Introduction: Successful bundled payment agreements require management of financial risk. Participating institutions must understand potential cost input before entering into these episode of care payment contracts. Elective anterior cervical discectomy and fusion (ACDF) has become a popular target for early bundles given its frequency and predictability. Thus the purpose of this study was to examine the influence of patient, hospital, and procedural characteristics on hospital costs and length of stay (LOS).

Materials / Methods: We queried the 2011 National Inpatient Sample (NIS) dataset for patients between 20 and 95 undergoing elective ACDF. International Classification of Disease 9th Revision (ICD-9) code, 81.02, was used to identify cases of ACDF. Pediatric, infectious, and non-elective cases were excluded. Using generalized linear models, we estimated the impact of each patient, hospital, and procedures characteristic on hospitalization costs and the length of stay (LOS). Procedural characteristics were identified by ICD-9 codes and treated as independent variables within the models.

Results: In 2011, 134,087 patients underwent ACDF in the United States. Of these 31.6% had no comorbidities while 18.7% had three or more. The most common conditions included hypertension (44.4%), renal disease (15.9%), and depression (14.7%). Mean hospital costs and LOS after ACDF were $18,622 and mean hospital LOS was 1.7 days. With incremental comorbidities, both hospital costs and LOS increased. Both marginal costs and LOS rose with inpatient death (+$17,180, +2.0 days), patients with recent weight loss (+$8,351, +1.2 days), electrolyte disturbances (+$4,175 +0.8 days), and pulmonary-circulatory disorders (+$4,065, +0.6 days). Costs and LOS were highest with the following procedures: addition of a posterior fusion / instrumentation ($+11,189, +0.9 days), revision anterior surgery (+$3,465, +0.3 days), and fusion of >3 levels (+$3,251, +0.2 days). Patients treated in the West had the highest costs (+$9,300, +0.3 days). All p values were <0.001.

Conclusion: Hospital costs and LOS after ACDF rise with increasing patient comorbidities. Stakeholders entering into bundled payments should be aware of that certain patient, hospital, and procedure characteristics are associated with greater consumption of resources.

Presentation #52

What are the Costs of Cervical Radiculopathy in the Year Prior to Anterior Cervical Discectomy and Fusion?

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Introduction: The majority of patients experiencing cervical radiculopathy (CRadic) have symptom resolution within 3 months, but for those failing non-operative (non-op) management, the gold standard treatment is Anterior Cervical Discectomy and Fusion (ACDF). While the costs of operative treatment have been previously described, less is known about the costs of CRadic leading up to ACDF. Thus we sought to determine the costs associated with non-op management of CRadic in the year prior to ACDF.

Materials / Methods: The Humana database was reviewed from 2007 to 2015 for all patients undergoing an ACDF for cervical radiculopathy. Only patients with claims records of at least 1 year prior to ACDF were considered. Myelopathy, trauma, tumor patients were excluded. Costs for diagnosistic tests (x-rays, CT, MRI) and non-op management (injections, physical therapy, braces, opioids, non-steroidal anti-inflammatories, and tramadol related to CRadic in the year prior to ACDF were calculated. Cost was defined as reimbursement paid by the insurance provider. All costs, except hospital / facility fees, were analyzed relative to the overall costs for CRadic.

Results: In total 12,514 CRadic patients spent $14,308,777 on non-operative diagnostic and treatment modalities during the year prior to ACDF ($1,143 / patient) (Table 1). All of the patients underwent at least one diagnosistic test, and 73.3% underwent non-op treatment. Diagnosistic imaging comprised 47.7% of the total costs and standard non-operative treatments, 28.9%. MR imaging had the highest total relative spend of 28.4%, and the highest number of patients completing 86.6% ($p<0.05$). A relatively low number of people completed PT, 17.8%, with a relative total cost of 6.1%. Surgical treatment (ACDF) however, was dramatically higher per patient at an average of $18,142 for the hospital stay, and $4,457 in professional payments.

Conclusion: In the year prior to ACDF, nearly half of the non-inpatient costs associated with CRadic are from diagnosistic modalities. A much smaller amount of the total spend was from non-operative treatments. With injections removed, only 12.8% of the non-operative spend was on treatments. As institutions begin entering into bundled payments for cervical spine disease, understanding condition specific costs is a critical first step.

See Disclosure Index pages 41–95.

Presentation #52 (cont.)

Table 1. Breakdown of Costs for Diagnosis and Treatment of Cervical Radiculopath

	Number of Patients (n=12514)	% total patients	Total Costs for Treatment ($14,308,777)	% total costs	Cost of Intervention per patient
Diagnostic Tests	**Any**	**100.00%**		47.67%	
X-Ray	7199	57.53%	$544,053	2.91%	$76
CT	4404	35.19%	$2,667,920	14.28%	$606
MRI	10831	86.55%	$5,300,149	28.36%	$489
EMG NCS	847	6.77%	$395,672	2.12%	$467
Treatments	**Any**	**73.27%**			
Physical Therapy	2228	17.80%	$1,135,368	6.08%	$510
Chiropractic	709	5.67%	$137,051	0.73%	$193
Bracing	1595	12.75%	$250,108	1.34%	$157
Injections	3051	24.38%	$3,015,705	16.14%	$988
Gabapentin	2275	18.18%	$211,353	1.13%	$93
Muscle relax	421	3.36%	$12,245	0.07%	$29
Narc	5085	40.63%	$512,337	2.74%	$101
Tramadol	1315	10.51%	$19,719	0.11%	$15
NSAID	2300	18.38%	$107,097	0.57%	$47

Presentation #53

WITHDRAWN

Presentation #54

The Medico-Legal Landscape of Spine Surgery: How Do Surgeons Fare?

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Introduction: The current medical malpractice environment heavily affects physicians of all specialties. Orthopaedic surgeons and neurosurgeons, however, have borne a disproportionately higher number of lawsuits due to the severity of potential complications in spine surgery. This is especially applicable in cervical spine surgery given the delicate technical nature inherent to the anatomy. Due to the limited and confidential nature of most legal data, scarce literature is available to physicians about litigation in spine surgery. In order to optimally compensate patients while also protecting physicians, further understanding of the medico-legal landscape is needed for high-risk procedures such as spine surgery.

Materials / Methods: All malpractice cases involving spine surgery available to public query between the years of 2010 to 2014 were included in our study. WestlawNext was used to analyze spine surgery malpractice cases at the state and federal level. WestlawNext is a subscription based, legal search engine that contains publicly available federal and state court records. All monetary values were inflation adjusted for 2016. Cases were stratified based on the anatomic location of surgery (cervical, thoracic, lumbar). One hundred three (103) malpractice cases were analyzed by case descriptors including state, lawsuit outcome, type of surgery, length of case, and plaintiff's complaint. Claims were categorized as either intraoperative complaints or preoperative complaints.

Results: Rulings in favor of the defendant (surgeon) were noted in 75% (77/103) of the cases. Lack of informed consent was cited in 34% of cases. For the 26 cases won by the plaintiff, the average amount in settlement was $2,384,775 vs. $3,945,456 in cases brought before a jury. Cases involving consent averaged a compensation of $2,029,884 while cases involving only intraoperative complaints averaged a compensation of $3,667,530. Technical / judgment complaints were the most common claims in the overall cohort; this remained consistent across anatomic groups (59% of cervical cases, 63% of thoracic cases, and 66% of lumbar cases). In cervical cases however we see nerve injury involved in 48% of cases, while only 34% of cases in lumbar cases. A significant correlation was seen between increased compensation for plaintiffs and cases involving nerve injury (p=0.005). Conversely, consent was disproportionately more involved in lumbar cases at 41%, vs. 22% of cervical cases. Wrong level surgery may be associated with lower plaintiff compensation (p=0.055). The length of cases resulting in defense verdicts averaged 5.51 years, which was significantly longer than the 4.34 years average length of settlements or verdicts in favor of plaintiffs (p=0.016).

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Presentation #54

Conclusions: Spine surgeons successfully defended themselves in 75% of lawsuits, although the cases won by physicians lingered significantly longer than those settled. Better understanding of these cases may help surgeons to minimize litigation. Spine surgeons are particularly vulnerable to litigation given the nature of the field. More than 1/3 of cases involved a claim of insufficient informed consent. Surgeons can protect themselves and optimize care of patients through clear and documented patient communication, education, and intraoperative vigilance to avoid preventable complications.

See Disclosure Index pages 41 – 95.

Presentation #55

Physical Performance Decreases in the Early Stage of Cervical Myelopathy Before the Myelopathic Signs Appear: The Wakayama Spine Study

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Introduction: We previously revealed a prevalence rate of 24.4% for cervical cord compression (CCC) in a population-based MRI study. However, the natural course of CCC remains unknown. The purpose of this study was to investigate the occurrence of cervical myelopathy (CM) among CCC cases and reveal the predictive factor of CM.

Materials / Methods: The present study is a part of "The Wakayama Spine Study", which was a large-scale population-based MRI cohort study. At baseline survey, we diagnosed 238 subjects as having CCC. Twenty-seven participants diagnosed as having CM at baseline were excluded from this study. We followed up for more than 4 years 211 subjects. Among the subjects, 142 (61 men and 81 women; mean age, 68.9 years) participated in the second survey (follow-up rate, 67.3%). De novo CM was defined clinically as the presence of myelopathic signs (e.g., the Hoffmann reflex, hyperreflexia of the patellar tendon, and the Babinski reflex), usually accompanied by bilateral sensory deficits or sensory level, and bowel / bladder symptoms in the second survey. For the participants with myelopathic signs, CCC was the essential condition for the diagnosis of CM. To evaluate physical performance, the following tests were conducted at baseline and the second survey: a 10-s grip and release test (GRT), grip strength, 6-m walking time at a usual and a maximal pace, step length at a usual and a maximal pace, chair-stand time (CST), and one-leg standing (OLS) time.

Results: Among the 142 participants, nine (mean age, 68.8 years; incidence rate, 6.3%) were newly diagnosed as having CM in the second survey. The CST (P=0.0002), 6-m walking time at a usual (P=0.0032) and a maximal pace (P=0.0019), and step length at a maximal pace (P=0.0063) significantly decreased in the de novo CM participants at baseline, but not grip strength (P=0.29), OLS (P=0.34), and GRT (P=0.41). Multivariate analysis revealed that CST (+1 s; odds ratio [OR], 1.22; 95% confidence interval [CI], 1.06–1.46; P=0.019), 6-m walking time at a usual pace (+1 s; OR, 1.56; 95% CI, 1.09–2.30; P=0.016), 6-m walking time at a maximal pace (+1 s; OR, 1.75; 95% CI, 1.13–2.81; P=0.012), and step length at a maximal pace (+1 cm; OR, 0.93; 95% CI, 0.87–0.99; P=0.025) were significant predictive factors of de novo CM.

Conclusion: In this study, we first clarified the incidence rate of CM in subjects with CCC and the predictive factor of de novo CM. CST, 6-m walking time at a usual and a maximal pace, and step length at a maximal pace can be useful diagnostic tools for the early stages of CM. This indicates that CCC influences physical performance, especially of the lower limbs, from an early stage of CM when other physical signs are subclinical.

Presentation #56

Enhancement of Neurological Recovery and Attenuation of Inflammation in Cervical Spondylotic Myelopathy with Intravenous IgG

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Introduction: Cervical spondylotic myelopathy (CSM), the most common cause of spinal cord impairment worldwide, results from progressive spinal cord compression by congenital or degenerative changes in the cervical spine. However, the vascular and inflammatory changes in the spinal cord which arise due to CSM or which occur in the setting of surgical decompression remain incompletely understood In this study, we postulated that CSM results in vascular disruption and inflammation, and that intravenous-administration of the FDA approved immunomodulatory drug IgG (IVIG) can effectively reduce these pathological changes and result in improved behavioural recovery. Further, we hypothesized that use of IVIG can enhance recovery following decompression surgery for CSM (DeCSM) by attenuating the perioperative inflammatory changes in the cord.

Methods: We used a validated novel mouse model of CSM where a biomaterial is inserted underneath the C5-6 lamina for 6-weeks resulting in progressive calcification and compression of the spinal cord. In the surgical decompression cohort (DeCSM), the biomaterial was removed 6-weeks post-CSM. A total of 50 mice were divided into 5 groups (N=10 / group): sham, CSM with saline, CSM with IVIG, DeCSM with saline, DeCSM with IVIG. IVIG-infusions began at the first sign of CSM symptoms (3 weeks following biomaterial insertion) and persisted for 6 weeks. The groups receiving IVIG were given weekly doses of IgG (0.4g/kg) via the tail vein. For vehicle control, volume and time-matched saline was used. Neurobehavioral outcomes were measured using the CatWalk system and rotarod test. We also investigated in detail the inflammatory response and blood vessel changes by immunohistochemistry, western blotting and Power Doppler readouts. These data were complemented by immunohistochemistry **results from human post-mortem spinal cord tissue from individuals with CSM.**

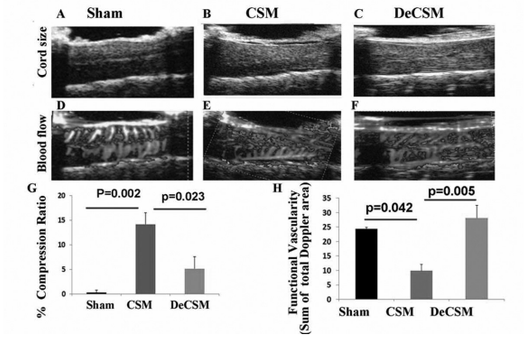
Results: The murine model of CSM was associated with neuronal loss, inflammation, reduced spinal cord blood flow, and increased blood vessel density. These changes mirrored similar effects in human tissue. In the mice with CSM that underwent surgical decompression (DeCSM) blood vessel density and spinal cord size was restored, however the inflammatory response remained pronounced. IVIG-infusion in CSM and DeCSM animals resulted in a significant decrease in inflammation, an increase in basement membrane Laminin expression in blood vessels, which was accompanied by an improvement in spinal cord blood flow and improved behavioural recovery as evidenced by changes in forelimb swing speed, stride length and speed compared with saline controls.

Conclusion: Taken together our results provide evidence that IVIG may attenuate the systemic immune response in CSM and also the localized immune response following surgical intervention by reducing the ischemia reperfusion injury (IRI) observed following surgery. As such use of IVIG represents a potential adjunctive non-surgical intervention treatment strategy for CSM in conjunction with decompression surgery.

See Disclosure Index pages 41–95.

Presentation #56 (cont.)

Figure 1.



There is a significant increase in the percentage of spinal cord compression ratio in CSM (B and G) when compared to shame controls (A and G). Cord compression also reduced the spinal cord % vascularity (blood flow) to 9.8% (E and H) when compared to normal 24.3% (D and H) by power Doppler signalling. After decompression at 7 weeks there was a significantly reduced spinal cord compression ratio (C and G) and increased blood flow (F and H) when compared to CSM.

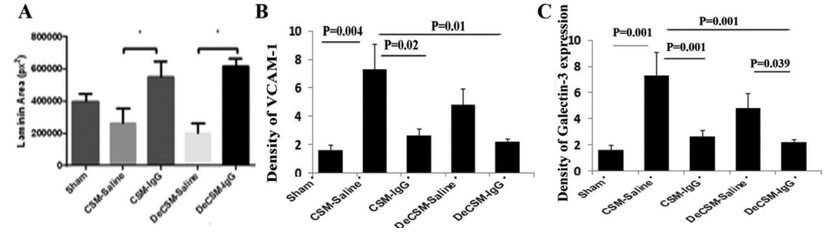
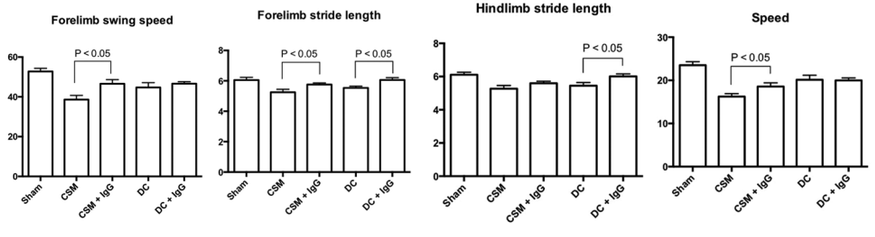


Figure 2.



IVIG-infusion of 6-weeks CSM and DeCSM animals resulted in a significantly increase in basement membrane Laminin expression (A) of the blood vessel and decrease in inflammation (B and C) by immunohistochemistry and Western blot analysis of the immune response following CSM.

Determination of neurobehavioral outcomes following treatment of CSM mice with IVIG alone or in combination with decompression surgery by CatWalk analysis.

Presentation #57

Neural Stem Cell Mediated Recovery is Enhanced by Chondroitinase ABC Pretreatment in Chronic Cervical Spinal Cord Injury

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Introduction: Traumatic spinal cord injury (SCI) interrupts sensory and motor tracts resulting in severe, lifelong functional impairments for patients. Despite the need, one of the greatest challenges in developing an effective therapy for chronic SCI has been the inhibitory microenvironment of the injured spinal cord. Aspects of chronic spinal cord injury (SCI) environment such as formation of glial scars and Chondroitin sulfate proteoglycans (CSPGs) act as barrier to repair and regeneration. To address this environment Chondroitinase ABC (ChABC) is used to breakdown CSPGs and facilitate a permissive environment for the transplantation neural stem cells (NSCs) derived from induced pluripotent stem (iPS) cell in cervical SCI mouse model.

Materials and Methods: Six weeks after cervical SCI we had continuously injected ChABC into subarachnoid space for a week using an osmotic pump. After which NSCs derived from iPS cells (iPSC-NSC) are intraspinally transplanted rostral and caudal to the injury site. We examined neurobehavioral tests in BMS score, grip strength meter, inclining test and CatWalk analysis. In addition 8 weeks after transplantation, we performed histological and electrophysiological analysis.

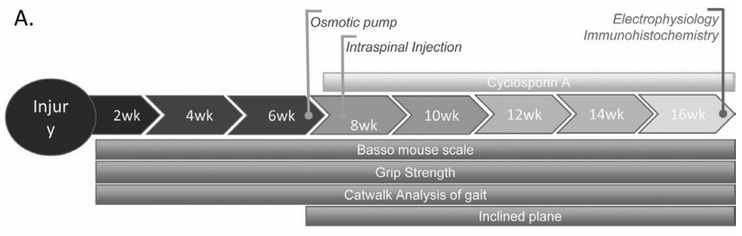
Results: The administration of ChABC reduces elements of the glial scar and result in greater iPSC-NSC survival and engraftment. Figure 1 is the Schematic representation of experimental design. The combinatory treatment of iPSC-NSCs and ChABC significantly promoted forelimbs neurobehavioral recovery in grip strength meter and CatWalk analysis. The iPSC-NSCs integrate into the chronically injured spinal cord (Figure 2) and differentiated into neurons, astrocyte and oligodendrocyte without evidence of tumorigenesis. There is evidence that exogenous cells that differentiate to oligodendrocytes contributing for remyelination, while other exogenous cells become motor neurons. These motor neuron make new functional synaptic connections between host and grafted neurons via glutamate and acetylcholine receptors in patch clump analysis and electron microscope.

See Disclosure Index pages 41–95.

Presentation #57 (cont.)

Conclusion: By altering the glial scar in cervical SCI prior to delivering iPSC-NSC, we demonstrate that even the chronic injury environment remained therapeutic relevant for iPSC-based treatments. This is the first report that we obtained the functional recovery in chronic SCI with solid scientific evidence. This results suggested that we can expect a good results in clinical trials in the patients with chronic SCI.

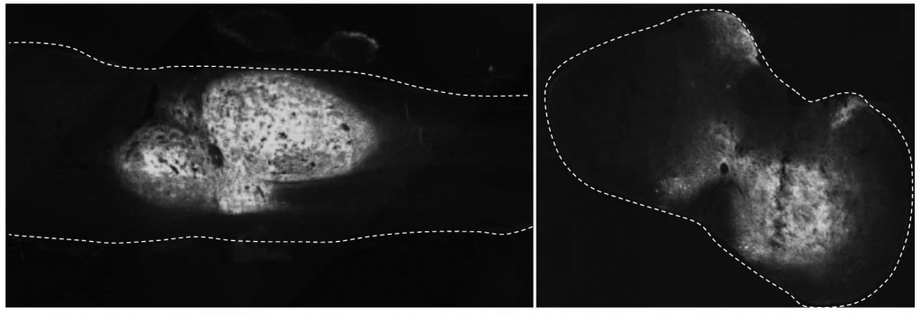
Figure 1. Schematic representation of experimental design.



B.

Group	n=	Injury	Osmotic pump	Intraspinal injection
1) Control	15	C6/C7 SCI	aCSF	PBS
2) ChABC Only	15	C6/C7 SCI	ChABC	PBS
3) iPSC-NSC Only	15	C6/C7 SCI	aCSF	iPSC-NSC
4) ChABC + iPSC-NSC	15	C6/C7 SCI	ChABC	iPSC-NSC
5) Sham	15	Laminectomy Only	n/a	n/a

Figure 2. Reprehensive longitudinal and cross sectional images of GFP+iPSCs-NSCs in spinal tissue 16 weeks post-SCI.



Presentation #58

Does Spinal Cord Compression Status Affect Pre- and Post-Operative Neurological Conditions?

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Introduction: Development of Magnetic Resonance Imaging (MRI) technology can provide precise information about the spinal cord condition in 3 dimensional views. On the other hand, we find a wide variety of neurological symptoms of a myelopathy patient regardless of MRI findings. Then this study aimed to investigate how the spinal cord compression status affected pre- and post-operative neurological conditions in patients with cervical compression myelopathy.

Methods: This study involved a total of 386 patients (270 men, 116 women) who were diagnosed with cervical compression myelopathy and underwent surgical treatments in our hospital with at least one year follow-up. The mean age at surgery was 63.1 (range, 23 to 91) years and the surgical method adopted was anterior decompression fusion (ADF) in 216 patients and laminoplasty (LAP) in 170. Neurological status was evaluated by the JOA score, performance tests (GRT: the finger grip and release test for upper extremity and TST: the triangle step test for lower extremity), and quantitative sensory scores. Then the estimated damage on the spinal cord in cross-sectional area was classified into five types according to each patient's neurological symptoms as follows: Type I (Anterior lesion), Type II (Central lesion), Type III (Posterior lesion), Type IV (Unilateral lesion) and Type V (Transverse lesion). In addition, the spinal cord compression patters on preoperative MRI were analyzed 3 dimensionally at the most compressed level and graded as Non-Entrapment: compressed but not entrapped, Partial Entrapment Minor: entrapped from both sides but less than 50% of the cord width in cross–sectional area, Partial Entrapment Major: 50–75% entrapment, and Total Entrapment: 75–100% entrapment. This study statistically analyzed how the cord compression status affected pre- and post-operative neurological conditions.

Results: All but two patients were successfully classified into five types of cervical myelopathy according to our system. Type I (Anterior lesion) patients demonstrated Non-Entrapment lesion at the responsible level in 43%, and the rate was significantly higher than the other types. On the contrary, 52% of Type V (Transverse lesion) and 45% of Type III (Posterior lesion) patients showed Total Entrapment lesion (Figure 1). As to postoperative neurological improvement, the JOA score recovery rate was highest in the patients with Non-Entrapment lesion (66.5%) and was lowest with Total Entrapment lesion (49.6%), but the differences were not statistically significant in total (Figure 2). Surgical method did not affect neurological improvement in Type III or Type V patients, however, Type I patients with Non-Entrapment lesion showed significantly higher recovery rate (76.1+/-26.2%) after ADF surgery.

Conclusion: There were obvious correlations between the myelopathy type and the cord compression pattern. Type I or Type II patients who mainly involved segmental signs showed less area of the cord entrapment as compared with Type III or V showing long-tract signs. Patients demonstrating segmental signs due to non-entrapped cord compression lesion were expected better neurological recovery after surgical treatments. We conclude that we should pay more attention on the relevance of neurological symptoms and cord compression form on pre-operative MRI.

See Disclosure Index pages 41–95.

Presentation #59

Multiparametric Quantitative MRI Detects Tissue Injury in Asymptomatic Cervical Spinal Cord Compression

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Background: Asymptomatic spinal cord compression (ASCC) due to age-related degenerative changes is common (8-57%), although previous studies have used vague and inconsistent definitions of compression. The clinical significance of ASCC is poorly understood, but one study reported myelopathy development in 25% at 4 years. Two studies employing diffusion tensor imaging (DTI) found decreased fractional anisotropy (FA) at the site of compression, suggestive of tissue injury, but these studies included minimally symptomatic subjects (radiculopathy or dexterity impairment), while DTI metrics may be biased by susceptibility artefact at compressed levels and require verification. This study investigates: 1) if ASCC can be accurately diagnosed with automated spinal cord (SC) shape analysis; 2) if ASCC causes SC tissue injury, similar to that seen in degenerative cervical myelopathy (DCM) using multiparametric quantitative MRI (qMRI); and 3) how often ASCC subjects develop symptomatic myelopathy at follow-up.

Methods: 40 neurologically intact subjects underwent 3T MRI (C1-C7) to calculate cross-sectional area (CSA), FA, magnetization transfer ratio (MTR), and T2*-weighted imaging white / grey matter signal intensity ratio (T2*WI WM/GM). qMRI data were extracted from rostral (C1-3), caudal (C6-7), and maximally compressed levels (MCL) and normalized for age and other variables. Diagnosis used automated SC shape analysis to detect flattening, indentation, and torsion, compared with ratings from 2 experts (Figure 1). Ten qMRI measures that previously showed significant changes in DCM were analyzed individually and as a composite score (averaged z scores, t distribution). MCL / rostral ratios of qMRI metrics were also calculated. 95% confidence intervals (CIs) used the Wilson method, group comparisons used Wilcoxon tests, and tissue injury in individual subjects was assessed using t scores.

Results: ASCC was present in 20/40 subjects (50%, 95% CI: 34.1-65.9%) and 15/21 over age 50 (71.4%, 95% CI: 47.7–87.8%). Shape analysis provided excellent diagnostic accuracy (area under the curve>97%). Five qMRI metrics showed significant pathological changes, including T2*WI WM/GM at rostral, MCL, and caudal levels, MCL FA, and rostral MTR ($p<0.05$), while the composite score showed stronger differences (6 subjects with $t_{10}<-2.23$; group difference: $p=0.002$; Figure 2). However, rostral CSA was unexpectedly higher in ASCC ($p=0.02$). A revised composite score that replaced MCL and rostral CSA with their ratio showed stronger results (9 subjects with $t_9<-2.26$; group difference: $p=0.00008$). At follow-up (median 21 months), two ASCC subjects developed mild symptoms and signs of DCM (10%, 95% CI: 1.8–33.1%).

Presentation #59

Conclusions: Myelopathy begins prior to the onset of neurological symptoms and signs, with SC compression causing subclinical tissue injury. ASCC is a highly prevalent age-related preclinical state with an increased risk of myelopathy development, and these subjects should be educated and monitored for neurological deterioration. A large SC may be a predisposing factor for development of compression due to reduced space in the spinal canal. SC compression can be objectively diagnosed with automated shape analysis, which has potential clinical utility. Multiparametric qMRI offers sensitive *in vivo* measurement of SC tissue injury, which has far-reaching clinical implications including the intriguing possibility of presymptomatic diagnosis and / or treatment of DCM and other spinal pathologies.

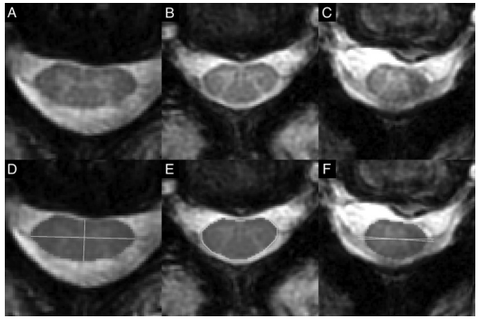

Figure 1. Automatic Shape Analysis. T2*WI of asymptomatic subjects showing flattening (A), indentation (B), and torsion (C) of the SC. D: The SC segmentation (red) is analyzed with 2D principle component analysis to identify the long (transverse) and short (anterior-posterior, AP) axes (green) that intersect at the centre of mass, and (compression ratio)=(AP diameter) / (transverse diameter) is calculated to measure flattening. E: A convex hull (green) is computed that surrounds the segmentation (red), and (solidity)=(segmented area) / (subtended area) is calculated to measure indentation. F: The angle between the transverse axis and horizontal is computed, and (relative rotation)=(angle in current slice) / (average angle of slices above / below) is calculated to measure torsion, in this case from a lateral bulging disc.

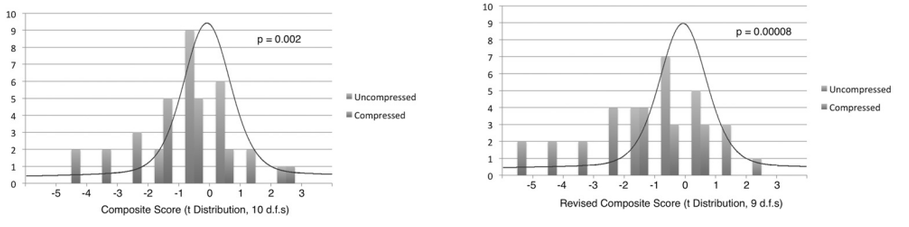

Figure 2: Distributions of Composite Scores. Top: histograms (bars) of composite scores (average of the z scores of 10 qMRI metrics) are displayed for subjects with ASCC (red) and no cord compression (blue). The expected distribution of results based on the null hypothesis (t distribution with ten degrees of freedom, d.f.s) is superimposed. Six ASCC subjects had abnormally low results (t10<-2.23) and group differences were significant (Wilcoxon test: p=0.002). Bottom: the same plot is displayed for a revised composite score that replaces rostral and MCL CSA with CSA ratio (selected post hoc), and the corresponding t distribution with nine d.f.s. Nine ASCC subjects had abnormal scores (t9<-2.26) and stronger group differences were found (p=0.00008).

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Presentation #60

Predicting the Occurrence of Complications Following Corrective Cervical Deformity Surgery: Analysis of a Prospective Muticenter Database Using Predictive Analytics

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International Spine Study Group, Brighton, CO

Introduction: Multivariate regression models may be useful in determining the relative impact of patient and clinical predictors for adverse outcomes. Cervical deformity (CD) surgical patients are growing in number, but remain under-studied in the literature. The purpose of this study was to develop a model that could describe factors that may predict surgical and medical complications in cervical deformity surgeries.

Methods: Retrospective review of prospective, multicenter CD database. CD was defined as at least one of the following: C2-C7 Cobb>10°, CL>10°, cSVA>4cm, CBVA>25°. Medical complications included: cardiopulmonary, dysphagia, GI/GU, neurologic, respiratory, peripheral vascular, post-op shock; surgical complications included: surgical site infection, vessel nerve injury, dural tear, hemorrhagic anemia, wound dehiscence, hematoma/seroma, radiographic and implant failure. Patient demographics and clinical data were assessed as risk factors for medical or surgical complications using multivariate regression models.

Friday, December 1, 2017, 1:06–1:11 pm CSRS–2017

Presentation #60

Results: 123 patients underwent CD corrective surgery (mean age 60.6 years, 60.8% female). Surgical approaches included anterior-only (16.3%), posterior-only (50.4%), and combined approach (33.3%). The mean levels fused were 8.11 levels, average operation time was 297.40 minutes, and estimated blood loss was 776.59cc. A total of 93 (73.2%) complications were reported up to 1-year. The most common complications were neurologic (24.4%), dysphagia (13.0%), cardiopulmonary (11.4%), infection (9.7%). 51 (41.5%) patients experienced a medical complication (cardiac, dysphagia, neurologic most common) and 73 (59.3%) had a surgical complication (infection, dural tear, DJK most common). In multivariate analysis, patients with worse baseline cSVA had an increased complication risk (OR: 2.15, CI: 1.03, 4.49). Corpectomy (OR: 0.54, CI: 0.30, 0.98), higher baseline cSVA (OR: 1.02, CI: 1.00, 1.04), and larger McGregor's slope (OR:1.03, CI: 1.00, 1.03) increased chances of a medical complication. Higher blood loss (OR:1.00, CI: 1.00, 1.01) and baseline global SVA (OR: 1.93, CI:1.04, 3.59) increased the chances of a surgical complication.

Conclusions: 73.2% of patients undergoing cervical deformity correction sustained any kind of complication. Cervical SVA was the strongest predictor for complications across categories.

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Presentation #61

Risk Factor Analysis of Postoperative Subaxial Cervical Alignment Change Following Upper Cervical Fixation

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Background: There have been few analysis about risk factors related to postoperative subaxial cervical kyphosis following craniovertebral junction (CVJ) fixation. The aims of this study were to evaluate the changes of cervical alignment and analyze the risk factors of postoperative kyphotic change of subaxial cervical spine after CVJ fixation.

Materials / Methods: The authors retrospectively reviewed 115 patients in whom CVJ pathology was treated with upper cervical fixation. Angles of OC1, C12, OC2 and C27 were determined based on an upright lateral radiograph in flexion, neutral and extension positions. The range of motion (ROM) at OC1, C12, OC2 and C27 was determined. The association between OC1, C12, OC2 and C27 angle was also investigated. All patients were examined before and 1 year after the surgery.

The postoperative subaxial cervical kyphotic change group included the patients whose C27 angle change was greater than -10 degree. The reciprocal changes of the C27 angle and other parameters (age, sex, etiology, occipital fixation, semispinalis cervicis resection at C2 spinous process, additional C12 posterior wiring and subaxial laminoplasty) were investigated. Univariate and multivariate analyses were conducted to determine the risk factors for postoperative kyphotic change of subaxial cervical spine.

Results: The mean angles of preoperative OC1, C12, OC2 and C27 angle in neutral position were -7.7, 19.6, 12.0 and 13.4 retrospectively. Those at final follow up were -7.3, 18.1, 10.8 and 13.3 retrospectively. There were statistically significant correlation between C12 angle change, OC2 angle change and C27 angle change. The C27 angle change was greater than -10 degree in twenty-nine of the 115 patients (25.2%).

Risk factor analysis showed combined CVJ fixation with subaxial laminoplasty (OR=10.326, 95% confidence interval [CI]=1.593 - 66.943, P=0.014), occipital fixation (OR=5.062, 95% CI=1742-14.708, P<0.01), and reduced range of motion (ROM) at C0-1 segment (OR=0.823, 95% CI=0.741-0.914, P<0.01) were related to the postoperative subaxial kyphosis. Resection of C2 semispinalis cervicis muscle, rheumatoid arthritis, additional C12 posterior wiring were not the risk factor of subaxial kyphosis

Conclusion: We demonstrated that alignment of subaxial cervical spine changed significantly at the 1 year follow-up after CVJ posterior fixation. Subaxial cervical alignment has reciprocal interaction with upper cervical angle after CVJ fixation. Our study suggest that combined subaxial laminoplasty, occipital fixation and reduced ROM of C01 segment are associated with subaxial kyphotic change after upper cervical fixation.

Presentation #62

The Risk Factor Analysis of Change of Intraoperative Neurophysiologic Monitoring During Cervical Open-Door Laminoplasty

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Study Design: Retrospective case-control study.

Objective: To find out when change of intraoperative neurophysiologic monitoring (IONM) take place, and what factors affect the alteration of IONM during cervical laminoplasty for cervical compressive myelopathy (CCM).

Summary of Background Data: IONM measures neural function and integrity during surgical procedure. If there are no any other confounding factors, decrease or loss of evoked potential means alteration of neural function and integrity. Few studies have found out when change of IONM occurred and evaluated the predictive preoperative parameters for it in cervical laminoplasty.

Methods: Seventy nine patients who underwent laminoplasty with motor evoked potential (MEP) and somatosensory evoked potential (SSEP) recording simultaneously were studied between 2010 and 2015. Patients with change in MEP or SSEP during surgery were classified as the change group. If MEP and SSEP were not changed, they were classified as no-change group. Radiologic parameters including maximal compression level (MCL), cervical spine stenosis grade, area and anterior posterior (AP) diameter of spinal canal and compressive lesion at ventral side (CLV), and occupying ratio of area and length at MCL were measured with cervical magnetic resonance imaging (MRI). Japanese orthopedic association (JOA) score as clinical outcome was evaluated before surgery and at 6 months after surgery.

Results: Thirteen patients enrolled in change group and 66 patients were assigned to no-change group. After total laminectomy of C3 or open of all laminas simultaneously, the IONM change occurred in all patients of change group. Multivariate analysis identified occupying ratio of area at maximal compressive level (odds ratio [OR]=1.520, 95% confidence interval [CI]: 1.192–1.37, p=0.001) as an independent risk factor for change of IONM during cervical laminoplasty. The best cut-off value for occupying ratio of area at MCL as predictive preoperative parameter of IONM change during cervical open-door laminoplasty was 34.5% (sensitivity 92.3% and specificity 89.4%).

Conclusion: IONM change occurred after C3 total laminectomy before open of all laminas or open of laminas all together without total laminectomy at C3. The risk factor of IONM change during cervical open-door laminoplasty in CCM patients was occupying ratio of area at MCL. If the occupying ratio of area was more than 34.5%, the possibility of IONM change would increase. Moreover, if the IONM change was not fully recovered during surgery, new neurologic deficit would occur about 50% in IONM change group after cervical open-door laminoplasty.

Key words: Cervical compressive myelopathy, Cervical open-door laminoplasty, Intraoperative neurophysiologic monitoring

See Disclosure Index pages 41–95.

Presentation #63

What is the Best Available Patient-Reported Outcome Measure for Dysphagia in Cervical Spine Surgery? A Comparison of the Eating Assessment Tool (EAT-10) and SWAL-QOL

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Introduction: Patient-reported outcome measures (PROMs) have been increasingly adopted in spinal surgery, however concerns still exist over how reliably these instruments capture the outcome of interest. The first PROM utilized to analyze post-ACDF dysphagia was the Swallowing-Quality of Life (SWAL-QOL) survey. The SWAL-QOL questionnaire used in this study and since embraced throughout the spine literature is a modified, non-validated, 14 question survey.4,5 The original SWAL-QOL outcome questionnaire consisted of 44 questions and due to its cumbersome nature was never widely adapted in the dysphagia-specific literature. Another dysphagia PROM, the Eating Assessment Tool (EAT-10), is a validated 10 question survey, that has been used in the spine literature to categorize the severity of dysphagia after ACDF. The purpose of this study is to compare the reliability of the EAT-10 and the modified, 14 question SWAL-QOL outcome measures for post-ACDF dysphagia.

Methods: 42 patients undergoing ACDF for the treatment of cervical spondylosis were recruited. Inclusion criteria were patients greater than 18 years undergoing primary ACDF for the treatment of radiculopathy or myelopathy. Exclusion criteria included: age under 18 years and operations for trauma / infection / tumor / revision. Primary outcomes were measured for dysphagia using both the EAT-10 and the modified, 14 question SWAL-QOL PROMs. Patient outcomes were collected pre-operatively and on post-operative day 1, week 2, week 6, and week 12. Paired-outcomes were compared using a Pearson correlation. Statistical analysis was completed with significance set at $p<0.05$.

Results: A total of 208 paired-dysphagia PROMs were included in the analysis. Of these, 46 had at least one of the outcomes, EAT-10 or SWAL-QOL, indicate a diagnosis of dysphagia. In patients with dysphagia, a Pearson correlation coefficient showed only a moderate correlation between the EAT-10 and SWAL-QOL outcomes ($r=0.6896$) (Figure 1). The EAT-10 and SWAL-QOL outcomes were statistically different when significance testing was performed ($p<0.00001$). In categorical terms, the PROMs only agreed on a dysphagia diagnosis 50% of the time (Figure 2). The EAT-10 outcomes indicated 34 outcomes with mild dysphagia and 12 outcomes with severe dysphagia. Whereas the SWAL-QOL outcomes indicated only 28 outcomes with mild dysphagia and 3 outcomes with severe dysphagia.

Conclusion: Our study shows that EAT-10 and SWAL-QOL PROMs do not strongly correlate and cannot be used interchangeably in post-ACDF dysphagia research. Given that the EAT-10 survey is validated, easily-administered, and has been widely adopted in recent dysphagia literature, it is our opinion that it is the cervical spine dysphagia PROM of choice. The modified 14 question SWAL-QOL questionnaire has not been validated and under-reports severe dysphagia compared to the EAT-10. It should, therefore, be used with caution for the interpretation of dysphagia outcomes.

Friday, December 1, 2017, 1:23–1:28 pm CSRS–2017

Presentation #63

Figure 1. Comparison of EAT-10 and SWAL-QOL Paired-Outcomes

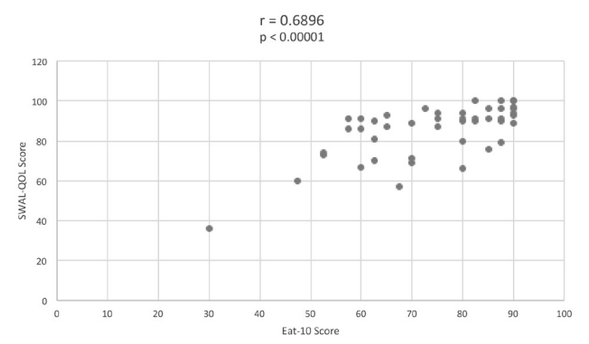
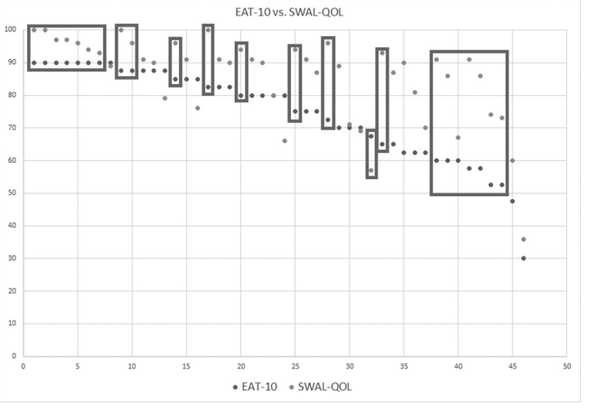


Figure 2. Comparison EAT-10 and SWAL-QOL Dysphagia Outcomes*+



* Data points surrounded with a red-box indicated disagreement on dysphagia diagnosis between the scales.

\+ Mild dysphagia is indicated with a score <92.5 and Severe dysphagia is indicated with a score <62.5

See Disclosure Index pages 41–95.

Presentation #64

Etiology and Surgical Strategies of Reoperation After Cervical Laminoplasty

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Objective: To evaluate the etiology and surgical strategies of reoperations after cervical laminoplasty.

Method: Within the last 10 years, all patients received reoperations in our center after cervical laminoplasty were retrospectively evaluated. Radiologic parameters, clinical data and interval between surgeries were analyzed.

Result: Forty-three patients were included in this study and the average interval between surgeries was 47.8 months. The etiology of reoperations included: 1) Technique related issues, 7 cases of lamina closure, 2 cases of nerve root or cord compression duo to hinge fracture; 2) Inadequate treatment, 15 cases of large anterior compression, 1 case of cervical kyphosis; 3) Disease progression, 14 cases of progression of ossification of posterior longitudinal ligament, 14 cases of herniated disc or osteophytic change. The reoperations included 28 cases of anterior approach and 14 cases of posterior approach, one case of combined approach. The mJOA score before the reoperation was 11.6±2.8, which increased to 13.5±2.5 after the reoperation. The mJOA improvement rates were similar between the anterior approach and the posterior approach.

Conclusion: Reoperations after cervical laminoplasty are not common. The reoperation approach should be based on the radiologic changes and clinical manifestations.

Presentation #65

Prevention of Pseudoarthrosis in Multilevel ACDF with Individual Level Plate Fixation vs. Single Long Plate

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Introduction: Historically, there is a decreasing fusion rate with increasing number of levels for ACDF. With an increasing aging spine population, there is increased incidence and need for 3,4 and 5 level ACDF constructs. Traditionally, single long plates which span the cephlad to caudal construct are used for multilevel ACDF. Clear evidence, which answers the question as to why there is an increase rate of pseudoarthrosis for longer multilevel cervical constructs is lacking.

There is a high rate of fusion with single level ACDF and plate fixation. Surgical fixation of each individual level could lead to a higher rate of fusion versus single long plate fixation, as each level is treated as a single level with symmetrical balanced biomechanical forces.

Materials / Methods: This is a retrospective review of prospectively collected data. 105 patient records including diagnostic studies of pre-op and post-op x-rays with AP and flexion extension lateral views were reviewed. CT scan was also obtained between 3-6 months post-op in 70 patients. All patients underwent ACDF from 1–4 levels primarily for degenerative conditions including stenosis and HNP resulting in radiculopathy and myelopathy. All Patients had individual 15.5 mm plates with 4-screw fixation and an interbody PEEK cage. In 50 patients rh-BMP-2 was the biologic choice and 50 utilized DBM, demineralized bone graft (Figure 1). Motion less than 2mm on flexion extension views and bridging trabecular bone on CT were criteria utilized to determine fusion. The rh-BMP-2 protocol was 0.7cc/level, utilized within the interbody device with minimal decortication of endplates. DBM was placed only inside the interbody device. Steroids were administered pre-operatively and post-operatively to minimize swelling.

Results: There was a 97.8% fusion rate utilizing individual plate fixation for each level and no statistically significant difference found between fusion rates using rhBMP-2 vs. allograft. Fusion rates for single to 4 levels respectively were, 100%, 100%, 97.6% and 95.8% for rhBMP-2 and 100%,100%, 93.3 and 91.7% for DBM (Table 1.) There was no construct failure including breakage of screws or plates, 5% subsidence of interbody devices, 2% revision for screw back out in one case and removal of plate in another case. No infection or injury to viscera was found. There were no significant differences in complications found between use of rhBMP-2 or DBM for biologic choice. There were 2 cases of revision done for symptomatic pseudoarthrosis.

Conclusion: Historically, in three or more levels for ACDF, pseudoarthrosis rates increase however the evidential basis for this reality is elusive. Pseudoarthrosis can be mitigated in long constructs by using single plate fixation vs. single long plates. Obtaining Consistent symmetrical biomechanical loading of individual levels utilizing multiple plates vs. variable loading of individual levels utilizing a single long plate is reasonably the explanation for improved fusion rates in multilevel multi-plate constructs. There was no statistical difference in fusion rates between the patients receiving either rH-BMP-2 or DBM (p-value=0.15625). There was also no statistical difference in fusion rates between 1 level and 4 level ACDFs (p-value=0.11507).

See Disclosure Index pages 41–95.

Presentation #65 (cont.)

Figure 1.

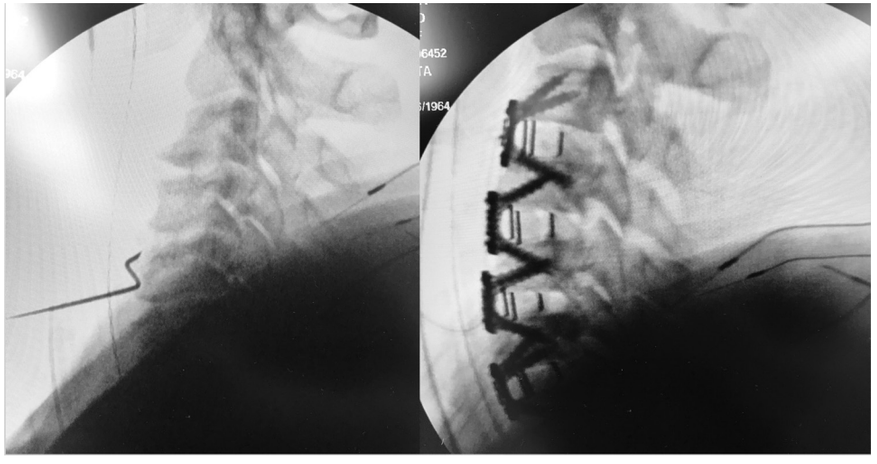

Table 1.

Levels/Pt	Pts	Fusion Rate					
		BMP/PEEK		Allograft/PEEK		Total	
		Levels	Rate	Levels	Rate	Levels	Rate
1	25	16	100%	9	100%	25	100%
2	47	58	100%	36	100%	94	100%
3	24	42	97.6%	30	93.3%	72	95.8%
4	9	24	95.8%	12	91.7%	36	94.4%
Total	105	140	98.5%	87	96.5%	227	97.8%

Presentation #66

The Real Costs of ACDF: A Time-Driven Activity Based Costing Analysis

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Introduction: As healthcare shifts to value-based reimbursement, it is imperative to determine the true cost of surgical procedures. Time Driven Activity Based Costing (TDABC) determines the cost of care by determining the actual resources used in each step of the care cycle. One of the first steps in performing this type of analysis is to develop a process map for the care episode, often with the help of a multidisciplinary team which estimates the time and resources utilized. However these results are completely dependent on this estimation and are subject to group biases. The purpose of this study is to determine the actual cost of a one or two level Anterior Cervical Discectomy and Fusion (ACDF) using actual patient data and the TDABC methodology.

Methods: 30 patients who underwent a one or two level ACDF by three surgeons at a specialty hospital were prospectively enrolled. To build an accurate process map, a research assistant accompanied the patient to every step in the care cycle including the pre-operative visit, the pre-admission testing, the surgery and the postoperative visits for the first 90 days. All resources utilized and the time spent with every member of the care team was recorded. The salary for every member of the care team was identified and the cost per minute was determined. All salaries were based on the total compensation paid to each employee (inclusive of bonus, benefits and base salary). The charges for all disposables were the actual cost that the facility paid for the item. All patients stayed overnight, and an estimate of the time and resources utilized for the overnight portion of the patients hospital stay was used. The total rent and overhead for the clinic/hospital was divided equally among the total number of clinic visits/surgeries from the previous year at the facility.

See Disclosure Index pages 41–95.

Presentation #66 (cont.)

Results: 30 patients were enrolled, however one patient had an adverse reaction to aesthesia and his surgery was cancelled; one patient had a medical complication that required a transfer, and one patient who was undergoing a three-level procedure was inadvertently enrolled, leaving 27 patients for analysis. Eleven patients underwent a single level ACDF and 16 underwent a two-level fusion. The total cost for the episode of care was $29,299+/-$5,048. The overwhelming cost driver for the care cycle was the hospital disposable costs ($13,920+/-$6,325) (this includes every item used during the hospital stay from pain medication to spinal instrumentation), with intraoperative personnel costs (surgeon, resident/fellow, anaesthesia, nursing, surgical technician, neuromonitoring, radiology technician and orderlies), accounting for the second largest cost at $6,066+/-$1,540 (Table 1, Figure 1). The total cost excluding hospital overhead and disposables was $9,071+/-$1,939.

Conclusion: Reimbursement for a bundle of care surrounding a one or two level ACDF should be no less than $29,299 if it is to cover the true costs of the care for the entire care cycle. Based upon our analysis, it appears that hospital disposables may provide the greatest opportunity for cost savings.

Table 1. Total Cost Per Stage of Care

	Total 90 Day TDABC Cost	Hospital Disposable Costs	Hospital Overhead	Preoperative Visit Costs	Preadmission Testing Costs
Total	$29,299	$13,920	$4,705.00	$926	$125
Standard Deviation	$5,048	$6,325	0	$136	$17

	Pre-operative Day of Surgery Personnel Costs	Intraoperative Personnel Costs	PACU Personnel Costs	First Postoperative Visit Costs	Second Postoperative Visit Costs
Total	$411	$6,066	$124	$975	$807
Standard Deviation	$101	$1,540	$11	$380	$317

Presentation #67

Favorable Prognosis for Significant Preoperative Upper Extremity Weakness following Elective Anterior Cervical Discectomy and Fusion

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Introduction: Cervical radiculopathy secondary to cervical disc herniation can manifest as pain, sensory disturbance, and/or motor deficit. While preoperative weakness is often used as an indication for early surgical intervention, few studies have examined the prognosis for upper extremity motor deficit following anterior cervical discectomy and fusion (ACDF).

Methods: To better understand the clinical outcomes of patients with preoperative weakness undergoing ACDF, our institution undertook a retrospective study to assess both prevalence and risk factors for lack of improvement. We examined a cohort of 618 consecutive patients that underwent elective ACDF from September 2015 until June 2016. Cases were performed by ten fellowship trained spine surgeons at our tertiary academic center. Data was collected regarding patient demographics and comorbidities. Cervical MRI imaging was reviewed for the presence of cord compression, myelomalacia, and foraminal stenosis. Patients were divided into a group exhibiting significant preoperative weakness (Medical Research Council motor grade less than 4) and a group without significant weakness. Data regarding affected muscle groups and significant improvement postoperatively (to a motor grade 4 or greater) was recorded. Univariate analysis was performed to determine risk factors for failure to improve.

Presentation #67 (cont.)

Results: Overall, out of the 618 patients 47.5% were male with an average age of 56.3 years. 43.0% of patients exhibited myeloradiculopathy with 57% patients having exclusively cervical radiculopathy. Of those patients with myelopathy and cord compression, 40.5% demonstrated myelomalacia on cervical MRI. Average follow up was 6.2 months. Two level fusions were most commonly performed (44.6%) followed by one level (29.3%), three level (21.7%), and four level (4.4%) fusions. 4.3% of patients demonstrated significant preoperative weakness. Of these patients, 57.1% of them had more than one muscle group affected. Triceps were the most commonly affected muscle group (26.9%) followed by hand intrinsics (23.1%), finger flexors (20.5%), deltoids (15.4%), and biceps (14.1%).

Postoperatively 75.3% of patients experienced an improvement in muscle strength (≥4). Despite being the most commonly weak muscle preoperatively, triceps most frequently showed improvement (95.2%) followed by finger flexors (87.5%), hand intrinsics (83.3%), and biceps (63.6%). Deltoids were much less likely to show improvement following surgery (8.3%). In a univariate analysis, myelomalacia on imaging (OR 28.9, $p<.01$) and greater than 2 level fusion (OR 10.1, $p<.01$) were found to be predictive of a failure to improve motor grade. A similar trend was observed with cord compression (OR 4.67, $p=.07$) although this did not reach statistical significance. Other risk factors such as elevated BMI, smoking, diabetes, and age were not found to be predictive.

Conclusion: These results are encouraging for patients undergoing ACDF with significant preoperative motor weakness. This cohort's outcomes would suggest with intermediate follow up one can expect the vast majority (over 70%) of patients to show marked strength improvement postoperatively. However, not surprisingly patients with myelomalacia seem to be at risk for not improving and should be counseled that their prognosis for strength improvement is more guarded.

Presentation #68

Comparison of Neck Pain and Complications of Stand-Alone vs. Conventional Plate and Interbody Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a well-established technique used in the single- or multiple-level treatment of degenerative cervical spine disorders. Standalone cages have gained popularity secondary to their ease of implantation, reduced operating time, and lower profile compared to traditional graft and plate systems. The aim of this retrospective cohort study was to assess differences in pain and clinical outcomes, including complication and readmission rates, following ACDF using either a stand-alone cage system or an interbody device with anterior plating.

Methods: Between 2014 and 2015 we identified 377 consecutive patients meeting study criteria. 211 patients underwent ACDF with a stand-alone system. 166 patients underwent ACDF with a plate and interbody construct. Patient-specific characteristics, surgical characteristics, and Numeric Pain Rating Scale (NRS) scores for neck pain were collected pre- and peri-operatively. Complication and readmission rates as well as NRS scores were collected at approximately one year (mean of 246±240 days) and two years postoperatively (mean of 714±123 days). Analyses assessed group differences at baseline (patient and surgical characteristics), as well as group differences in NRS score changes and post-operative complication and readmission rates.

Results: There were a number of significant differences in general demographics and surgical characteristics between the two groups. There was a significant difference in NRS change scores at 2 years follow-up favoring patients having undergone ACDF with a plate and interbody construct, controlling for sex and length of surgery ($p=.02$).

Conclusion: Both clinical and pain outcomes were better in the plate and interbody group, presumably resulting from biomechanical advantages when compared to stand-alone cage systems.

See Disclosure Index pages 41–95.

Presentation #69

Is Two-Level Cervical Disc Replacement More Cost-Effective than Anterior Cervical Discectomy and Fusion at 7 Years?

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Introduction: Cervical disc replacement (CDR) and anterior cervical discectomy and fusion (ACDF) are both effective treatment strategies for managing degenerative conditions of the cervical spine. CDR has been shown to be the more-cost effective intervention for both one and two-level procedures in the short term, but the long-term cost-effectiveness has not been established. The objective of this study was to investigate the 7-year cost-effectiveness of two-level cervical disc replacement (CDR) and anterior cervical discectomy and fusion (ACDF).

Methods: We analyzed 7-year follow-up data from a two-level food and drug administration (FDA) investigational device exemption (IDE) study. Short-form 36 (SF-36) data were converted into health utility scores using the SF-6D algorithm. Costs were based on direct costs from the payer perspective, and effectiveness was measured as quality adjusted life years (QALYs). The willingness to pay (WTP) threshold was set to $50,000/QALY. A probabilistic sensitivity analysis was conducted via Monte Carlo simulation.

Results: Two-level CDR had a 7-year cost of $176,654.19, generated 4.65 QALYs, and had a cost-effectiveness ratio of $37,993.53/QALY. Two-level ACDF had a 7-year cost of $158,373.48, generated 4.44 QALYs, and had a cost-effectiveness ratio of $35,635.72. CDR was associated with an incremental cost of $18,280.71 and an incremental effectiveness of 0.21 QALYs, resulting in an incremental cost-effectiveness ratio (ICER) of $89,021.04, above the WTP threshold. Our Monte Carlo simulation demonstrated CDR would be chosen 46% of the time based on 10,000 unique simulations.

Conclusions: Two-level CDR and ACDF are both cost-effective procedures at 7-year follow-up for treating degenerative conditions of the cervical spine. Based on an ICER of $89,021.04/QALY, we cannot conclude which treatment is the more cost-effective option at 7-years. This finding is supported by our Monte Carlo simulation, in which CDR was chosen 46% of the time based on 10,000 iterations.

Presentation #70

Impact of Body Mass Index on Surgical Outcomes, Narcotic Consumption, and Costs Following Anterior Cervical Discectomy and Fusion

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Introduction: With the increasing prevalence of obesity, more patients with high body mass index (BMI) will require surgical treatment for degenerative spinal disease. In previous investigations of lumbar spine pathology, obesity has been associated with worsened postoperative outcomes and increased costs. However, few studies have examined the association between BMI and postoperative outcomes after anterior cervical discectomy and fusion (ACDF) procedures. As such, the purpose of this study is to compare surgical outcomes, postoperative narcotics consumption, complications, and costs amongst BMI stratifications for patients undergoing primary 1–2 level ACDF procedures.

Methods: A prospectively maintained surgical database of patients that underwent primary, 1–2 level ACDF for degenerative spinal pathology between 2008-2015 was reviewed. Patients were stratified by BMI as follows: normal weight (<25.0kg/m2), overweight (25.0–29.9 kg/m2), obese I (30.0–34.9 kg/m2), or obese II-III (≥35.0 kg/m2). Differences in patient demographics and preoperative characteristics were compared across the BMI cohorts using one-way analysis of variance or chi-square analysis. Multivariate linear or Poisson regression with robust error variance was used to determine the presence of an association between BMI category and narcotics utilization, improvement in VAS pain scores, incidence of complications, arthrodesis rates, reoperation rates, and costs. Regression analyses were controlled for preoperative demographic and procedural characteristics.

Results: A total of 277 patients were included in the analysis, of which 20.9% (58) were normal weight, 37.5% (104) were overweight, 24.9% (69) were obese I, and 16.6% (46) were obese II-III. Higher BMI was associated with older age (p=0.049) and increased comorbidity burden (p=0.001). No differences in sex, smoking status, or preoperative Visual Analogue Scale (VAS) pain scores were found between cohorts (p>0.05). No significant differences were found between BMI cohorts in regards to operative time, intraoperative blood loss, length of hospital stay, or number of operative levels (p>0.05). Additionally, no significant differences existed across BMI stratifications in postoperative narcotics consumption, VAS pain score improvement, complication rate, arthrodesis rate, reoperation rate, or total direct costs (Table 1-2, p>0.05).

See Disclosure Index pages 41–95.

Presentation #70 (cont.)

Conclusions: Patients with higher BMI demonstrated comparable surgical outcomes, narcotics consumption, and hospital costs compared to those with lower BMI. As such, ACDF procedures are both safe and effective for patients across the entire BMI spectrum. Patients should be counseled to expect similar rates of postoperative complications and eventual clinical improvement regardless of their BMI status.

Table 1. Inpatient Pain Scores, Narcotics Consumption, and Postoperative Outcomes.*

	Normal (N=58)	Overweight (N=104)	Obese I (N=69)	Obese II-III (N=46)	†p-value
VAS Pain Scores (mean±SD)					
POD 0	4.9±1.8	5.0±1.7	4.7±1.9	4.9±1.8	0.879
POD 1	3.9±1.8	4.3±1.7	3.7±2.0	4.1±1.5	0.342
Daily OME Consumption (mean±SD)					
POD 0	55.8±46.7	67.7±58.4	73.5±65.5	58.0±51.5	0.279
POD 1	33.6±20.9	38.1±35.7	44.8±38.7	42.0±35.0	0.394
Hourly OME Consumption (mean±SD)					
POD 0	4.5±3.5	6.5±11.9	6.1±6.0	4.8±4.9	0.517
POD 1	2.1±1.3	2.3±1.9	2.5±1.8	2.4±2.0	0.652
Change in VAS Neck (Mean±SD)					
6-week D	-3.1±2.5	-3.4±2.4	-2.6±3.1	-2.9±2.4	0.208
12-week D	-3.9±3.1	-3.8±2.7	-3.8±3.2	-3.2±3.0	0.429
6-month D	-4.2±3.2	-4.2±2.9	-4.3±3.4	-3.9±2.3	0.722
Complication Rate (n)f	13.8% (8)	13.5% (14)	5.8% (4)	8.7% (4)	0.274
Pseudarthrosis (n)	5.2% (3)	5.8% (6)	4.3% (3)	4.3% (2)	-
Arthrodesis at 1 year (n)	94.8% (55)	94.2% (98)	95.7% (66)	95.7% (44)	0.978
Reoperations (n)g	8.6% (5)	10.6% (11)	11.6% (8)	6.5% (3)	0.727

SD = Standard deviation; OME=Oral Morphine Equivalents; POD=Postoperative Day; VAS=Visual analogue scale

* Boldface indicates statistical significance.

† P-value calculated using multivariate Poisson or linear regression controlled for age, sex, smoking status, modified Charlson Comorbidity Index, and number of fusion levels.

f Complications included: urinary retention requiring catheterization (n=24), reintubation (n=2), epidural hematoma (n=1), altered mental status (n=1), and instrumentation failure (n=4).

g Indications for reoperation included: pseudarthrosis (n=9), adjacent segment degeneration (n=13), residual stenosis (n=3), and ossification of the posterior longitudinal ligament (n=2).

Presentation #70

Table 2. Direct Costs*

	Normal (N=58)	**Overweight (N=104)**	**Obese I (N=69)**	**Obese II-III (N=46)**	**P-value†**
Total Costs (Mean±SD)	$9097±4264	$8605±3345	$8839±2816	$9006±3112	0.969
Blood	$0±0	$2±10	$2±9	$1±8	0.232
Cardiology	$10±68	$15±118	$5±26	$22±83	0.732
ER	$0±0	$2±22	$0±0	$0±0	0.421
Radiology	$169±65	$157±42	$171±56	$159±46	0.212
Laboratory	$26±57	$20±25	$24±29	$23±27	0.536
Nursing Unit	$731±611	$789±573	$919±901	$823±536	0.441
ICU	$101±603	$0±0	$22±183	$25±171	0.171
Pharmacy	$345±224	$330±132	$356±195	$357±155	0.880
PT/OT/Speech Therapist	$82±74	$85±68	$96±85	$94±62	0.834
Surgical Services	$7579±3384	$7152±2855	$7181±2014	$7369±2805	0.971
Other	$53±124	$52±113	$61±130	$132±245	0.059

SD=Standard deviation; ER=Emergency room; ICU=Intensive Care Unit; PT=Physical Therapy; OT=Occupational Therapy

*__Boldface__ indicates statistical significance.

† P-value is from multivariate linear regression adjusted for age, sex, smoking status, modified Charlson comorbidity index, and number of operative levels

See Disclosure Index pages 41–95.

Presentation #71

Clinical and Radiographic Outcomes of Patients with Cervical Deformity Secondary to Thoracolumbar Proximal Junctional Kyphosis

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Introduction: Cervical deformity (CD) development secondary to proximal junctional kyphosis (PJK) has recently been documented in adult spinal deformity (ASD) patients after surgical correction for thoracolumbar ASD. This study aims to analyze surgical management of patients with CD secondary to PJK versus patients with primary CD.

Methods: Retrospective review of prospective, multicenter CD database. CD was defined as at least one of the following: C2-C7 Cobb>10°, CL>10°, cSVA>4cm, CBVA>25°. Patients were grouped into those who had PJK (UIV+2<-10°) prior to cervical surgery versus whose who did not (Non-PJK). 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), Numeric Scale Rating (NSR). ANOVA, t-tests and chi-squared tests were used to compare radiographic, clinical, and surgical metrics between PJK and Non-PJK groups at baseline and 1yr follow-up.

Presentation #71

Results: Of 123 eligible cervical deformity patients, 26 (21.1%) had radiographic PJK prior to their cervical surgery. There were no significant differences in age, gender, BMI, Charlson Comorbidity Index, history of prior cervical surgery, or baseline HRQL measures (p>0.05). PJK patients had significantly greater T2-T12 thoracic kyphosis (-58.78° vs. -45.04°, p=0.002), cSVA (49.07mm vs. 38.86mm, p=0.020), T1 Slope (42.64° vs. 28.41°, p<0.001), TS-CL (44.08° vs. 35.64°, p=0.048), C2-T3 SVA (98.82mm vs. 75.75mm, p=0.015), C2 Slope (45.40° vs. 36.04°, p=0.043), C2-S1 (-12.63 vs. -1.29, p=0.033) and CTPA (6.44° vs. 4.57°, p=0.005). Comparing their surgeries, the PJK group had significantly more levels fused (10.68 vs. 7.42 levels, p=0.01) and their average posterior LIV was more caudal (T6 vs. T4, p=0.004). There were significantly more posterior column osteotomies performed in the PJK group (38.5% vs. 16.5%, p=0.018). Posterior lateral mass screws and pars screws were used significantly more frequently for patients with PJK than Non-PJK (lateral mass: 76.9% vs. 50.5%, p=0.013; pars: 38.5% vs. 12.4%, p=0.004). There was significantly greater blood loss in patients with PJK (1158.08±1062.65cc vs. 678.27±760.39cc, p=0.028); operative time, surgical approach, and BMP-2 use did not significantly differ between the two groups (all p>0.005). PJK patients experienced higher rates of complications 30 and 90 days postoperatively (23.1% vs. 5.2%, p=0.004; 30.8% vs. 19.6%, p=0.026), and had higher instrumentation failure 30 days postoperatively (7.8% vs. 1.03%, p=0.004). However, there were no significant differences in HRQLs between PJK and Non-PJK patients at 3M, 6M, or 1Y for NDI, EQ5D, mJOA, NSR Back, or NSR Neck (all p>0.05).

Conclusions: The prevalence of pre-operative PJK was 21.1% among CD cases. Patients with cervical deformity secondary to PJK had worse baseline cervical deformity, despite no differences in HRQL or demographics. Surgical correction of CD associated with PJK required more invasive surgery and had higher complication rates than Non-PJK patients, despite achieving similar outcomes.

See Disclosure Index pages 41–95.

Presentation #72

The Relationship between Improvements in Myelopathy and Sagittal Realignment in Cervical Deformity Surgery

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Introduction: Cervical deformity (CD) correction involves both radiographic malalignment correction and procedures to improve motor function and pain. It is not known whether alignment or myelopathy improvement drives patient outcomes. The goal was to determine if reaching cervical alignment goals or meeting clinically significant modified Japanese Orthopaedic Association (mJOA) score improvements at 1 year contribute most to overall outcomes for patients after CD corrective surgery.

Methods: Retrospective review of a prospective, multicenter CD database. Inclusion criteria were CD patients with baseline and 1-year radiographic and outcome scores. *Outcome Measures:* Cervical alignment: cervical sagittal vertical axis (cSVA); Health-related quality of life (HRQL) measures: Neck Disability Index (NDI), EuroQol-5 (EQ5D), mJOA. Improvement in cervical alignment was defined by ranking pre- and post-operative cSVA and T1S-CL $0 \leq cSVA \leq 40mm$, $0 \leq T1S\text{-}CL \leq 20°$. Improvement in mJOA was defined by: Mild [15-17], Moderate [12-14], and Severe [<12]. Patient groups were constructed: those who only improved in alignment category, only improved in mJOA category, those who improved in both, and those who did not improve. These four groups were evaluated for changes in patient-reported quality of life scores (NDI, EQ5D, and mJOA).

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Results: 41 patients (63.7 yrs, 51.2% F) were included. The overall pre-operative mJOA score was 13.29±2.10. Categorically, at baseline: 14 (34%) patients had mild myelopathy, 19 (46%) moderate, and 8 (20%) severe. 17/41 (42%) of patients improved in mJOA score and 9(19.5%) met 1Y mJOA MCID after CD correction. Radiographic improvement was seen at 1-year in 21/41(51%) patients in cSVA, 10(24%) Horizontal Gaze, and 6(15%) TS-CL. The distribution of improvement groups was: 13/41(32%) alignment improvement only, 7(17%) myelopathy improvement only, 10(24%) alignment and myelopathy improvement, 11(27%) no improvement in myelopathy / alignment. EQ5D improved in 8/13(62%) alignment-only improvement patients, 6/10(60%) alignment and myelopathy improvement, 7/7(100%) myelopathy only, and 5/11(46%) no myelopathy / alignment improvement. There were no differences in surgical approach, decompression, or baseline alignment or mJOA scores between improvement groups. Patients who improved in myelopathy only displayed a significant difference in baseline-1Y EQ-5D score (baseline: 0.74, 1Y: 0.82, $p=0.010$). C2-S1 SVA baseline-1Y was the strongest predictor of improvement in all three HRQL scores ($r=-0.285$, $p=0.042$).

Conclusions: 42.1% of patients improved in mJOA score and 19.5% met 1Y mJOA MCID after CD correction. Patients who improved in myelopathy displayed better outcomes at 1Y than patients who improved in alignment only, despite no differences in surgical approach, decompression rate, baseline alignment or mJOA scores.

See Disclosure Index pages 41–95.

Presentation #73

Cost-Effectiveness Analysis of Intraoperative Corticosteroid Administration in Anterior Cervical Discectomy and Fusion for Degenerative Disease

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Introduction: Recent prospective studies suggest perioperative corticosteroids reduce postoperative dysphagia and dysphonia after anterior cervical discectomy and fusion (ACDF). However, the increased probability of rare complications associated with steroids (e.g. wound complications, esophageal perforations, and diminished fusion) may lower functional outcomes and incur additional medical costs. The objective of this study was to estimate the direct medical costs, quality-adjusted life years (QALYs), and cost-effectiveness of intraoperative intravenous (IV) corticosteroids, local corticosteroids, and no corticosteroid administration to reduce postoperative dysphagia and dysphonia in ACDF without corpectomy for degenerative disease.

Methods: A decision tree model (Figure 1) was used to compare a single intraoperative dose of IV dexamethasone (10 mg), a single intraoperative dose of local triamcinolone (40 mg), and no intraoperative steroid over a two-year time horizon from a third-party payer perspective. Probabilities and utilities were derived from prior published literature and unpublished results of a randomized control trial (RCT). Costs (2017 US$) were derived primarily from the Centers for Medicare & Medicaid Services (CMS). A willingness-to-pay (WTP) threshold of $50,000 per QALY was used to determine cost-effectiveness. One-way, three-way, and probabilistic sensitivity analyses (PSA) were used to explore parameter uncertainty.

Results: The base case analysis revealed local steroid was less costly and more effective ($62, 1.51 QALYs) than both IV steroid ($627, 1.49 QALYs) and no steroid ($1860, 1.49 QALYs). In a three-way sensitivity analysis (SA) varying the probabilities of fusion for each treatment strategy (0.92-0.9999) and in a three-way SA varying the probabilities of wound complication for each treatment strategy (0.001-0.04), local steroid was the most cost-effective strategy across the majority of the values considered. The no steroid strategy was not the preferred option at any of the combination of values explored. Lastly, PSA revealed local steroid was cost-effective 86% of the time at a WTP of $50,000/QALY (Figure 2).

Conclusion: A single dose of intraoperative local triamcinolone is the most cost-effective treatment for the reduction of dysphagia and dysphonia following ACDF for degenerative disease.

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Figure 1. Decision tree model

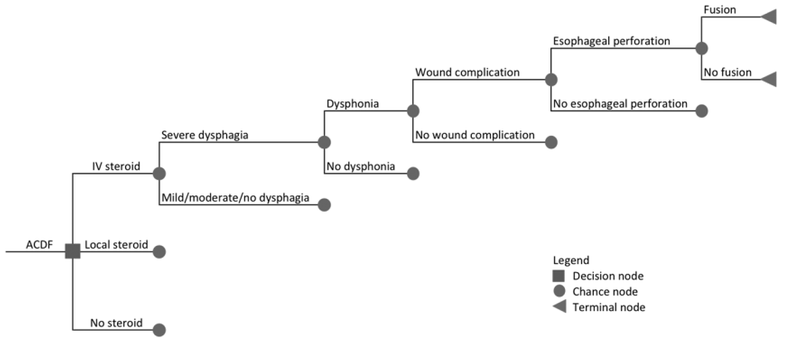
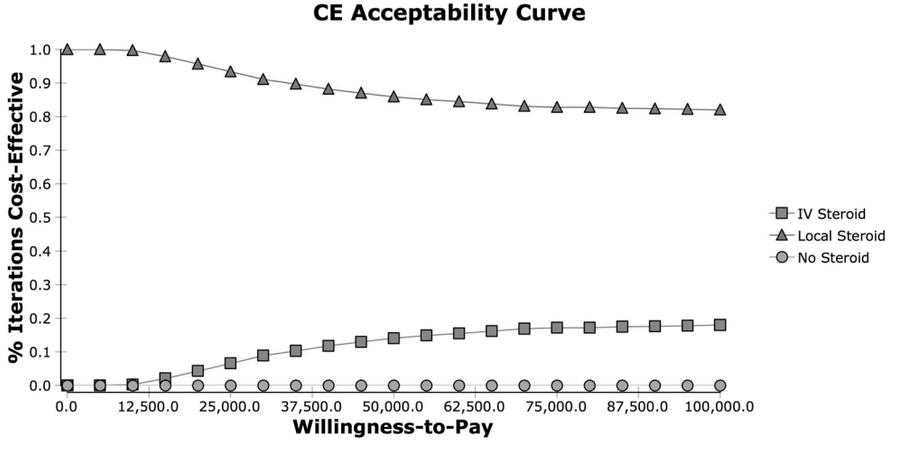


Figure 2. Results of the probabilistic sensitivity analysis (PSA).



See Disclosure Index pages 41–95.

Presentation #74

Is There a Preoperative Morphine Equianalgesic Dose that Predicts Ability to Achieve a Clinically Meaningful Improvement Following Spine Surgery?

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Introduction: Preoperative opioid use is widespread and associated with worse patient reported outcomes following spine surgery. This study was conducted to calculate a threshold preoperative morphine equianalgesic (MEA) dose beyond which patients are less likely to achieve the minimum clinically important difference (MCID) following elective surgery for degenerative spine disease.

Methods: This study included 543 cervical and 1293 lumbar patients enrolled in a prospective, web-based registry. Neck Disability Index (NDI) and Oswestry Disability Index (ODI) were collected at baseline and 12 months postoperatively, and combined into a single outcome variable. The level of surgical invasiveness for each patient was determined using previously accepted methodology. Preoperative MEA doses were calculated retrospectively. Multivariate logistic regression adjusting for level of surgical invasiveness, baseline psychiatric comorbidities, and baseline disability, was then performed to determine the relationship between MEA dose and the odds of achieving MCID. As a part of this regression, Bayesian inference and Markov Chain Monte Carlo (MCMC) methods were used to estimate the values of inflection points (or "thresholds") in MEA.

Results: Overall, 1,020 (55.5%) patients used preoperative opioids, with distribution of opioid use shown in Figure 1. A total of 50.3% of cervical and 61.9% of lumbar patients achieved MCID. The final logistic regression model (Figure 2) demonstrated that MCID achievement decreased significantly when mean preoperative MEA dose exceeded 47.8 mg/day, with a 95% credible interval of 29.0–60.0 mg/day.

Conclusion: Patients using preoperative MEA doses exceeding 47.8 mg/day are significantly less likely to achieve clinically meaningful improvement following spine surgery. Patients with preoperative MEA dose exceeding 29 mg/day, the lower limit of the 95% credible interval for the mean MEA dose above which patients exhibit significantly decreased achievement of MCID, may be considered for preoperative opioid weaning.

Saturday, December 2, 2017, 9:08–9:13 am CSRS–2017

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Figure 1. Historgram demonstrating the distribution of preoperative morphine equianalgesic dose usage in milligrams per day among patients included in the study cohort.

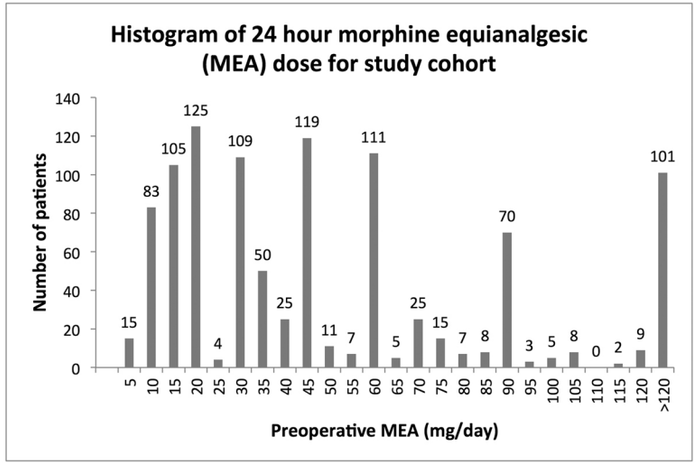
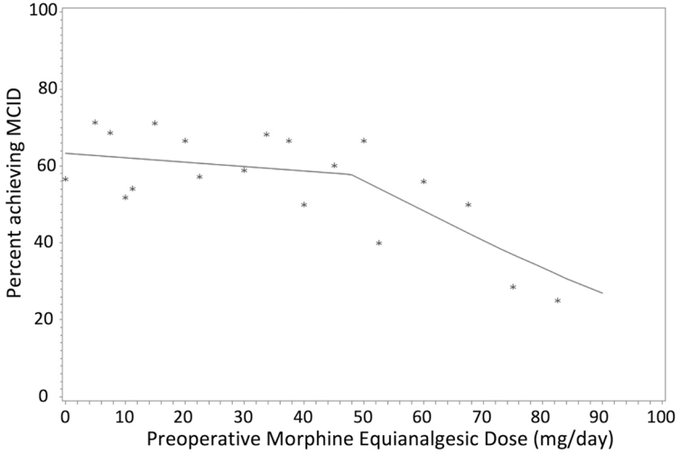


Figure 2. Multivariate linear regression model for achievement of the minimum clinically important difference (MCID) in Neck Disability Index and Oswestry Disability Index versus preoperative morphine equianalgesic dose.



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Presentation #75

The Natural History of Acute Cervical Radicular Pain

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Introduction: Cervical radicular pain is a common disorder characterized by upper limb pain resulting from cervical nerve root irritation. Despite the prevalence of this disorder, there is very little high quality research on its natural history. Existing studies on this topic are limited because they are retrospective series, include chronic cases, are part of treatment comparison studies, or do not use validated patient reported outcome measures. The purpose of this study is to prospectively characterize the natural history of acute cervical radicular pain for a period of 12 months.

Methods: A total of 60 consecutive patients with acute cervical radicular pain were included. This number was based on a power analysis to show a minimum clinically important difference (MCID) on the neck disability index (NDI). Inclusion criteria included radicular pain for less than one month with a clear radicular pattern below the elbow, at least one positive neurologic finding on exam (motor, sensory, reflex change) or positive Spurling's test, and age 18–75. MRIs were ordered on all subjects. Follow-up was done at 6 weeks, 3, 6 and 12 months. Primary outcome measure was NDI. Secondary outcomes were mean NRS (numerical rating scale) pain scores when not taking pain medications, substantial clinical benefit (SCB) for NDI, whether surgery was performed and medication use. Patients were asked if their pain was worse, same or better (mildly, moderately or markedly). Treatment was conservative without utilizing major medical or surgical treatments within first 3 months. Patients received NSAIDs unless contra-indicated. If pain was severe, there was an option for short-term opiates.

Results: A total of 62 patients were consented but two were excluded for myelopathy. Mean baseline NDI was 40.9 (95% CI: 36.7, 45.1). This dropped to 29.5 (24.8, 34.2), 22.1 (16.7, 27.5), 19.5 (14.3, 24.7) and 17.9 (12.7, 23.1) at 6 weeks, 3, 6 and 12 months respectively (Figure 1). The percent having SCB was 49.1%, 67.3%, 75.9% and 80.8% at 6 weeks, 3, 6 and 12 months. Upper limb mean NRS pain scores started at 8.0 (7.5, 8.4) and went to 4.6 (3.78, 5.5), 3.0 (2.2, 3.8), 2.1 (1.4, 2.7) and 1.8 (1.1, 2.5) at 6 weeks, 3, 6 and 12 months (Figure 2). Neck pain started at 5.4 (4.6, 6.2) and ended at 1.8 (1.1, 2.5) at 12 months. The total number of patients that reported moderate-to-marked improvement of their pain was 52.7%, 74.5%, 81.5% and 84.6% at 6 weeks, 3, 6 and 12 months. Five subjects underwent surgery. Of the initial 60 subjects, 57, 56, 54 and 52 completed questionnaires at 6 weeks, 3, 6 and 12 months respectively.

Conclusion: This study suggests a favorable natural history of acute cervical radicular pain with the majority of improvement occurring in the first three months. At one year 85.6% reported moderate-to-marked improvement in their symptoms and only 8% of patients had surgery. Our study is the first prospective study of the natural history of acute cervical radiculopathy using NDI and NRS and may guide treatment of acute cervical radiculopathy.

Saturday, December 2, 2017, 9:14–9:19 am CSRS–2017

Presentation #75

Figure 1. Mean NDI and 95% confidence intervals over time, adjusting for correlation within study subjects (p-value<0.0001)

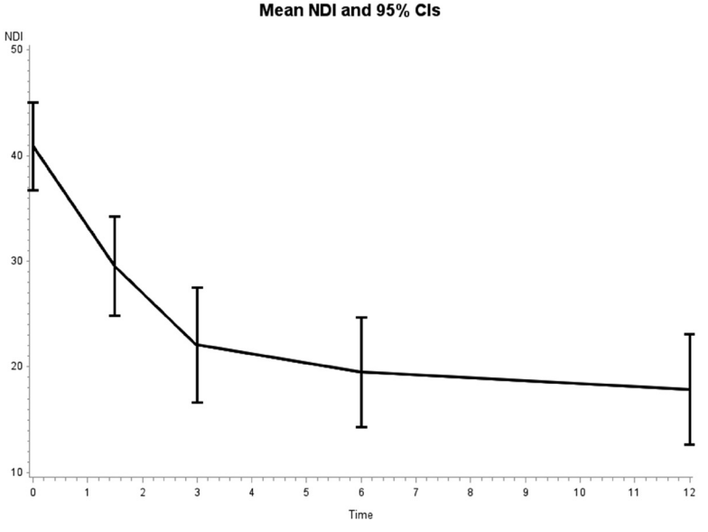
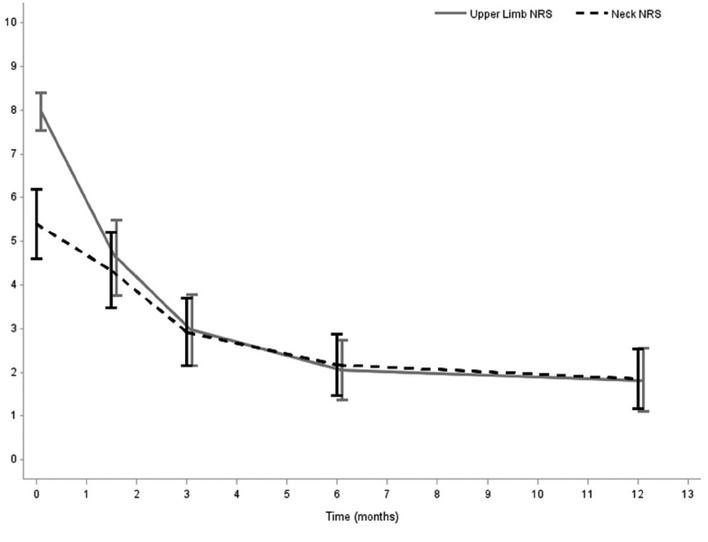


Figure 2. Mean upper limb pain (scapular, arm, forearm, hand) and neck NRS pain score and 95% confidence intervals over time.



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Presentation #76

The Impact of Local Steroid Application on Dysphagia Following an Anterior Cervical Discectomy and Fusion: Preliminary Results of a Prospectively, Randomized, Single Blind Trial

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Background Information: Intraoperative local steroid application has been theorized to reduce swelling and to improve swallowing in the immediate postoperative period following an anterior cervical discectomy and fusion (ACDF). As such, the purpose of this study is to quantify the impact of intraoperative local steroid application on patient-reported swallow function and postoperative swelling following an ACDF.

Materials / Methods: A prospective, randomized, single-blinded controlled trial was conducted. A total of 38 patients undergoing 1- or 2-level ACDF procedures for degenerative spinal pathology were randomized to depomedrol (DEPO) or no depomedrol (NODEPO) cohorts. Prior to surgical closure, DEPO patients received 1cc depomedrol applied directly to the surgical site using a gel-foam carrier (retroesophageal). NODEPO patients received 1cc saline on the same gel-foam carrier. Patients were blinded to the application of steroid or saline following surgery. The SWAL-QOL (Quality of Life in Swallowing Disorders) questionnaire was administered both pre- and post-operatively with responses being compared between cohorts. Using preoperative and postoperative lateral radiographs, a ratio of the prevertebral swelling distance to the anterior posterior (AP) diameter of each vertebral body level C3-C5 was calculated. The ratios of the three levels were averaged and multiplied by 100 to obtain a swelling index. An air index was created using the same methodology, but using tracheal air window diameter in place of the prevertebral swelling distance. The changes in these radiographic ratios (from preoperative to 1 day, 6 weeks, and 12 weeks postoperatively) were compared between cohorts.

Results: Of the 81 patients, 41 patients (56.8%) were randomized to the DEPO cohort while 40 patients (43.2%) were randomized to the NODEPO group. No differences in baseline patient demographics or preoperative characteristics were demonstrated between cohorts. Similarly, estimated blood loss, operative time, and length of hospitalization did not differ between cohorts (Table 1).

There was no difference in the mean change in scaled total SWAL-QOL score between the DEPO and NODEPO patients at either postoperative time point (6 weeks: -4.1 vs. -6.5, p=0.484; 12 weeks: -2.4 vs. 0.3, p=0.143; Table 2).

Lastly, the mean change in both swelling and air indices demonstrated no differences between the DEPO and NODEPO cohorts at any postoperative time point (p>0.05 for each).

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Conclusions: The preliminary results of this prospective, randomized, single blinded study do not demonstrate an impact of local intraoperative steroid application on patient-reported swallowing function or postoperative swelling following an ACDF. Both cohorts exhibit an increase in radiographic swelling in the immediate postoperative period, which subsides to near normal levels by 6-weeks postoperatively. Administration of DEPO also did not lead to an earlier hospital discharge compared to the NODEPO cohort. Additionally, patient reported swallowing scores did not correlate with changes in radiographic swelling or airway diameter. Enrollment of additional patients is ongoing and will help determine the true impact of local intraoperative steroid application on patient-reported dysphasia.

Table 1. Baseline characteristics.*

	NODEPO (N=40)	DEPO (N=41)	p-value
Age (Mean±SD, years)	50.1±10.1	50.4±8.6	0.908
Sex (n)			0.558
Female	37.5% (15)	43.9% (18)	
Male	62.5% (25)	56.1% (23)	
Body Mass Index			0.212
Non-obese (BMI<30)	66.7% (16)	50.0% (16)	
Obese II (BMI≥30)	33.3% (8)	50.0% (16)	
Smoking Status (n)			0.667
Non-smoker	90.0% (36)	92.7% (38)	
Smoker	10.0% (4)	7.3% (3)	
Operative Level (n)			0.068
C3-C4	2.5% (1)	4.9% (2)	
C3-C5	2.5% (1)	2.4% (1)	
C4-C5	0.0% (0)	7.3% (3)	
C4-C6	2,5% (1)	22.0% (9)	
C5-C6	22.5% (9)	22.0% (9)	
C5-C7	35.0% (14)	24.4% (10)	
C6-C7	32.5% (13)	17.1% (7)	
C7-T1	2.5% (1)	0.0% (0)	
Number of Operative Levels (n)			0.427
1-level	60.0% (24)	51.2% (21)	
2-level	40.0% (16)	48.8% (20)	
Comorbidity Burden (CCI)	1.3±1.4	1.6±1.6	0.279
Preoperative VAS (Mean±SD, min)	5.8±2.6	6.5±2.7	0.269

SD=Standard deviation; CCI=Charlson comorbidity index; VAS=Visual Analogue Scale; BMI=Body mass index; DEPO=Depomedrol Cohort, NODEPO=No depomedrol cohort

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Presentation #76 (cont.)

Table 2. Perioperative, Swallowing, and Radiographic Outcomes.*

	NODEPO (N=40)	DEPO (N=41)	†p-value
Operative Time (Mean±SD, min)	55.6±17.5	53.0±14.8	0.101
Estimated Blood Loss (mL)	29.8±15.4	30.7±11.6	0.922
Length of Hospital Stay (hours)	11.8±10.1	13.3±9.8	0.951
SWAL-QOL Results (Mean±SD) ‡			
Preoperative	94.8±6.5	91.7±10.4	0.233
6-weeks Postoperative	93.2±6.7	89.8±13.0	0.365
12-weeks Postoperative	**95.1±5.9**	**89.1±13.3**	**0.026**
Changes in SWAL-QOL (Mean±SD) ‡			
Δ Preoperative to 6-weeks	-6.5±23.0	-4.1±19.1	0.484
Δ Preoperative to 12-weeks	0.3±4.9	-2.4±10.9	0.143
Swelling Index Average (Mean±SD) ∫			
Preoperative	71.2±16.8	65.6±18.9	0.517
6-week Postoperative	88.2±15.9	78.0±18.4	0.061
12-week Postoperative	83.0±13.6	78.8±19.8	0.468
Swelling Index Difference (Mean±SD) º			
6-week Postoperative	19.0±19.3	12.2±13.7	0.149
12-week Postoperative	15.5±22.9	13.0±13.6	0.548
Air Index Average (Mean±SD) ∫			
Preoperative	111.2±17.7	112.1±17.1	0.991
6-week Postoperative	108.3±19.9	105.2±22.0	0.399
12-week Postoperative	107.1±21.2	107.6±21.2	0.838
Air Index Difference (Mean±SD) º			
6-week Postoperative	-0.1±23.9	-6.2±16.5	0.290
12-week Postoperative	2.9±34.2	-3.9±19.1	0.421

SD=Standard deviation; CCI=Charlson comorbidity index; VAS=Visual Analogue Scale;
BMI=Body mass index
DEPO=Depomedrol Cohort; NODEPO=No depomedrol cohort;
SWAL-QOL=Quality of life in swallowing disorders survey
***Boldface** indicates statistical significance.
† P-value is from linear regression adjusted for preoperative characteristics observed in Table 1.
‡ SWAL-QOL scale=0-100; 0=Worse swallowing; 100=Better swallowing
∫ Air/Swelling Index Average=Average of Tracheal Air/Pretracheal Swelling Measurement for Index, Index±1-level
º Air/Swelling Index Difference=Postoperative Air/Swelling Index Average – Preoperative Air/Swelling Index Average

Presentation #77

Do Cervical Spine Surgery Patients Recall Their Preoperative Status? A Cohort Study of Recall Bias in Patient-Reported Outcomes

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Introduction: Surgery for cervical degenerative myelopathy or radiculopathy focuses on addressing pain and disability while improving the patients' quality of life. Although Patient-Reported Outcomes (PROs) are being widely adopted, their interpretability may be limited by the accuracy of a patient's ability to recall preintervention impairment. Recall bias has been previously investigated in multiple orthopedic and lumbar spine studies, but recall accuracy in cervical spine patients remains unknown. We sought to characterize the accuracy of patient recall as a function of time on validated outcomes after cervical spine surgery.

Materials / Methods: We analyzed a consecutive series of patients undergoing cervical spine surgery for degenerative myelopathy or radiculopathy at a single institution. Using standardized questionnaires, we recorded preoperative neck and arm Numeric Pain Scores (NPS), Neck Disability Indices (NDI) and 36-Item Short Form Health Survey (SF-36). Patients were asked to recall their preoperative status through a standardized phone-call script and were subsequently stratified based on the timing of their recall into short-term (<1 year) and long-term (>1 year) follow-up sub-groups. Actual and recalled scores were compared using McNemar's or paired t tests, and relations were quantified using Pearson correlation coefficients. Characteristics between the subgroups were compared using Wilcoxon rank sum tests, t-tests, chi-square tests, or Fisher's exact tests as appropriate.

Results: Seventy-three patients with a mean age of 58.2 years (range 22 to 83 years) were included, with 34 and 39 patients in the short-term and long-term follow-up subgroups patients respectively. The mean period of recall from surgery was 4.6 months and 22.2 months for the short-group and long-term follow-up subgroups respectively. Compared to the preoperative scores, patients showed significant improvement in neck NPS (mean difference [MD]=-2.9, 95% CI -3.5 to -2.3), arm NPS (MD -3.4, 95% CI -4.0 to -2.8), and NDI (MD -12.4%, 95% CI -16.9 to -7.9). Patient recollection of preoperative status was more severe than actual for neck NPS (MD+1.5, p< 0.001), arm NPS (MD+2.3, p< 0.001), and NDI (MD+5.8%, p<0.001) and this was maintained across the sub-groups as shown in the Table. No difference in recall accuracy was noted in SF-36 scores signifying that patients could accurately recall their pre-operative physical and mental health status. Moderate correlation between actual and recalled scores for neck NPS (r=0.41), arm NPS (r=0.50), NDI (r=0.67), and a strong correlation in SF-36 scores (r=0.74) was observed. Further, the predominant symptom was switched from neck pain to arm pain or arm pain to neck pain on recall for 31.5% of patients.

See Disclosure Index pages 41 – 95.

Presentation #77 (cont.)

Conclusion: Patient recollection of preoperative status after cervical spine surgery was significantly more severe than their actual preoperative status for neck pain, arm pain, and disability. Relying on retrospectively recalled data for outcome assessment does not provide an accurate measure of preoperative status. Prospective collection of PROs remains the gold standard to measure outcomes following cervical spine surgery.

Table 1:

Outcome measure	Short-term sub-group (n= 34) Δ in Patient Recall of Preoperative and Actual Preoperative Mean (SD)	Long-term subgroup (n= 39) Δ in Patient Recall of Preoperative and Actual Preoperative Mean (SD)	All patients (n= 73) Δ in Patient Recall of Preoperative and Actual Preoperative Mean (SD)
NPS neck	+1.4 (2.8)	+1.5 (3.6)	+1.5 (3.2)
NPS arm	+2.2 (2.8)	+2.1 (2.9)	+2.3 (2.9)
NDI (%)	+6.1 (13.9)	+5.6 (16.0)	+5.8 (14.9)

All p-values were significant (P< 0.05); A positive sign indicates a worse recalled score compared to the actual preoperative score for each outcome measure.

Presentation #78

The Impact of Preoperative Depression on Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) Survey Results in a Cervical Spine Surgery Setting

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Introduction: Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) surveys are used to measure the quality of the patient experience, and directly influence reimbursement for hospital systems and spine surgeons in the United States. While it is well-established in the literature that untreated depression is associated with worse functional outcomes in cervical spine surgery, relatively few studies have analyzed the association between depression and patient satisfaction in this setting. Therefore, we sought to elucidate whether HCAHPS responses were impacted by preoperative depression in a population undergoing cervical spine surgery.

Methods: Prospectively collected functional outcome data including Patient Health Questionnaire (PHQ-9), EuroQol 5 Dimensions index (EQ-5D), and Visual Analog Scale for neck pain (VAS-NP) were analyzed preoperatively. Preoperative PHQ-9 scores of greater than or equal to 10 (moderate to severe depression) defined our depressed cohort of patients. HCAHPS responses were obtained for each individual, along with patient demographic, surgical and other preoperative patient characteristics. Descriptive statistics summarizing population and surgical characteristics were compared using chi-squared tests for categorical variables and student's t-tests for continuous variables. Additionally, multivariable logistic regression analysis was performed to determine whether preoperative depression was independently associated with top-box satisfaction, while adjusting for a number of important covariates.

Results: In our 145 patient cohort, depressed patients were on average younger (p=0.003), experienced higher neck pain (p<0.001) and had a lower EQ-5D index (p<0.001). 87.8% of depressed patients felt doctors treated them with respect, compared to 97.1% of patients without depression (p=0.027). Also, depressed patients felt doctors did not always listen to them carefully (p=0.030). After adjusting for age, gender, neck pain and EQ-5D, multivariable logistic regression analysis revealed that patients with preoperative depression had lower odds of feeling respected by physicians (Odds Ratio=0.14, p=0.035).

Conclusions: In patients undergoing cervical spine surgery, preoperative depression was shown to have negative impact on patient perception of doctor communication as measured by the HCAHPS survey. These results suggest that depression may be a modifiable risk factor for poor experience communicating with their spine surgeon.

See Disclosure Index pages 41–95.

Presentation #79

Psychosocial Risk Factors for Chronic Opioid Use After Single-Level Cervical Fusion for Radiculopathy: A Workers' Compensation Population

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Introduction: Postoperative pain is an important concern in patients who undergo surgery; up to 75% of patients often experience moderate to severe pain that interferes with postoperative rehabilitation and discharge from hospital. While the use of opioids may be effective over the short term, evidence is lacking to support the overall benefits of long term postoperative pain management with opioid medications. In addition, opioid use requires special attention in patients with work-related injuries receiving benefits from workers' compensation systems, which is considered a high risk population for poorer surgical and functional outcomes. We aim to evaluate presurgical psychosocial and surgical risk factors associated with chronic opioid use after single-level cervical fusion for radiculopathy in a WC population.

Materials / Methods: A retrospective study using data was from Ohio Bureau of Workers' Compensation (BWC) between 1993 and 2011 for subjects with work related injuries. We identified 1,927 patients who had single-level cervical fusion for radiculopathy and had a minimum of 3 years of follow-up after surgery. 493 patients received opioids after surgery. Based on opioid use after surgery, two groups were constructed. Chronic opioid use group included 349 patients who received opioids >3months after fusion, and short-term opioid use group included 144 patients who received opioids <3months after fusion. Using multivariate logistic regression model, predictors of chronic opioid use after fusion were identified. Secondary outcome measures include: Return-To-Work (RTW) <3years after surgery, reoperation rate, psychological comorbidities, permanent disability filed (partial and total) after fusion, and total medical costs per claim.

Results: The regression model showed that preoperative opioid use was an independent risk factor for chronic opioid use (OR: 1.84; 95% CI: 1.12–3.04, p: 0.01). At work status within one month of fusion was negatively associated with chronic opioid use (OR: 0.40; 95% CI: 0.24–0.70, p: 0.001). Preoperative conservative measures, psychological comorbidities diagnosed prior to fusion, as well as surgical factors were not significant predictors of chronic opioid use after fusion.

At 3 years follow-up after fusion, chronic opioid use was associated with 9% higher reoperation rate, 8% higher rate of gained permanent disability, 10% higher rate of newly diagnosed psychological comorbidities, more than $30,000 higher total medical costs, and 22% lower RTW rate.

Conclusion: Postoperative opioid use is an important measure for successful surgery. Activity level and opioid use prior to surgery were paramount to determining opioid use level after surgery. Future studies should evaluate other risk factors that may impact spine surgery outcomes particularly in high-risk populations.

Presentation #80

The Impact of Multiple Patient-Reported Allergies on Clinical Outcomes after Anterior Cervical Discectomy and Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a viable treatment for degenerative cervical spine disease. Multiple patient-reported allergies have been shown in the hip and knee arthroplasty literature to be associated with poor clinical outcomes. This relationship has not been studied in the cervical spine literature. The goal of this study was to assess the impact of multiple patient-reported allergies on patient-reported outcome (PRO) measures following ACDF. Being able to identify patients who are at increased risk for poor post-operative results allows surgeons to effectively counsel patients pre-operatively on potential surgical risks and benefits.

Materials / Methods: This was a retrospective cohort study of 86 adult patients with the following inclusion criteria: age≥18, a primary diagnosis of degenerative cervical spine disease with symptomatic myelopathy, radiculopathy, or myeloradiculopathy, undergoing anterior cervical discectomy and fusion, and 1–6 month post-operative follow up. PROMIS physical function (PF), pain (PI), depression and Neck Disability Index questionnaires were completed pre-operatively and at early follow-up (1–6 months). Patients were divided into≤1allergy or ≥2allergy groups. Student's T test was used for continuous variables and Fisher's exact test for categorical variables. A multivariate regression model was constructed to assess the impact of peri-operative variables on PROMIS PF and PI outcomes. Significance was set at $p<0.05$.

Results: There were 62 patients with ≤1 allergy and 24 patients with ≥2 allergies with similar baseline age, BMI, comorbidities and surgical indications (Table 1). Number of levels fused, EBL, and length of surgery were similar between groups. Patients with multiple allergies had more depression at baseline (54.75 vs. 48.99, p=0.02). Furthermore, they continued to have worse PROMIS depression scores at early follow-up (51.24 vs. 45.58, p=0.03). However, there was no significant difference between the ≤1allergy and ≥2allergy groups when comparing the change in all scores from the pre-operative to post-operative time period (Δ (delta) NDI -12.61 vs. -18.18, p=0.2; Δ (delta) PROMIS PF 4.54 vs. 7.40, p=0.19; Δ (delta) PROMIS PI -7.45 vs. -7.60, p=0.95; Δ (delta) PROMIS Depression -3.41 vs. -3.51, p=0.97) (Table 2). Regression analysis demonstrated no significant relationship between number of allergies and PRO measures.

Conclusion: Patients with multiple self-reported allergies had more depression at baseline compared to patients with one or no allergies. Their depression also did not significantly improve post-operatively. Contrary to hip and knee replacement studies, multiple allergies did not negatively affect post-operative PRO measures. Both groups had significant improvement in PROMIS physical function, pain and NDI scores at early follow-up and the relative change from baseline in these measures was similar for the two groups. Surgeons can utilize multiple self-reported allergies as a potential indicator of depressive symptoms, but can expect similar improvement in PROs after ACDF for cervical degenerative disease.

See Disclosure Index pages 41–95.

Presentation #80 (cont.)

Table 1. Patient Demographics and Surgical Data

Demographics/Surgical Data	≤1 Allergy (n=62)	≥2 Allergies (n=24)	p Value
Age (years)	53.26 ± 1.66	53.88 ± 2.25	0.83
Sex (males)	41	7	0.003
Body Mass Index	28.95 ± 0.79	29.08 ± 1.19	0.93
Diabetes	10	3	0.99
Smoker	4	2	0.99
Myelopathy	17	9	0.43
No. of Surgical Levels	1.85 ± 0.11	1.75 ± 0.19	0.62
Length of Surgery (hours)	2.42 ± 0.21	2.57 ± 0.35	0.69
EBL (mL)	48.85 ± 8.79	59.38 ± 18.14	0.56

Table 2. Patient reported outcome measures

Surveys	≤1 Allergy		≥2 Allergies		p Value
Pre-Operative NDI	38.09 ± 2.25		45.56 ± 2.90		0.06
Post-Operative NDI	25.27 ± 2.19		28.4 ± 3.69		0.46
Δ NDI	(-) 12.61 ± 17.92	<0.0001	(-) 18.18 ± 17.68	<0.0001	0.2
Pre-Operative PROMIS PF	39.28 ± 1.03		36.27 ± 1.26		0.1
Post-Operative PROMIS PF	43.81 ± 1.19		43.67 ± 1.73		0.95
Δ PROMIS PF	4.54 ± 9.3	0.0003	7.40 ± 8.44	0.0003	0.19
Pre-Operative PROMIS Pain	64.11 ± 0.85		65.98 ± 0.98		0.21
Post-Operative PROMIS Pain	56.66 ± 1.27		58.38 ± 1.60		0.45
Δ PROMIS Pain	(-) 7.45 ± 10.53	<0.0001	(-) 7.60 ± 7.93	<0.0001	0.95
Pre-Operative PROMIS Depression	48.99 ± 1.33		54.75 ± 2.05		0.02
Post-Operative PROMIS Depression	45.58 ± 1.26		51.24 ± 2.58		0.03
Δ PROMIS Depression	(-) 3.41 ± 10.18	0.01	(-) 3.51 ± 11.84	0.16	0.97

Presentation #81

Impact of Obesity on Radiographic Alignment and Short-Term Complications after Surgical Treatment of Adult Cervical Deformity

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Introduction: Obesity can alter compensation for sagittal deformity and is an established risk factor that increases complications in thoracolumbar deformity surgeries. However, little is known whether higher BMI alters radiographic cervical alignment or increases complications after cervical deformity correction. The purpose, therefore, was to investigate 30-day complication incidence and 1-year radiographic correction in patients undergoing surgical treatment for cervical deformity.

Methods: Patients were stratified according to world health organization's definition for obesity into: Obese (O group; patients with BMI+30) and Non-Obese (NO group; BMI<30). Patient baseline demographic, comorbidity, and radiographic data were compared between the groups at baseline and 1 year follow-up. 30-day complication incidence was stratified according to complication severity (any, major, or minor), and type (cardiopulmonary, dysphagia, infection, neurological, and operative). Binary logistic regression model was utilized to investigate the impact of obesity on developing those complications adjusting for patient's age and levels fused.

See Disclosure Index pages 41–95.

Presentation #81 (cont.)

Results: 124 patients were included and grouped into 53 Obese and 71 Non-Obese patients. The two groups had similar TS-CL (O: 37.2º vs. NO: 36.9º, p=0.932), similar C2-C7 (-5.9º vs. -7.3º, p=0.718), and C2-C7 SVA (50.1 mm vs. 44.1 mm, p=0.184). At baseline, obese patients displayed different lumbopelvic parameters: greater c2-s1 SVA (O: 65.8 mm vs. NO: 30.2mm, p=0.015), less T1SPTI (-4.2º vs. -6.7º, p=0.044), and similar T1PA (16.9º vs. 12.5º, p=0.062). Radiographic cervical correction at 1 year was similar: TS-CL (O: +8.2º vs. NO: +9.8º, p=0.749), C2-C7 SVA (O: +0.9mm vs. NO:+5.1 mm, p=0.190), and C2-C7 lordosis (O: -14.3º vs. NO: -15.0º, p=0.897). At 1 yr T1PA (1.0º vs. -3.1º, p=0.021) and C2-S1 SVA (-5.9mm vs. -35.0mm, p=0.036) were different, while T1SPTI (-1.0º vs. -2.9º, p=0.123) was similar. Obesity did not increase the incidence of any complication at 30-day, including when all categories were combined: OR: 1.096 CI: 0.844–2.146. Patient age and levels fused were controlled for, but there was no increase in any type of complication category assessed: cardiopulmonary, dysphagia, infection, neurological, and operative (all p>0.05).

Conclusions: Obese patients are at similar risk of developing short-term complications after surgical treatment for adult cervical deformity. Cervical alignment was similar at baseline and 1 year follow up. However, persistent global malalignment was observed in patients with increased body mass after their cervical deformity surgeries. While preoperative weight loss in obese patients with thoracolumbar deformity may be beneficial in preventing complications, it may not carry the same magnitude of negative impact in cervical patients.

Presentation #82

Predictive Model for Distal Junctional Kyphosis After Cervical Deformity Surgery

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Background: Although advances in alignment targets frequently allow for good short-term clinical results, the durability of cervical deformity correction remains a challenge. Revision rates frequently exceed 20%. Junctional kyphosis is one of the most important risks surgeons consider in planning surgical correction for cervical deformity. Distal junctional Kyphosis (DJK) is defined as construct failure or loss of alignment one or two levels distal to the lowest inststrumented vertebra. DJK results from fixation failure, adjacent level fracture, or spondylolisthesis and results in pain, radiculopathy, myelopathy, and deformity.A Random Forest statistical model employed on a large, multi-center study group database may allow for valuable insights into DJK avoidance generalizable to a plethora patient groups.

Methods: Patients undergoing surgery to correct cervical deformity were consecutively enrolled. Cervical deformity was defined as one of the following: cervical kyphosis (C2-7 Cobb angle >10°), cervical scoliosis (coronal Cobb angle >10°), positive cervical sagittal imbalance (C2-C7 sagittal vertical axis >4cm or T1-C6 >10 o), or horizontal gaze impairment (chin-brow vertical angle >25o). DJK was defined by both clinical diagnosis (by enrolling surgeon) and post-hoc identification of development of an angle <-10 degrees from the end of fusion construct to the 2nd distal vertebra, as well as a change in this angle by <-10 from baseline. Conditional Inference Decision Trees were used to identify factors predictive of DJK incidence and the cut-off points at which they have an effect. A conditional Variable-Importance table was constructed based on a non-replacement sampling set of 2,000 Conditional Inference Trees. 12 influencing factors were found, binary logistic regression for each variable at significant cut-offs indicated their effect size.

See Disclosure Index pages 41–95.

Presentation #82 (cont.)

Results: Statistical analysis included 101 surgical patients (average age: 60.1 years, 58.3% female, BMI: 30.2) undergoing long cervical deformity correction (mean levels fused: 7.1, osteotomy used: 49.5%, Approach: 46.5% Posterior, 17.8% Anterior, 35.7% Combined). In two years after surgery 6% of patients were diagnosed with clinical DJK, however 23.8% of patients met radiographic definition for DJK. Patients with neurologic symptoms were at risk for DJK (OR:3.71 CI:0.11-0.63). However, no significant relationship was found between osteoporosis, age, or ambulatory status with DJK incidence. Baseline radiographic malalignments were more the most numerous and strong predictors for DJK: [1] C2-T1 Tilt >5.33 (OR:6.94 CI:2.99 – 16.14), [2] Kyphosis <-50.6º (OR:5.89 CI:0.07 – 0.43), [3] C2-C7 lordosis <-12º (OR:5.7 CI:0.08-0.41), [4] T1 Slope minus Cervical Lordosis>36.4 (OR:5.6 CI:2.28 – 13.57), [5] C2-C7 SVA>56.3º (OR:5.4 CI:2.20 – 13.23), and [6] C4_Tilt >56.7 (OR:5.0 CI:1.90 – 13.1).Clinically, combined approaches (OR:2.67 CI:1.21 – 5.89) and usage of Smith Petersen osteotomy (OR:2.55 CI:1.02 – 6.34) were the most important predictors for DJK.

Conclusions: Different procedures and patient malalignment predicted incidence of DJK up to 1-year. Preoperative C2-T1 Tilt, Cervical Kyphosis, SVA, and Cervical Lordosis all strongly predicted DJK at specific cut-off points.

Presentation #83

Identifying Sources of Improvement of Axial Pain in Corrective Cervical Deformity Surgery

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Introduction: Cervical deformity (CD) patients are frequently older with numerous comorbidities and an uncertain ability to heal, making it difficult to justify total scoliosis correction. Neck pain, radiculopathy, and deformity are the primary complaints of CD patients. Identifying factors most likely to improve symptomology is key to patient selection and improving surgical outcomes. Our purpose, therefore, was to identify key prognostic variables associated with improvements in neck pain after cervical deformity surgery.

Methods: Patients undergoing cervical surgery to correct deformity were consecutively enrolled. Cervical deformity was defined as any one of the following: cervical kyphosis (C2-7 Cobb angle >10°), cervical scoliosis (coronal Cobb angle>10°), positive cervical sagittal imbalance (C2-C7 sagittal vertical axis>4cm or T1-C6 >10 o), or horizontal gaze impairment (chin-brow vertical angle>25o). Patients who reached 1 year postoperative MCID (defined as improvement >2.6 in NRS Neck and >1.2 in NRS Back) for pain improvement were compared to those who did not. Two groups, those who met MCID (MCID group), and those who did not (NOT group), were constructed with equal baseline Numeric Rating Scale (NRS) for neck pain by propensity score matching for baseline pain. Clinical and deformity data were analyzed using t-tests to identify how treatments that improved neck pain and back pain differed from those that did not.

See Disclosure Index pages 41 – 95.

Presentation #83 (cont.)

Results: 122 patients (61.1 years, 60.4% female, 30.1 average BMI) presented with an average baseline neck pain score of 7.0. Patients improved neck pain at each follow-up time-point: 3 months (4.4), 6 months (4.0), and 1-year (4.4), all $p<0.05$. 51.1% of patients reached 1-year MCID improvement for neck pain. 33 MCID group patients were compared with 33 NOT group patients after matching for similar baseline NRS neck pain (neck MCID group: 7.0 vs. NOT: 6.8, $p=0.72$). NOT group patients had significantly more posterior approach surgeries (MCID: 37.5% vs. NOT: 62.5%, $p=0.04$) and were more frequently revisions (MCID: 25.8% revision vs. NOT: 53.1%, $p=0.03$), but had similar levels fused (MCID: 7.2 levels fused vs. NOT: 8.1 levels, $p=0.32$). Either group had similar cervical deformities, as measured by TS-CL, C2-C7 lordosis, and cervical SVA, all $p>0.05$. However, MCID group patients presented with large lumbar deformities: Pelvic Tilt (MCID: 22.3 vs. NOT: 16.6, $p<0.05$) and PI-LL (MCID: 5.4 vs. NOT: -4.5, $p=0.02$). There was no significant overlap between patients who improved in back pain with those who improved in neck pain (MCID: 9.4% vs. NOT: 21.9%, $p=0.30$).

Conclusions: Revision status and posterior approach were found to be predictors of failure to reach significant improvement in neck pain. Patients also improved in lower back pain following cervical realignment, despite having primary cervical pathology.

Presentation #84

Sagittal Alignment Parameters Associated with Adjacent Segment Pathology After Anterior Cervical Discectomy and Fusion

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Introduction: Changes in the cervical alignment from preoperative to postoperative may alter cervical spine mechanics, and increase the rate of early adjacent segment pathology. We sought to evaluate the relationship between cervical spine sagittal alignment and adjacent segment disease (ASD) following anterior cervical discectomy and fusion (ACDF) as determined by radiographic and clinical outcomes.

Methods: Patients undergoing ACDF from 2008-2015 who developed radiographic signs of ASD(+) were identified and compared to a matched group of ACDF patients who did not develop radiographic evidence of ASD(-) for a period of at least 1 year. The number / location of levels fused was recorded and radiographs were reviewed preoperatively, immediately postoperative, and at final follow up. The sagittal parameters measured included change in C2-C7 lordosis, T1 angle, levels fused, sagittal vertical axis (SVA), fusion mass lordosis, proximal and distal adjacent segment lordosis. Appropriate statistical tests were performed to calculate relationships between the variables and the development of ASD.

Results: 101 ASD(+) patients were identified having underwent ACDF from 2008-2015 and compared to 131 ASD(-). The ASD(-) were free of ASD for a period of at least 1 year. The groups were similar with regard to demographic and surgical variables, but with a predominance of males in the ASD group 61.2% ($p=0.001$). Rigid plates were used in 42% of all constructs and were more represented in the ASD(-) than ASD(+) group (48% vs. 33%, respectively, $p=0.017$). The most common levels included in the fusion were C5-7 (28%). For all patients, preoperative lordosis was increased from 4.8±11.4 degrees to 7.9±10.2 degrees postoperatively and improved to 9.4±9.9 degrees at final followup (Table 1). Patients with greater kyphosis throughout the cervical spine at final followup had increased odds of developing ASD (OR 0.97 per degree, $p=0.040$). Patients with greater preoperative kyphosis through the planned fusion segment had increased odds of ASD (OR 0.93 per degree, $p=0.003$). Patients who lost lordosis through the fusion from initial postop to final followup had greater odds of developing ASD (OR 0.85 per degree, $p<0.001$). Patients who had greater change in preoperative to postoperative fusion segment lordosis were found to exhibit a greater risk of ASD (OR 1.06 per degree, $p=0.019$) [Table 2]. The SVA and T1 slope angles did not change substantially from preoperative to postoperative and there were no differences between ASD groups. The mean postoperative and final proximal and distal segment lordosis was also not different between groups except for significantly less proximal adjacent segment lordosis in ASD patients at final follow-up (0.2±5.0 vs. 1.4±4.4; $p=0.026$).

See Disclosure Index pages 41 – 95.

Presentation #84 (cont.)

Conclusions: Our results suggest that preoperative and postoperative measures of cervical spine alignment, specifically related to C2-C7 and fusion segment lordosis, may predict the development of radiographic signs of adjacent level pathology following an ACDF.

Table 1. Sagittal parameters preoperatively and postoperatively

				Bivariate		Multivariate	
	No ASD	**ASD**	**All patients**	Odds Ratio*	p-value	Odds Ratio*	p-value
Preoperative							
Lordosis (deg)	5.3±11.2	4.1±11.7	4.8±11.4	0.99	0.432	0.99	0.368
SVA (mm)	26.8±11.5	28.4±10.5	27.5±10.5	1.01	0.298	1	0.755
Fusion seg lordosis (deg)	1.4±6.5	-1.1±7.1	0.3±6.9	0.94	0.009	0.93	0.003
T1 slope (deg)	26.4±7.8	26.1±9.0	26.2±8.3	0.99	0.826	0.99	0.922
Proximal lordosis (deg)	1.9±8.5	2.3±8.4	2.1±8.4	1.00	0.721	1.02	0.342
Distal lordosis (deg)	4.1±4.6	3.3±4.9	3.8±4.7	0.96	0.325	0.97	0.422
Immediate postoperative							
Lordosis (deg)	8.6±10.5	6.9±9.8	7.9±10.2	0.98	0.204	0.98	0.247
SVA (mm)	28.3±10.1	31.5±11.2	29.7±10.7	1.02	0.032	1.02	0.094
Fusion seg lordosis (deg)	7.3±5.3	5.8±6.4	6.6±5.8	0.96	0.062	0.97	0.186
T1 slope (deg)	28.4±7.6	28.2±7.5	28.3±7.6	0.99	0.86	1.00	0.933
Proximal lordosis (deg)	1.8±9.3	1.5±8.4	1.7±8.9	0.99	0.792	1.00	0.889
Distal lordosis (deg)	3.2±4.9	2.3±4.9	2.8±4.9	0.96	0.253	0.94	0.105
Final							
Lordosis (deg)	10.6±9.9	8.0±9.8	9.4±9.9	0.97	0.056	0.97	0.040
SVA (mm)	26.7±10.9	29.7±9.7	28.0±10.4	1.03	0.033	1.03	0.078
Fusion seg lordosis (deg)	7.1±5.4	3.7±6.3	5.6±6.0	0.90	<0.001	0.9	<0.001
T1 slope (deg)	29.4±7.7	28.9±7.5	29.2±7.6	0.99	0.765	0.99	0.809
Proximal lordosis (deg)	3.2±8.9	2.3±8.6	2.8±8.6	0.99	0.434	0.99	0.471
Distal lordosis (deg)	4.4±4.9	3.6±5.3	4.0±5.1	0.97	0.351	0.96	0.206

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

Presentation #84

Table 2. Change in parameters at different time points

				Bivariate		Multivariate	
	No ASD	**ASD**	**All patients**	Odds Ratio*	p-value	Odds Ratio*	p-value
Change Preoperative to Postoperative							
Lordosis (deg)	3.1±8.4	2.8±8.2	3.0±8.3	0.99	0.801	1	0.927
SVA (mm)	2.2±8.9	2.7±6.7	2.5±8.0	1.01	0.666	1.02	0.270
Fusion seg lordosis (deg)	5.7±6.0	7.1±6.8	6.3±6.4	1.03	0.135	1.06	0.019
T1 slope (deg)	1.6±6.1	2.2±5.5	1.9±5.8	1.01	0.611	1.05	0.222
Proximal lordosis (deg)	0.1±4.1	-0.6±4.1	-0.2±4.1	0.96	0.258	0.95	0.151
Distal lordosis (deg)	-0.8±4.8	-1.5±4.2	-1.1±4.6	0.97	0.349	0.93	0.113
Change Postoperative to Final							
Lordosis (deg)	1.8±6.1	0.8±5.9	1.4±6.0	0.97	0.217	0.96	0.095
SVA (mm)	-2.3±7.4	-2.0±7.9	-2.1±7.6	1.01	0.694	1.01	0.570
Fusion seg lordosis (deg)	-0.2±3.6	-2.2±3.8	-1.1±3.8	0.86	<0.001	0.85	<0.001
T1 slope (deg)	0.8±4.4	-0.3±4.6	0.2±4.6	0.94	0.202	0.89	0.034
Proximal lordosis (deg)	1.3±3.6	0.7±4.7	1.1±4.1	0.96	0.267	0.96	0.228
Distal lordosis (deg)	1.2±3.6	1.5±4.4	1.3±4.0	1.02	0.584	1.02	0.583
Change Preoperative to Final							
Lordosis (deg)	5.3±7.6	3.6±7.7	4.5±7.7	0.97	0.126	0.97	0.101
SVA (mm)	0.1±8.7	1.1±6.6	0.5±7.8	1.02	0.344	1.03	0.092
Fusion seg lordosis (deg)	5.4±5.9	4.7±6.7	5.1±6.3	0.98	0.405	0.99	0.832
T1 slope (deg)	2.4±6.1	2.8±6.1	2.1±6.1	0.98	0.64	0.99	0.686
Proximal lordosis (deg)	1.4±4.4	0.2±5.0	0.9±4.7	0.95	0.076	0.93	0.026
Distal lordosis (deg)	0.3±4.5	-0.1±5.0	0.1±4.7	0.98	0.627	0.95	0.248

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

See Disclosure Index pages 41–95.

Presentation #85

Predictive Model for Achieving a Good Overall Outcome at One-Year Following Surgical Correction of Adult Cervical Deformity

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Introduction: For adult cervical deformity (ACD), goals include realignment, improved patient quality of life, and improved clinical outcomes. There is limited research identifying patients most likely to achieve all three. The goal of this study is to create a model predicting achievement good 1-year post-operative realignment, quality of life, and clinical outcomes following ACD surgery using baseline demographic, clinical, and radiographic factors.

Methods: Retrospective review of a multicenter ACD database. ACD patients≥18yrs with available baseline and 1-year post-operative follow up data were included. ACD patients were defined as having one of the following radiographic criteria: cSVA> 4cm, cervical kyphosis> 100 and TS-CL mismatch> 200. Data collected included demographic, radiographic, surgical and HRQOL (mJOA- modified Japanese Orthopedic association, EQ5D-EuroQuol-5D, and NDI–Neck Disability Index) outcomes. Patients were evaluated using the Ames-ACD classification system's radiographic modifiers (cSVA, CBVA, TS-CL, and SVA from the Schwab classification system). Alignment modifiers are graded from 0 (normal) to 2 (markedly abnormal/severe). A good radiographic outcome was achieved if patients did not have any 'severe' Ames modifier grades at 1-year. A good quality of life outcome was achieved if a patient reached the MCID for two of the three HRQL measures. The outcome assessed was whether a patient achieved both a good radiographic and clinical outcome. The primary analysis were stepwise regression models which generated a dataset-specific prediction model for achieving a good radiographic and clinical outcome. Model internal validation was achieved by bootstrapping and calculating the area under the curve (AUC) of the final model.

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Results: 73 ACD patients were included (mean age: 61.8yrs, 58.9% F). The final model predicting the achievement of a good outcome (radiographic and clinical) yielded an AUC of 84.8% with 95% confidence interval of 71.5-88.0%. The following baseline demographic, clinical, and radiographic factors were included in the model predicting a good outcome following ACD surgery: gender, CCI, osteoporosis, Ames type driver, baseline cSVA, T2-T12 kyphosis, T1 slope, C2 slope, maximum kyphosis value, T1SPi, C2SPi, baseline neurologic weakness, and presence of neurologic symptoms. Females were three times more likely to achieve a good overall outcome (OR 3.2 [1.01–10.11], p=0.048) and lower baseline cSVA, T1 slope, T1SPi and C2SPi predict a good outcome at 1-year post-operatively (all $p<0.02$).

Conclusions: Achievement of a good outcome following surgical correction of ACD can be predicted with high accuracy using the following factors: gender, CCI, osteoporosis, Ames type driver, baseline cSVA, T2-T12 kyphosis, T1 slope, C2 slope, maximum kyphosis value, T1SPi, C2SPi, baseline neurologic weakness, and presence of neurologic symptoms. Pre-operative assessment of patients' overall characteristics can help counsel patients and increase the chance of the patient improving in radiographic and clinical factors and achieving a good outcome after surgery.

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Presentation #86

The Relationship Between MRI Signal Intensity Changes, Clinical Presentation, and Surgical Outcome in Degenerative Cervical Myelopathy: Analysis of a Global Cohort

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Introduction: Degenerative Cervical Myelopathy (DCM) encompasses a group of conditions that typically result in progressive cervical spinal cord injury. This injury frequently coincides with T2-weighted (T2WI) and T1-weighted (T1WI) image signal intensity changes. However, the relationships between MRI signal intensity changes, neurological status, and surgical outcome remain subjects of controversy.

Materials / Methods: MRI data derived from a global cohort of 757 patients from two prospective and multicenter studies were combined and retrospectively reviewed. T2WIs and T1WIs were assessed for the presence, extent, and location of signal intensity changes and compared with the presence of clinical signs and symptoms, and correlated with functional status measures (mJOA, Nurick, NDI, SF-36). Additionally, signal change characteristics were evaluated for their ability to predict surgical outcome. Intra-rater reliabilities of signal changes characteristics were computed for a subset of patients.

Results: T1WI and T2 MRIs were available for 419 patients. Patients without signal changes [T2WI(-)/T1(-)], with T2 hyperintensity [T2WI(+)/T1(-)], and with both T2WI hyperintensity and T1WI hypointensity [T2WI(+)/T1WI(+)] comprised 28.9%, 51.8%, and 19.3%, respectively. The prevalence of clinical signs and symptoms were consistently lower in patients without signal changes, and more common in patients with both T1WI and T2WI signal changes and those with multilevel T2 hyperintensity changes, Table 1. On univariate analysis, signal groups T2WI(-)/T1WI(-), T2WI(+)/T1WI(+) and the number of signal levels were related to surgical outcome ($p<0.01$), Table 2. Multivariate logistic analysis resulted in a final model comprised of T2WI(+)/T1WI(+) and baseline mJOA, with an AUC of 0.774.

Conclusion: This analysis shows a stepwise trend toward increasing impairment from no signal change to T2WI-hypertensity to T1WI hypointensity. T1WI signal change indicates more permanent injury, portending decreased functional recovery. T2WI hyperintensity in isolation appears to be nonspecific in its association with baseline neurological status and does not predict surgical outcome, however, when taking into consideration the number of hyperintensity levels, greater impairment at presentation and worse surgical outcome are expected with multilevel involvement. Multivariate analysis indicates that spinal cord T1WI hypointensity at baseline translates to a lower likelihood for a good postoperative outcome at 2-years.

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Table 1. Impact of signal changes characteristics on the preoperative presence of clinical signs and symptoms.

Clinical Sign / Symptom	No Signal Changes N=121		T2WI-only N=217		T2WI+T2WI N=81		Discontinuous T2WI Hyperintensity N=30		Number of T2WI Hyperintensity Levels N=419		
	Freq	P-val	Freq	P-val	Freq	P-val	Freq	P-val	Presence	Absence	P-val
Upper Limb											
Numb Hands	84.3%	.104	88.9%	.675	92.6%	.181	93.3%	.557*	1.28±.06	0.84±.12	**.007**
Clumsy Hands	62.0%	**.009**	70.0%	.615	87.7%	**<.001**	76.7%	.487	1.32±.06	1.02±.09	**.010**
Bilateral arm paresthesia	44.6%	**.010**	56.7%	.334	63%	.085	63.3%	.309	1.32±.07	1.13±.08	.074
Hand muscles atrophy	25.6%	**.023**	34.6%	.763	44.4%	**.025**	40.0%	.463	1.42±.10	1.14±.06	**.014**
Hoffmann sign	49.6%	**<.001**	65.9%	.204	75.3%	**.011**	63.3%	.969	1.27±.06	1.17±.09	.344
Lower Limb											
Babinski sign	15.7%	**<.001**	43.8%	<.001	42.0%	.163	60.0%	**.003**	1.51±.09	1.08±.06	**<.001**
Lower limb spasticity	26.4%	**<.001**	53%%	.019	64.2%	**.001**	70.0%	**.010**	1.49±.08	1.00±.07	**<.001**
Impairment of gait	63.6%	**.001**	77.4%	.225	85.2%	**.018**	86.7%	.124	1.32±.06	0.95±.09	**.001**
Broad, unstable gait	39.7%	**<.001**	68.2%	<.001	61.7%	.539	76.7%	**.038**	1.41±.07	0.98±.08	**<.001**
Other Manifestations											
Lhermitte phenomenon	24.8%	.834	23.0%	.598	25.9%	.670	30.0%	.433	1.15±.10	1.26±.06	.339
Weakness	69.4%	**.001**	82.0%	.180	87.7%	**.042**	93.3%	.051	1.32±.06	0.89±.09	**<.001**
Motor deficits	55.4%	.084	65.9%	.074	60.5%	.785	60.0%	.832	1.31±.07	1.11±0.8	.057
Hyperreflexia	62.8%	**<.001**	79.3%	.058	84.0%	**.047**	73.3%	.783	1.31±.06	0.97±.10	**.005**
Overall Average	48.0%		62.2%		67.2%		68.2%		1.34	1.04	

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Table 2. Univariate and Multivariate Logistic Regression Analysis for the Prediction of an Optimal (≥16) vs. Suboptimal (<16) mJOA Outcome.

Univariate Parameters (n=398)	**OR (95% C.I.), p-value**
Baseline mJOA	1.35 (1.24-1.47), **p=8.3x10-12**
No signal change	1.66 (1.06-2.61), **p=0.027**
T2WI-only	1.23 (0.83-1.83), p=0.302
T1WI+T2WI	0.37 (0.22-0.62), **p=1.7x10-4**
Number of T2 Hyperintensity Levels	0.74 (0.61-0.89), **p=0.001**
Discontinuous T2WI Hyperintensities	0.75 (0.35-1.63), p=0.471
Multivariate Prediction Model	
Baseline mJOA	1.34 (1.22-1.46), **p=9.2x10-11**
T1WI+T2WI	0.45 (0.26-0.78), **p=0.005**
AUC=0.741	AUC=0.726

Presentation #87

Correlation of Radiographic Outcomes and Quality of Life for Multilevel Cervical Spondylotic Myelopathy

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Introduction: Posterior operative approaches have demonstrated clinical benefit for multilevel cervical spondylotic myelopathy (CSM). Prior investigations have independently reported the radiographic and quality of life (QOL) outcomes associated with posterior cervical surgery, but the relationship between radiographic metrics and QOL remains unclear.

Methods: A retrospective cohort study was conducted among patients undergoing laminoplasty or laminectomy with fusion for the treatment of multilevel CSM. QOL and radiographic data were collected preoperatively and postoperatively between 2008 and 2015. The EQ-5D instrument served as a measure of overall QOL, while the PDQ measured disability and the PHQ-9 assessed mental health. Radiographic metrics included C2-C7 Cobb angle, C2-C7 sagittal vertical axis (SVA), and modified Ishihara index. Multivariable linear regression models were used to investigate the association between radiographic measurements and QOL, while controlling for the following variables: age, gender, marital status, type of surgical procedure, Body Mass Index, Charlson Comorbidity Index.

Results: 125 patients were eligible for inclusion. Following multivariable linear regression, change in radiographic measurements – preoperative to postoperative – did not correlate with change in QOL (Table 1). Similarly, change in radiographic measurements was not associated with achieving a minimum clinically important difference (MCID) in any of the QOL instruments (Table 2). When preoperative radiographic measurements were compared to change in QOL, SVA was found to be a statistically significant predictor of improvement in EQ-5D ($p=0.03$; $\beta=0.0004$). All other preoperative radiographic metrics showed no correlation with change in QOL (Table 3).

Conclusions: Cobb angle and Ishihara index were not associated with QOL. One statistical model revealed an association between preoperative SVA and improvement in EQ-5D; however, the small β coefficient indicates that this correlation is unlikely to be clinically significant. We therefore conclude that radiographic outcomes are a poor surrogate for QOL in patients undergoing posterior surgery for multilevel CSM.

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Presentation #88

Brain Changes in Functional Connectivity and Anatomies in Patients with Cervical Myelopathy: A Resting-State Functional MRI Study

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Introduction: Spinal cord compression causes motor and sensory disorder in patients with cervical myelopathy (CM). Recently, several studies reported functional and anatomical brain changes in various central and peripheral nervous system disorders. Chronic spinal cord compression also can involve functional and anatomical changes in brain. However, whether these brain changes occur in CM patients is still unknown. Resting-state functional MRI (rs-fMRI) is a relatively new and powerful method for evaluating functional connectivity that occur when a subject is not performing an explicit task. The purpose of this study is to elucidate functional and anatomical brain changes in patients with CM using rs-fMRI.

Materials / Methods: Twenty-three CM patients (11 women and 12 men; mean age, 68 years old [range 48–80[) and 23 healthy matched control group (11 women and 12 men; mean age, 68 years old [range 46–79]) underwent rs-fMRI. During scanning, the subjects closed their eyes but kept wakefulness. Analyses were performed in the following items; (1) functional connectivity with seed-based correlation analysis, (2) spontaneous brain activity by amplitude of low-frequency fluctuations (ALFF), (3) volumes of local gray matter with voxel based morphometry (VBM), and (4) number of local nerve fibers by diffusion tensor image fractional anisotropy (DTIFA).

Results: In the CM group, the Japanese Orthopaedic Association scoring system for evaluation of cervical compression myelopathy (JOA score) was 11.2 in average (SD 2.3) and Neck disability index was 31.1 in average (SD 18.1). Functional connectivity between sensorimotor and cerebellum were significantly lower in the CM group compared to that in the control group ($p<0.001$, Figure 1A). Functional connectivity between medial prefrontal cortex and supplementary motor area in the CM group were significantly higher than the control group ($p<0.001$, Figure 1B). Gray matter volume of left insular cortex and basal ganglia significantly decreased in the CM group ($p<0.001$, Figure 1C). The values of ALFF and DTIFA were not significantly different between the groups.

Conclusion: Lower functional connectivity between sensorimotor and cerebellum in the CM group may reflect the damage to the posterior funiculus of the spinal cord. Higher functional connectivity between medial prefrontal cortex and supplementary motor area in the CM group may reflect optimization of cognitive resources to take an action in a motor disorder condition. As for the anatomical changes, sensory disorder may alter gray matter structure of insular cortex and basal ganglia. This is the first study that demonstrates the functional and anatomical brain changes caused by spinal cord compression.

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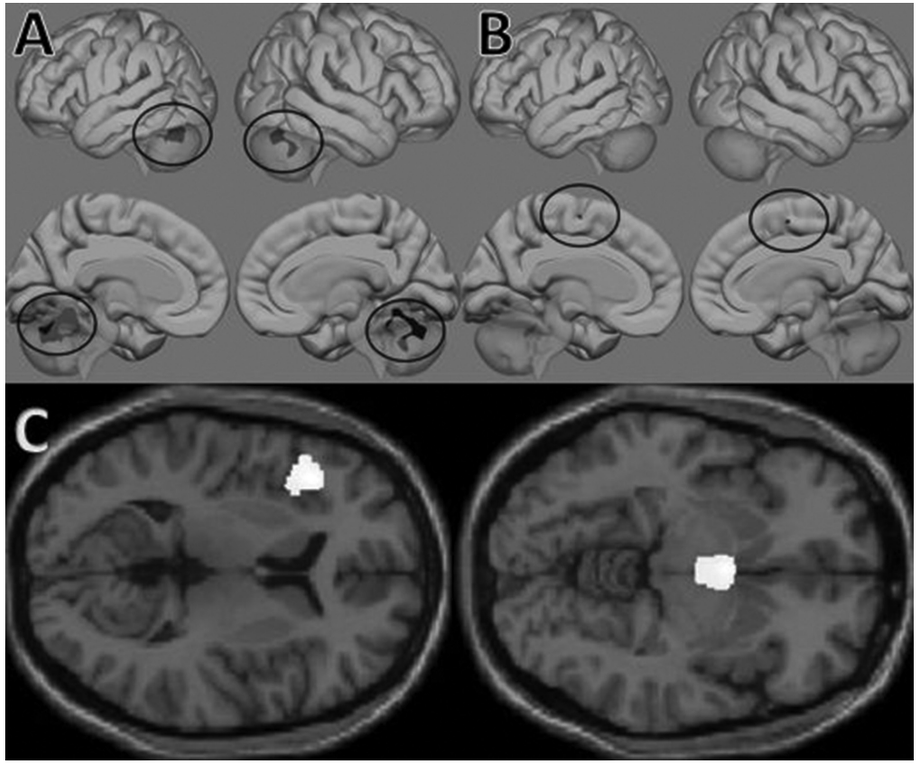
Figure 1.

A. Significant differences in the connectivity pattern of sensory-motor network and cerebellum (the CM patients < the control group)
B. Significant differences in the connectivity pattern of medial prefrontal cortex and supplementary motor area (the CM patients > the control group)
C. decreased gray matter volume of left insular cortex and basal ganglia in the CM group



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Presentation #89

Monitoring for Myelopathic Progression with Multiparametric Quantitative MRI

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Background: Degenerative cervical myelopathy (DCM) involves spinal cord (SC) compression by discs, ligaments, and vertebrae leading to neurological dysfunction. Clinical practice guidelines recommend surgical treatment for moderate-severe DCM, but optimal treatment for mild cases is unclear and many are managed non-operatively. Surgery is recommended for mild DCM when neurological deterioration occurs, but detection of subtle changes is highly subjective. Quantitative MRI (qMRI) directly measures spinal cord (SC) microstructural changes, including axonal injury, demyelination, and atrophy. This longitudinal study compares multiparametric qMRI with various clinical assessments to identify myelopathic progression in non-operative DCM patients. A clinical decision-making algorithm is then developed and implemented.

Methods: 26 DCM patients were followed. Clinical data including modified Japanese Orthopedic Association (mJOA) and assessments of strength, sensation, hand dexterity, gait, balance, and overall function. 3T qMRI data included cross sectional area, diffusion fractional anisotropy (FA), magnetization transfer ratio, and T2*-weighted white / grey matter signal intensity ratio (20 minutes, standard hardware and pulse sequences). qMRI metrics were extracted from the maximally compressed level and above / below. Progression was defined as 1) patients' subjective impression (gold standard), 2) 2-point mJOA decrease, 3) ≥3 clinical measures worsening by ≥5%, 4) increased compression on MRI, or 5) one of 10 qMRI measures or composite score (average of z scores) worsening. Age-corrected qMRI metric changes were tested between groups with paired t tests, or in individual subjects against null hypotheses that standard error of measurement (established previously) alone would influence changes, with z<-2.65 (individual metrics) or t10<-3.30 (composite score) considered significant (p<0.0045, corrected; Figure 1).

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Results: Follow-up (13.5±4.9 months) included mJOA in all 26 patients, MRI in 25, and clinical / qMRI in 22. 42.3% reported subjective progression, compared with mJOA (11.5%), anatomical MRI (20%), comprehensive assessments (54.5%), and qMRI (68.2%). Relative to subjective worsening, qMRI showed sensitivity=100%, specificity=53.3%, and Youden's Index=53.3% compared with comprehensive assessments (75%, 60%, 35%), mJOA (27.3%, 100%, 27.3%), and anatomical MRI (18.2%, 81.3%, -0.5%). Eight qMRI measures showed individuals with progression and 6 showed group worsening. Composite score outperformed single qMRI measures, identifying 7 individuals with progression and strong group changes (p=0.00004). A decision-making algorithm was implemented that requires subjective and objective evidence (including qMRI, Figure 2) to diagnose myelopathic progression, which recommended surgical treatment for 11 subjects (42.3%). Seven (26.9%) had possible myelopathic progression and surgery was discussed as a treatment option.

Conclusions: Clinically feasible multiparametric qMRI detected myelopathic progression more sensitively and congruently with patients' perceptions than other assessments. The results suggest that the natural history of DCM is less benign than previously thought, in part because neuroplasticity and behavioural adaptation may mask incremental tissue injury. The use of multiparametric acquisitions and multivariate analysis help to overcome limitations of individual qMRI measures, while longitudinal assessments in the same patient circumvent the wide range of normal values that occur in these data. This study is among the first to show that qMRI can help inform decision-making for individual patients, representing a major advance toward clinical translation of these promising techniques.

Figure 1: Statistical Tests for Myelopathic Progression in Individual Patients. Observed changes in age-corrected qMRI metrics for individual subjects are plotted on the expected distribution based on the null hypothesis of no change, in which individual metrics (e.g. rostral FA, top panel) are assumed to be normally distributed with mean=0 and standard deviation=$\sqrt{2}$ * standard error of measurement (derived from previous reliability data). Composite score (calculated as an average of z scores) is plotted as a t distribution with 10 degrees of freedom (bottom panel). Each subject is coded based on his / her subjective impression of neurological worsening (red: worse, yellow: maybe worse, and green: same / better).

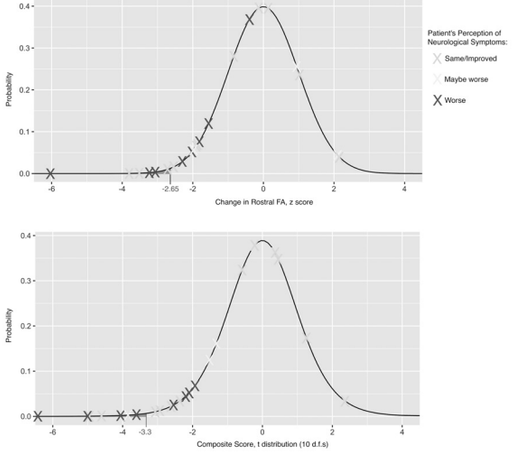

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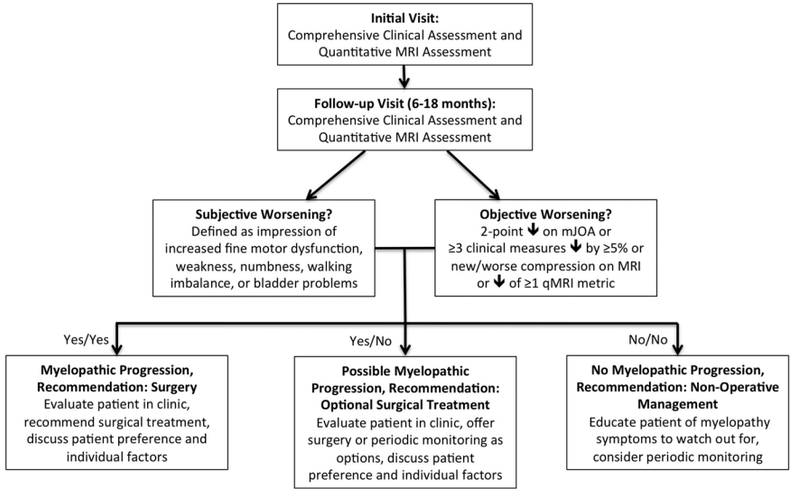
Figure 2: Decision-Making Algorithm for Degenerative Cervical Myelopathy Patients Initially Managed Non-operatively. The decision-making algorithm requires clinical and quantitative MRI data collection at 2 time-points, and takes into account the patient's subjective impression of worsening and objective measures of progression, including mJOA, a battery of clinical assessments, anatomical MRI, or qMRI.



Presentation #90

Brain Connectivity Can be a Novel Predictor for Neurological Improvement in Patients with Cervical Myelopathy

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Introduction: Several radiographic prognostic factors (f.e. T2 high intensity area of spinal cord 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. And there is also a possibility that recruitment of other neural networks may contribute to the neurological recovery. 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: Nineteen CSM patients (7 female, 12 male, mean age; 69.2 years) received rs-fMRI at preoperative 2 days. Brain functional connectivity with seed-based correlation analysis was performed. Clinical evaluation including upper extremity function [UEF] and sensory [UES] in JOA score, 10-second test, and VAS (pain or numbness in arms or hands) were performed at preoperative 2 days and postoperative 6 months. Correlation between preoperative functional connectivity and clinical improvement were analyzed by Spearman's rank correlation coefficient.

Result: Clinical scores (UEF and UES in JOA score, 10-second test) significantly improved at postoperative 6 months (pre-op./post-op.; UEF: 2.2±0.7 / 3.3±0.5, $p<0.001$; UES: 1.0±0.3 / 1.3±0.4, $p=0.02$; 10-second test: 15.5±3.4/27.1±8.1, $P<0.001$) though VAS was not significantly improved (pre-op./post-op.; 5.9±2.7/4.7±3.2, $p=0.43$). Correlation analysis between the scores and functional connectivity demonstrated the following results. The recovery of UEF was negatively correlated with connectivity between several locations in salience network and lateral occipital cortex; superior division (sLOC). The recovery of 10-second test was positively correlated with connectivity between cerebellar network and frontal pole (FP), and default mode network (DMN) and subcallosal cortex (SubCalc), and negatively correlated with connectivity between salience network and sLOC and cerebellar network and middle temporal gyrus; posterior division (pMTG). The recovery of UES was negatively correlated with connectivity between DMN and sLOC, salience network and sLOC and fronto/parietal network and precuneous cortex (Precuneous), middle frontal gyrus (Mid FG), and sLOC. The recovery of VAS was positively correlated with connectivity between DMN and Precuneous, paracingulate gyrus (PaCiG), Salience network and supramarginal gyrus; posterior division (pSMG), angular gyrus (AG), and negatively correlated with DMN and temporal pole (TP), insular cortex (IC), juxtapositional lobule cortex (SMA), central opercular cortex (CO) and Salience network and PaCiG, FP, Precuneous, and Dorsal attention network and TP, postcentral gyrus (PostCG). (Table.1,2)

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Conclusions: Several positive and negative correlations between preoperative brain connectivity and neurological improvement were demonstrated though no connectivity relating sensory-motor network was detected. The results suggest the recruitment of connectivity other than sensory-motor network play an important role for the neurological recovery caused by spinal cord damage. Although further research including establishment and validation of prediction formula, brain connectivity can be a novel predictor for neurological improvement in patients with cervical myelopathy.

Table. 1

	Network	Seed	Related region	R	P value
UEF in JOA (Upper extremity function)	Salience	AInsula (L)	sLOC (L)	-0.71	0.003
		AInsula (R)	sLOC (L)	-0.74	0.002
		AInsula (R)	sLOC (R)	-0.80	<0.001
		SMG (R)	sLOC (L)	-0.85	<0.001
		SMG (R)	sLOC (R)	-0.64	0.007
10-second test	Default mode	LP (L)	SubCalC	0.63	0.007
	Salience	AInsula (R)	sLOC (L)	-0.71	0.002
	Cerebellar	Anterior	FP (L)	0.85	<0.001
		Posterior	pMTG(L)	-0.81	<0.001
UES in JOA (Upper extremity sensory)	Default mode	LP (R)	sLOC (L)	-0.68	0.004
	Salience	SMG (L)	sLOC (L)	-0.85	<0.001
		SMG (R)	sLOC (L)	-0.74	0.002
	Frontoparietal	LPFC (L)	Precuneous	-0.86	<0.001
		PPC (L)	MidFG (R)	-0.81	<0.001
		PPC (R)	sLOC (L)	-0.79	<0.001

R: right, L: left

Table. 2

Abbreviation	
AInsula	Anterior insula
SMG	Supramarginal Gyrus
LOC	Lateral occipital cortex
LP	Lateral parietal lesion
SubCalC	Subcallosal cortex
FP	Frontal pole
pMTG	Middle temporal gyrus, posterior division
SMG	Supramarginal gyrus
Precuneous	Precuneous cortex
MidFG	Middle frontal gyrus
LPFC	Lateral prefrontal cortex
PPC	Posterior cingulate cortex

Presentation #91

Risk Factors for Inpatient Morbidity and Mortality After One- and Two-Level ACDF

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Introduction: In an effort to decrease the overall cost of care, more spine procedures such as anterior cervical discectomy and fusion (ACDF) are being performed on an outpatient basis in ambulatory surgery centers. Major complications such as airway compromise and neurologic injury following ACDF are rare but can have devastating consequences. Patients at increased risk for adverse events in the immediate postoperative period need to be identified. Our goal was to determine the rate of inpatient complication following one- and two-level ACDF using the National Inpatient Sample (NIS) administrative database. We also sought to identify patient factors that are associated with increased risk of mortality or serious morbidity in the immediate postoperative period.

Methods: A retrospective review of the NIS database from 2006-2010 was performed and all patients over age 18 undergoing elective 1- or 2- level ACDF for a diagnosis of radiculopathy, myelopathy, or myeloradiculopathy were identified. Patients who had additional spine procedures, who underwent ACDF for infection, neoplasia or trauma and those who underwent 3 of more level ACDF were excluded. Common medical comorbidities were chosen and identified in the database using ICD-9CM codes. Multivariate logistic regression analysis was performed to identify patient risk factors for serious complication following ACDF in the immediate postoperative period.

Results: The mortality rate was 0.074% and the overall complication rate was 3.73%. The rate of any medical complication was 3.13%. Airway compromise, neurologic deficit, and surgical site infection occurred in 0.75%, 0.046% and 0.038% of cases, respectively (table 1).

Chronic kidney disease was the strongest predictor of mortality with an odds ratio of 11.14 ($p<0.001$). Age over 65, a preoperative diagnosis of myelopathy, bleeding disorder, and COPD were also associated with increased mortality ($p<0.05$). Airway complication was associated with age over 65, male sex, myelopathy, diabetes, anemia, bleeding disorder, COPD, obesity and OSA ($p<0.05$). Smoking was not associated with increased incidence of airway complication ($p=0.363$). A preoperative diagnosis of myelopathy was most strongly associated with an increased rate of neurologic complication (OR 6.67, $p<0.001$). Anemia was associated with a significantly increased rate of surgical site infection with an OR of 14.34 ($p<0.001$). Infections were also more common in men ($p<0.05$) (table 2). There were only 3 reported cases of esophageal injury and dural tear therefore multivariate regression analysis could not be performed for these complications.

See Disclosure Index pages 41–95.

Presentation #91 (cont.)

Conclusion: Age over 65, multiple medical comorbidities and a preoperative diagnosis of myelopathy were all associated with increased risk of death, airway compromise, and neurologic injury in the immediate postoperative period following ACDF. Patients with these risk factors should be considered candidates for inpatient ACDF rather than in an outpatient ambulatory surgery center. Regardless of patient risk factors, meticulous hemostasis and surgical technique are of paramount importance when performing ACDF in an ambulatory surgery center.

Table 1. Complications

	N	Percent
Any complication	2,926	3.734 [3.545, 3.933]
Mortality	57	0.074 [0.057, 0.096]
Complication Type		
Medical complication	2,452	3.13 [2.96, 3.31]
Acute kidney injury	193	0.25 [0.213, 0.291]
Bleeding requiring transfusion	249	0.321 [0.275, 0.375]
Myocardial infarction	77	0.098 [0.078, 0.013]
Cardiac arrest	50	0.064 [0.048, 0.086]
Deep venous thrombosis	1,007	0.129 [0.119, 0.139]
Pulmonary embolism	27	0.035 [0.024, 0.052]
Pneumonia	250	0.320 [0.277, 0.369]
Sepsis	226	0.288 [0.250, 0.333]
Septic shock	16	0.021 [0.013, 0.035]
Urinary tract infection	668	0.856 [0.781, 0.939]
Stroke	21	0.026 [0.017, 0.040]
Airway compromise	591	0.750 [0.681, 0.827]
Reintubation	371	0.474 [0.419, 0.536]
Hematoma	292	0.368 [0.324, 0.418]
Surgical site infection	29	0.038 [0.026, 0.056]
Neurologic complication	35	0.046 [0.029, 0.072]
Paralysis	25	0.033 [0.022, 0.049]
Nerve root injury	10	0.013 [0.004, 0.045]
Other complication		
Esophageal perforation	3	0.003 [6e-6, 0.011]
Dural tear	3	0.004 [0.001, 0.012]

Presentation #91

Table 2. Multivariate Logistic Regression Models

	Mortality		Airway compromise		Neurologic complication		SSI	
	OR	P-value	OR	P-value	OR	P-value	OR	P-value
Age > 65	**3.24**	**< 0.001**	**2.11**	**<0.001**	**2.28**	**0.037**	1.66	0.265
Female	0.74	0.288	**0.50**	**<0.001**	0.61	0.149	**0.39**	**0.024**
Myelopathy	**4.50**	**< 0.001**	**2.37**	**<0.001**	**6.67**	**< 0.001**	1.77	0.189
Diabetes	1.71	0.109	**1.36**	**0.003**	0.65	0.408	1.70	0.267
Anemia	1.07	0.906	**4.23**	**<0.001**	n/a	n/a	**14.34**	**<0.001**
Bleeding disorder	**6.45**	**0.001**	**4.35**	**<0.001**	n/a	n/a	3.06	0.201
Hypertension	0.90	0.746	0.96	0.687	0.79	0.467	0.87	0.782
COPD	**2.15**	**0.047**	**2.26**	**<0.001**	n/a	n/a	1.93	.0249
CKD	**11.14**	**< 0.001**	1.41	0.164	4.83	0.055	1.23	0.799
Obesity	1.29	0.590	**1.69**	**0.014**	1.87	0.212	1.63	0.417
OSA	0.27	0.176	**1.68**	**0.003**	0.75	0.772	2.26	0.191
Smoking	0.93	0.850	1.11	0.363	1.83	0.091	1.05	0.926

See Disclosure Index pages 41–95.

Presentation #92

Bleeding vs. Clotting Complications After Cervical Spine Surgery: An Analysis of 207,794 Patients

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Introduction: Unlike almost all other inpatient surgery, chemical anticoagulation after spine surgery is frequently withheld due to fear of bleeding complications. Unlike most other surgeries, bleeding complications after spine surgery can result in neurological injury. The purpose of this study was to compare the incidence of bleeding and clotting complications in patients who have undergone cervical spinal surgery without postoperative anti-coagulation, using a large national database.

Materials/Methods: A retrospective review of the Truven Health Marketscan® Research Databases was conducted for patients undergoing cervical spine operations between 2003 and 2014. Patients were divided into 3 groups: anterior cervical fusion, posterior cervical fusion, and posterior cervical decompression. The ICD-9-CM diagnosis codes for epidural hematoma, hematoma, seroma, deep vein thrombosis (DVT), and pulmonary embolism (PE) were used to calculate the incidence of these complications within three months of surgery in each group. The rate of operative intervention for the bleeding complications was assessed and compared to the rate of PE. The relative risks of these complications were calculated for surgical approach and fusion vs. decompression.

Results: 207,794 patients were included in the study. Overall, 5623 (2.7%) patients developed bleeding complications (seroma+hematoma+epidural hematoma) while 8034 (3.9%) developed clotting complications (DVT+PE). 811 (.39%) patients underwent surgical drainage for their bleeding complication, and 4,353(2.1%) patients developed PE.

While the rates of all bleeding complications were comparable to the rates of all thrombosis complications in all subgroups (Table 1), the rate of PE was 5-7 fold higher than the rate of bleeding complication requiring operative intervention in all sub groups ($p<0.001$) (Table 2).

We observed a significantly higher risk of bleeding and thrombotic complications in posterior cervical fusion as compared to anterior cervical fusion (RR 1.83, 2.1 respectively, $p<0.001$). We also observed a significantly higher risk of bleeding and thrombotic complications in posterior cervical fusion as compared to posterior cervical decompression alone ((RR 1.44, 1.44 respectively, $p<0.001$).

Conclusion: We observed that PE rates were 5-7 fold higher than rates of bleeding complications requiring surgery. Given this large disparity in these complication rates, it may be worthwhile considering routine chemical anticoagulation after spine surgery.

Saturday, December, 2, 2017, 11:46–11:48 am CSRS–2017

Presentation #92

Table 1. Incidence of Bleeding and Clotting Complications for each Surgical Subcategory

	Sample Size	Bleeding Complications	Clotting Complications
Anterior Cervical Fusion	99,985	2,227 (2.2%)	2,925 (2.9%)
Posterior Cervical Fusion	26,666	1,090 (4.1%)	1,643 (6.2%)
Posterior Cervical Decompression	81,143	2,306 (2.8%)	3,466 (4.3%)
Overall	207,794	5623 (2.7%)	8034 (3.9%)

Table 2. Incidence of Bleeding Complications Requiring Surgical Intervention and Pulmonary Embolism for each Surgical Subcategory

	Sample Size	Bleeding Complications w/ Operative Intervention	Pulmonary Embolism
Anterior Cervical Fusion	99,985	323 (0.32%)	1,611 (1.6%)
Posterior Cervical Fusion	26,666	167 (0.63%)	887 (3.3%)
Posterior Cervical Decompression	81,143	321 (0.4%)	1,855 (2.3%)
Overall	207,794	811 (.39%)	4,353(2.1%)

See Disclosure Index pages 41–95.

Presentation #93

Does Screw Density Affect the Revision Rate of a Multilevel Posterior Cervical Decompression and Fusion

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Introduction: A multilevel posterior cervical decompression and fusion (PCF) is a common procedure for patients with cervical spondylotic myelopathy. In some cases screws may be skipped in one of the levels. There is a paucity of evidence available to determine if skipping a single level affects the revision rate. The purpose of this study is to determine if skipping a single level affects the revision rate for patients undergoing a multilevel posterior cervical decompression and fusion.

Methods: A database of cervical spine surgeries at a single practice was used to identify patients who underwent three or more level posterior cervical decompression and fusion by one of seven fellowship-trained spine surgeons between 1/2008 and 9/2013. Patients were included if they had screws placed at every level, or if they had a single level without screws bilaterally. Additionally, patients were excluded if the surgery was performed for tumor, trauma or an infection, if they were under the age of 18, or if there was less than one year of follow-up.

Separate univariable logistic regression analyses were performed to evaluate factors predicting revision, including age, length of follow-up, ethnicity, total number of levels fused, start level end level, having had prior surgery, indication (myelopathy, radiculopathy), body mass index (BMI), pre-operative lordosis, preoperative C2-C7 Sagittal Vertical Axis (SVA), type of instrumentation at C7, and whether a single level was unistrumented. Separate multivariable logistic regressions then evaluated each of these same factors while controlling for whether a level was skipped.

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Presentation #93

Results: A total of 157 patients met inclusion criteria, with 86 undergoing a PCF with instrumentation at all levels. Overall average follow up was 46.5+/-22.8 months, and no difference was found between patients who had instrumentation at every level (47.4+/-22.6 months) and those who had a single unistrumented level (45.72+/-23.1) (p=0.51). Patients who had a level skipped were slightly younger (59.76 years+/-9.90 vs. 63.18 years+/-10.23, p=0.03) and had more levels fused (5.23 levels+/-1.17 vs. 4.68 levels+/-1.21, p=0.003) (Table 1). The overall revision rate was 25%. In patients with or without a skipped level, the revision rate was 25% and 26%, respectively (p<1.00).

Univariable regression analysis demonstrated that a start level in the upper cervical region, having the fusion end at C7, having had a prior surgery and having myelopathy were each significant predictors of revision (p<0.05), however skipping a single level was not predictive of a revision (Odds ratio: 2.46 [0.30, 16.41], p=0.351 (Table 2). Next a bi variable regression analysis was preformed controlling for an unistrumented level. This re-demonstrated that start level, end level, having had a prior surgery and having myelopathy remained significant predictors of revision (Table 2).

Conclusion: When performing a multilevel posterior cervical decompression and fusion there is no increase rate of revision surgery if a single level is unistrumented. Conversely, other surgical factors including the cranial and caudal level do affect revision rates.

Table 1. Preoperative variables

	All Levels Instrumented	One Unistrumented Level	P value
Age	63.18+/-10.23	59.76+/-9.90	0.029*
Gender (% Male)	48%	56%	0.382
Ethnicity (% Caucasian)	78%	71%	0.735
Number of Levels	4.68+/-1.21	5.23+/-1.17	0.003*
Preoperative Cervical Lordosis	7.66+/-12.98	3.84+/-15.51	0.155
Preoperative C2-C7 Sagittal Vertical Axis	34.07+/-16.43	30.73+/-17.93	0.288
Myelopathy	95%	97%	0.828

See Disclosure Index pages 41–95.

Presentation #93 (cont.)

Table 2. Logistic regression to determine predictors of revision. Multiple univarible regressions were performed, followed by bi variable regression that controls for both if a level was uninstrumented and the variable

	Univariable		Bi Variable Regression Analysis Also Controlling for an Uninstrumented Level	
Predictor	odds ratios [95% CI]	p-value	odds ratios [95% CI]	p-value
Age	0.98 [0.95, 1.01]	0.253	age: 0.98 [0.95, 1.02]	0.386
Follow-up	1.00 [0.99, 1.00]	0.167	follow-up: 1.00 [0.99, 1.00]	0.187
Ethnicity	White: reference Black: 0.58 [0.16, 1.67] Hispanic: NA	W-B 0.577 W-H: 1.000 B-H: 1.000	White: reference Black: 0.31 [0.05, 1.16] Hisp: NA	W-B: 0.247 W-H: 1.00 B-H: 1.00
Total number levels	1.22 [0.95, 1.56]	0.117	no. of levels: 1.26 [0.95, 1.68]	0.108
Start level	C3-C7: reference C0-C2: 2.26 [1.14,4.44]	p=0.019*	C3-C7: reference C0-C2: 2.16 [1.00, 4.64]	0.0478*
End level	C7: reference T1: 0.46 [0.23, 0.93] T24: 1.15 [0.44, 2.286]	C7-T1: 0.033* C7-T24: 0.761 T1-T24: 0.135	C7: reference T1: 0.43 [0.19, 0.95] T24: 1.78 [0.60, 5.23]	C7- T1: 0.039* C7- T24: 0.291 T1-T24: 0.068
C7 Screw (1) Lateral Mass (2) Pedicle (3) Skipped level	1: reference 2: 0.78 [0.40, 1.52] 3: 0.90 [0.12, 4.58]	1v2: 0.720 1v3: 0.992 2v3: 0.983	1: reference 2: 1.16 [0.46, 2.91] 3: 1.39 [0.16, 8.89]	1v2: 0.939 1v3: 0.937 2v3: 0.977
Level skipped	6: reference 7: 2.46 [0.30, 16.41]	0.351	N/A	N/A
Prior surgery	No prior: reference Prior: 21.01 [9.61, 49.01]	<0.001*	No prior: reference Prior: 25.75 [10.65, 68.35]	<0.001*
Indication myelopathy vs. radiculopathy	R: reference M: 7.73 (1.60, 55.29)	0.017*	R: reference M: 17.01 [2.62, 332.14]	0.011*
BMI	0.98 [0.93, 1.03]	0.474	bmi: 0.95 [0.89, 1.02]	0.154
Preoperative Lordosis	0.98 [0.95, 1.00]	0.069	lordosis: 0.98 [0.95, 1.01]	0.131
Preoperative C2-C7 SVA	1.00 [0.98, 1.03]	0.761	sva: 1.01 [0.98, 1.03]	0.497
Skipped	0.99 [0.49, 1.98]	0.972	N/A	N/A

Presentation #94

Neurological Complications and Recovery Rates in Adult Cervical Deformity Surgery

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Introduction: The rates of neurologic complications and recovery rates in cervical deformity patients are poorly defined. To our knowledge, there are no reports on the rate of neurologic complications and their resolution following cervical deformity surgery. Our objective was to define the risk factors for neurologic complications associated with cervical deformity surgery and the recovery rates of those complications.

Methods: Cervical deformity patients undergoing surgery from 2013-2015 were enrolled in a prospective, multicenter database. Cervical deformity was defined as a cervical kyphosis >10°, cervical scoliosis >10°, C2-7 SVA >4cm and/or chin-brow vertical angle >25°. Neurologic complications were divided as major or minor. Several demographic, operative and radiographic parameters were compared between patients diagnosed with neurologic complications and those without neurologic complications. Recovery was noted as none, partial and complete. Statistical analysis was performed with t-tests or Chi-square tests as appropriate.

Results: 106 patients met inclusion criteria for the study. Average age was 62 years old with a mean follow-up of 29 months. The overall rate of neurologic complications was 21%. One case was excluded for lost to follow-up. The incidence of a major neurologic complications was 11% while a minor was 11% and the majority of cases were identified within 30 days of surgery (57%, n=14). Motor deficit (11%) was the most common followed by radiculopathy (6%), sensory deficit (5%) and spinal cord injury (1%). Of the motor deficits, 50% were C5 palsies. There was no correlation between age, gender, body mass index and neurologic complications. Patients with neurologic complications had a higher preop mJOA scores (p=0.01) but similar NDI and EQ5D. Of the deficits, 92% had partial or complete recovery in 30 months after surgery with only 8% with permanent deficits (60% complete recovery, 32% partial). No operative variables (prior cervical surgery, estimated blood loss, total operation time, fusion levels, BMP use, osteotomy and surgical approach) were associated with an increased risk of neurologic complications. No differences in HRQOLs were noted between groups at latest follow-up.

Conclusions: The overall neurologic complication rate in cervical deformity surgery was 21% and the incidence of major neurologic complications was 11%. While motor deficit was the most common (11%), spinal cord injury was rare (1%). Permanent deficits were noted in 1.7% of patients. No demographic or operative risk factors for neurologic complication could be identified.

See Disclosure Index pages 41–95.

Presentation #95

The Rothman Index as a Predictor of Post-Discharge Adverse Events After Elective Spine Surgery

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Introduction: The Rothman Index (RI) is a comprehensive rating of overall patient condition in the hospital setting. It is used at many medical centers and calculated based on vital signs, lab values, and nursing assessments in the electronic medical record. Past research has demonstrated an association with adverse events, readmission, and mortality in other fields, but it has not been investigated in spine surgery. The current study assessed the potential utility of the Rothman Index as a predictor of adverse events after discharge following elective spine surgery.

Materials / Methods: A retrospective cohort study was performed at a large academic medical center. Patients undergoing elective spine surgery between 2013 and 2016 were identified. Patient characteristics and 30-day perioperative outcomes were characterized. Rothman Index scores from the hospital encounter were analyzed and compared for those who did or did not experience adverse events after discharge. The association of lowest and latest RI scores on adverse events was determined with multivariate regression, controlling for patient demographics and comorbidities. Lastly, the incidence of readmission and any post-discharge adverse event were determined based upon patients' lowest and latest RI values, clustered into 10-unit groupings. These values were used to determine whether certain RI score ranges were associated with increased risk of readmission or adverse events, based on the overall cohort rates.

Results: The study included 2,687 patients. Post-discharge adverse events were experienced by 7.1% of patients. The latest and lowest RI values were significantly inversely correlated with any adverse events, major adverse events, minor adverse events and readmissions after controlling for age, sex, body mass index, and American Society of Anesthesiologists (ASA) class (Table 1). Rates of readmission and any adverse event consistently had an inverse correlation with lowest and latest RI scores; for example, rate of any post-discharge adverse event declined from 100% in patients with latest RI score of 25-35 to 3.1% for patients with latest RI score of 95 or higher. Patients were at significantly increased risk of both readmission and post-discharge adverse events with lowest RI score below 65 (Figure 1A) or latest RI score below 85 (Figure 1B).

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Conclusion: The Rothman Index is a tool that is already used by nursing staff at many medical centers, but has not routinely been incorporated into physician decision-making regarding discharge decisions. The current study finds that this can be used to stratify patients' risk of post-discharge adverse events following elective spine surgery that adds value to commonly used indices such as patient demographics and ASA. It is found that this can help physicians identify high-risk patients prior to discharge and should be able to better inform clinical decisions.

Table 1. Multivariate regression for association with post-discharge adverse events

	Any Adverse Event		Major Adverse Event		Minor Adverse Event		Readmission	
	OR	P-value	OR	P-value	OR	P-value	OR	P-value
Lowest RI value	1.29	<0.001	1.28	0.001	1.30	0.001	1.28	<0.001
Age	1.01	0.109	1.02	0.062	1.00	0.716	1.02	0.023
Male sex	1.21	0.212	1.49	0.102	0.59	0.057	1.28	0.143
BMI	1.03	0.052	1.03	0.121	1.02	0.294	1.02	0.092
ASA ≥ III	1.49	0.018	1.45	0.161	1.79	0.054	1.55	0.018
Latest RI value	1.45	<0.001	1.36	0.014	1.73	<0.001	1.41	<0.001
Age	1.01	0.072	1.02	0.041	1.00	0.658	1.02	0.013
Male sex	1.16	0.348	1.42	0.151	0.56	0.042	1.22	0.242
BMI	1.03	0.026	1.04	0.074	1.02	0.275	1.03	0.050
ASA ≥ III	1.51	0.015	1.49	0.134	1.72	0.077	1.58	0.014

For latest and lowest RI values, the odds ratio represents a 10-unit decrease in Rothman Index value. OR=Odds ratio; RI=Rothman Index; ASA=American Society of Anesthesiologists class. Shading indicates significance at P<0.05

See Disclosure Index pages 41–95.

CERVICAL SPINE RESEARCH SOCIETY

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E-Poster Abstracts

The Effect of Phytochemicals to Inhibit the Detrimental Effects of Cigarette Smoke

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Introduction: Cigarette smoking is associated with increased rates of pseudarthrosis after spine fusion procedures. We have previously reported that activation of the Aryl Hydrocarbon Receptor (AhR) inhibits bone regeneration and spinal fusion in an *in vivo* murine model. In addition, we have demonstrated that dioxin-induced inhibition of osteogenic differentiation can be recovered by co-treatment with Aryl Hydrocarbon Receptor (Ahr) antagonists *in vitro*. The purpose of this study was to elucidate downstream mechanisms of cigarette smoke extract (CSE) and to identify therapeutics that might mitigate the effects of CSE on bone.

Materials / Methods: 8 weeks old Sprague Dawley rats were injected with either 50mg/kg or 10mg/kg of Cigarette Particular Phase Extract (PPE) every 2, 4, or 7 days for 2 weeks. DMSO vehicle control animals were injected every 2 days for 2 weeks. For *in vitro* studies, bone marrow stromal cells (BMSC) isolated from Long Evans rat femurs and tibiae were cultured under standard or osteogenic conditions. BMSC were subsequently exposed to vehicle control or PPE. Cells were also co-treated with Ahr antagonists including: alpha-naphthoflavone (ANF); a synthetic antagonist), resveratrol (Res; a stilbenoid found in grapes and present in red wine), 3,3'-diindolylmethane (DIM; a flavonoid product of cruciferous vegetables). Known downstream factors of Ahr activation and markers of osteogenesis were evaluated.

Results: PPE increased mRNA and protein expression of CYP1A1, as well as EROD activity both *in vivo* and *in vitro*. PPE inhibited, but Ahr antagonist co-treat mitigated inhibition of ALP activity, matrix mineralization, and cell proliferation *in vitro*. RNA and protein expression studies showed that PPE down-regulates numerous pro-osteogenic genes such as ALP, RunX2, OCN and Phex, but co-treatment with Ahr antagonists prevented PPE-induced inhibition.

Conclusion: Cigarette-smokers are a historically difficult patient population for spine surgeons to treat, with increased rates of pseudarthrosis and complications following spinal fusion procedures. Our results suggest that Ahr activation may play a critical role in the adverse effects of cigarette smoke on bone healing, and that Ahr antagonists present a naturally available, potential therapeutic to combat cigarette smoke induced inhibition of bone regeneration. Future studies will include Ahr antagonist co-treatment in an animal model.

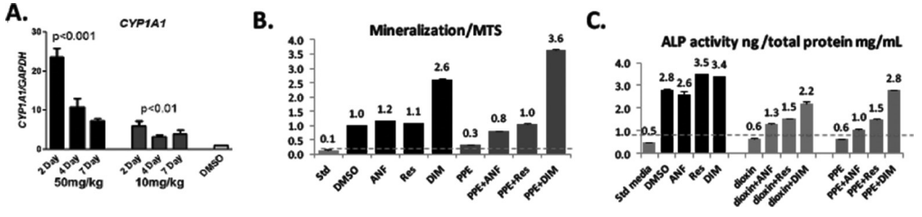

Figure 1. Rats were injected with 50mg/kg and 10 mg/kg of PPE or DMSO vehicle control for 2 weeks, and liver samples were harvested. CYP1A1 mRNA expression (A) was increased in PPE injected animals. Rat BMSC were harvested and treated with 20 mg/mL PPE. Co-treatment of cells with Ahr antagonists demonstrated rescue from the inhibitory effects of PPE and dioxin on mineralization (B) and ALP activity (C).

See Disclosure Index pages 41–95.

Identifying the Most Effective Types of Integration-Free Human iPS Cell-Derived Neural Stem / Progenitor Cells in the Treatment of Spinal Cord Injury

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Introduction: We have previously demonstrated the therapeutic potential of transplanting human iPS cell-derived neural stem / progenitor cells (hiPSC-NS/PCs) in the treatment of spinal cord injury (SCI) models. However, for the induction of conventional hiPSCs, transgenes were integrated using virus which meant it was unfit for clinical application. Recently, we have produced integration-free hiPSCs using episomal vectors which is safer for clinical use. The purpose of this study is to assess the efficacy of integration-free hiPSC-NS/PCs, and to investigate their genetic and epigenetic profiles in order to evaluate factors related to therapeutic efficacy.

Materials / Methods: Two integration-free hiPS cell lines were prepared (836B3-hiPSCs, 414C2-hiPSCs), and were induced to hiPSC-NS/PCs (836B3-NS/PCs, 414C2-NS/PCs). ES cells were also used for analysis as a target for comparison of hiPSCs. Each of the hiPSC-NS/PCs were differentiated *in-vitro* and were histologically evaluated. For the *in-vivo* study, hiPSC-NS/PCs were transplanted into the injured spinal cord of NOD-SCID mice, and phosphate buffered saline (PBS) was injected to the control group (414C2-NS/PCs; n=27, 836B3-NS/PCs; n=23, control; n=15). Transplanted cells were monitored using bio-imaging and evaluated histologically; and motor function was evaluated by basso mouse scale (BMS) score. For genetic and epigenetic analyses of hiPSCs and hiPSC-NS/PCs, single nucleotide variants (SNVs) were evaluated using Ion proton, HumanHT-12 was used to evaluate gene-expression analyses and single-cell RNA-sequence (700 cells each) was performed using Illumina Hiseq2500.

Results: In the *in-vitro* assay, 414C2-NS/PCs revealed good differentiation potential, whereas 836B3-NS/PCs were resistant to differentiation. In the *in-vivo* study, better motor functional recovery was observed in the 414C2-NS/PCs group compared with the control group ($p < 0.001$). In contrast, 836B3-NS/PCs group showed no improvement in motor function, and formed undifferentiated tissues (Figure 1, Figure 2). SNVs related to neural differentiation such as SRGAP3 were detected in 836B3-NS/PCs and not in 414C2-NS/PCs. The gene-expression profile of 414C2-hiPSCs resembled that of ES cells with clustering analysis, and 12 genes which included genome-stabilization gene such as DPPA3 and differentiation related genes such as IRX2 and LEF1 were highly expressed in 414C2-hiPSCs, similar to those found in ES cells. None of these findings, however, were observed in 836B3-hiPSCs. In single-cell RNA-sequence, Delta-Notch signal positive cells which are important for neural differentiation were more abundant in 414C2-NS/PCs, whereas 836B3-NS/PCs only contained a small population (80 cells and 32 cells, respectively).

Conclusion: In order to pursue our mission of conducting a clinical trial for SCI patients within the next several years, it is critical to build guidelines for selecting "effective" hiPSC-NS/PCs, such as 414C2-NS/PCs. Here, we have shown that the key to good motor function recovery is to transplant integration-free hiPSC-NS/PCs that differentiate well within the spinal cord tissue. Through both *in-vitro* and *in-vivo* analyses, we revealed differences in the SNVs, gene-expression, and single-cell population between two cell lines with contrasting levels of differentiation capacity. Our results suggest that examining hiPSCs quality with 12-gene markers and establishing hiPSC-NS/PCs that contain more than 10% Delta-Notch(+) cells and does not contains any crucial SNVs could be an important factor in selecting "effective" hiPSC-NS/PCs for SCI treatment.

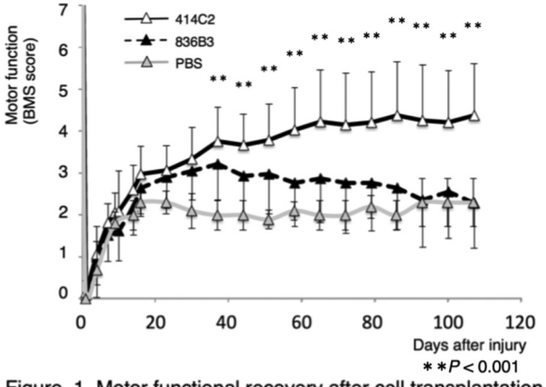

Figure. 1 Motor functional recovery after cell transplantation

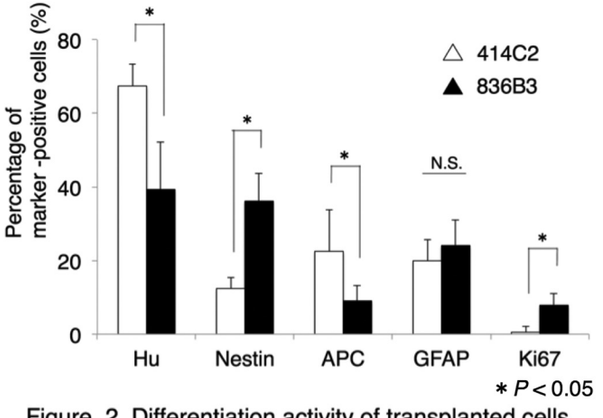

Figure. 2 Differentiation activity of transplanted cells

See Disclosure Index pages 41–95.

The Effects to Relieve Neuropathic Pain After Spinal Cord Injury by Early Transplantation of Mesenchymal Stem Cells Through Suppression of Pain-Related Signaling Cascades and Reduced Inflammatory Cell Recruitment

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Introduction: Bone marrow-derived mesenchymal stem cells (BMSC) modulate inflammatory / immune responses and promote motor functional recovery after spinal cord injury (SCI). However, the effects of BMSC transplantation on central neuropathic pain and neuronal hyperexcitability after SCI remain elusive. This is of importance because BMSC-based therapies have been proposed for clinical treatment. In the present study, we investigated the effects of BMSC transplantation on post-SCI chronic neuropathic pain. Specifically, we focused on the effects of BMSC transplants on microglia and macrophages and MAPK signalling at the level of the lesion. Furthermore, we used chimeric mice wherein the bone marrow contained hematogenous cells that expressed green fluorescent protein (GFP). This was to determine the differential effects of transplanted BMSC on spinal-resident microglia and bone marrow-derived macrophages.

Materials / Methods: C57BL/6 mice (8–14 weeks old) were subjected to SCI induced with the Infinite Horizon impactor (60kdyn) at T9-T10 level. EGFP+ bone marrow cells were obtained from C57BL/6-transgenic (CAG-EGFP) mouse. The 2.0×105 BMSC in 3μl of DMEM transplantation was performed on days 1, 3, 7 and 14 post-SCI. In a sham SCI operation group, each mouse underwent a laminectomy only at the T9-T10 vertebral level, with no SCI performed. Behavioral and sensory testing were recorded at times indicated post-SCI. To evaluate the expression of pain-related protein in the spinal cord, immunohistochemistry, flow cytometry analysis and western blotting were performed.

Results: BMSC transplantation at day 3 post-SCI improved motor function and relieved SCI-induced hypersensitivities to mechanical and thermal stimulation. The pain improvements were mediated by suppression of PKC-γ and p-CREB expression in dorsal horn neurons. BMSC transplants significantly reduced levels of p-p38 MAPK and p-ERK1/2 in both hematogenous macrophages and resident microglia, and significantly reduced the infiltration of CD11b and GFP double-positive hematogenous macrophages without decreasing the CD11b-positive and GFP-negative activated spinal-microglia population. BMSC transplants prevented hematogenous macrophages recruitment by restoration of the blood-spinal cord barrier, which was associated with decreased levels of: (i) inflammatory cytokines (TNF-α, IL-6); (ii) mediators of early secondary vascular pathogenesis (MMP-9); (iii) macrophage recruiting factors (CCL2, CCL5, CXCL10), but increased levels of a microglial stimulating factor (GM-CSF).

Conclusion: In this study, we have demonstrated that early BMSC transplants not only decreased the activation of MAPK signaling in injured spinal cord, but also altered the localized presence of inflammatory mediators, which will have contributed to a decrease BSCB disruption and reduction in the recruitment of harmful blood-borne macrophages. The net effect of these changes is likely to play a major role in reducing pain hypersensitivity in the BMSC treated SCI animals. These findings support the use of BMSC transplants for SCI treatment.

Involvement of Autophagy in Intervertebral Disc Degeneration and Its Contribution to Cell Survival with the Maintenance of Notochordal Phenotype

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Introduction: The intervertebral disc is the largest avascular, low-nutrient organ in the body. Autophagy, the intracellular process by self-digestion and recycling damaged components, is an important cell survival mechanism under stress, primarily nutrient deprivation. Therefore, resident disc cells may utilize autophagy to cope with the harsh environment of the disc (low nutrition, pH, and oxygen concentration). However, clinical relevance of disc cellular autophagy is unknown. Our objective was to elucidate the involvement and roles of autophagy in human clinical and rat experimental disc degeneration.

Materials / Methods: Human discs were collected from anterior cervical discectomy and fusion surgery for degenerative disease (n=20; 62.0±16.2 years; male 10, female 10; Pfirrmann degeneration grade, 3.5±0.5). 12-week-old male Sprague-Dawley rat tails were instrumented with an Ilizarov-type device with springs and loaded at 1.3 MPa statically for up to 56 days (n=42). To clarify the involvement of autophagy during degeneration, Western blotting for autophagy marker LC3-II and substrate p62/SQSTM1 was performed in human and rat disc nucleus pulposus (NP) and annulus fibrosus (AF) tissues. Immunofluorescence for notochordal brachyury, autophagic LC3, and apoptotic TUNEL was also performed in rat model disc sections. To understand roles of autophagy, RNA interference (RNAi) of autophagy-essential ATG5 gene was applied to human disc NP cells, and apoptosis incidence was assessed by measuring PARP and caspase-9, pro-apoptotic Bax, and anti-apoptotic Bcl-2.

See Disclosure Index pages 41–95.

Results: In human disc NP and AF specimens, Western blotting showed that autophagic LC3-II and p62/SQSTM1 expression transiently increased in middle ages of 40–70 but subsequently decreased in older ages of >70 (R^2=0.392–0.614, p≤0.01) (Figure 1A). Meanwhile, in rat disc NP and AF tissues, LC3-II and p62/SQSTM1 consistently decreased with compression (p<0.01) (Figure 1B). Then, multi-color immunofluorescence showed markedly high expression of LC3 in brachyury-positive NP notochordal cells in unloaded control discs (Figure 2). Notably, while brachyury- and LC3-co-positive notochordal cells decreased with compression, positivity for apoptotic TUNEL increased in brachyury-negative non-notochordal cells (p<0.05) (Figure 2). These *in-vivo* findings suggest a possible contribution of autophagy to cell survival with the maintenance of notochordal phenotype in the disc, raising the necessity of mechanistic *in-vitro* experiments. In human disc NP cells, RNAi of ATG5 decreased LC3-II and increased p62/SQSTM1 as well as ATG5 expression, consistent with autophagy inhibition. Then, inflammatory cytokine IL-1β-induced apoptotic changes, as shown by PARP and caspase-9 cleavage and increased BAX and decreased Bcl-2 expression, were further enhanced by ATG5 RNAi (p<0.05), which indicates anti-apoptotic roles of autophagy.

Conclusion: This is the first report to demonstrate that autophagy is clinically involved in intervertebral disc degeneration. Autophagy transiently increased potentially by stress response in human middle-aged discs, but subsequently decreased in human older-aged and rat severely degenerated discs. Autophagy can be protective against apoptosis and notochordal cell disappearance, contributing to the maintenance of disc health including notochordal cell homeostasis. Autophagy modulation is suggested to be a more physiological, future molecular treatment strategy for degenerative disc disease.

Figure 1. Western blotting analysis for autophagy in human disc aging and degeneration and rat tail static compression-induced disc degeneration

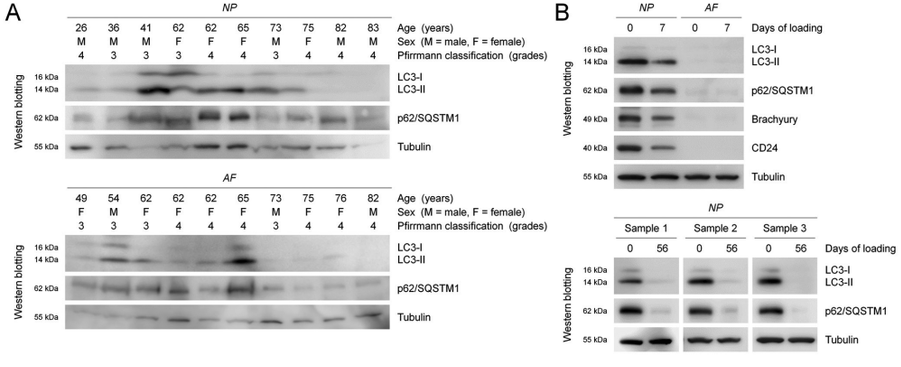
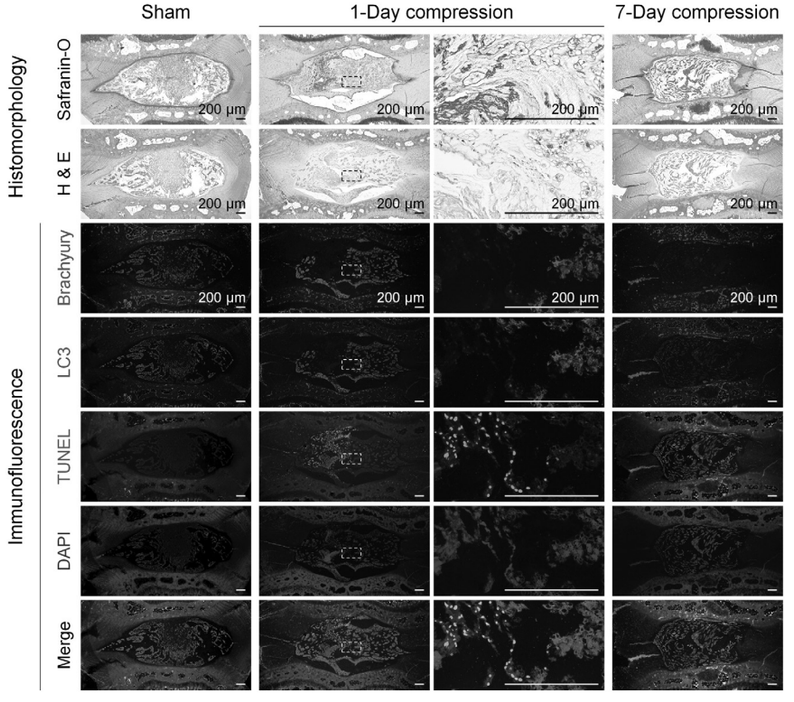


Figure 2. Histomorphological and immunofluorescent analysis for autophagy, apoptosis, and notochordal cell disappearance in rat tail static compression-induced disc degeneration



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Lateral Olfactory Tract Usher Substance (LOTUS) Promoted Axonal Regeneration and Functional Recovery After Spinal Cord Injury in Adult Mice

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Introduction: Lateral olfactory tract usher substance (LOTUS) can be found as both membrane and secreted protein that functions as a molecule for neuronal circuit formation. Five ligands, Nogo, MAG, OMgp, BLys and CSPG are known to bind to Nogo receptor 1 which acts to suppress axonal regeneration following spinal cord injury (SCI). LOTUS binds and inhibits this receptor. It has been reported that, in LOTUS knockout mice, the motor function recovery after SCI is significantly worse when compared with wild-type mice. The purpose of this study is to evaluate the axonal regeneration and motor function recovery after SCI in LOTUS overexpressed mice.

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 DigiGate system and rotarod test was used on the sixth week after SCI. On this sixth week, five mice from both groups were injected with biotinylated dextran amine (BDA) into the primary motor cortex to trace the corticospinal tract (CST), and another five from both groups were injected with fluoro-gold (FG) into the lumbar spinal cord to trace the reticulospinal tract. Two weeks after the injection, electrophysiological analysis using spinal cord-evoked potential was conducted. After the mice were sacrificed, histological analyses were performed.

Results: 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, $p<0.01$). DigiGate analysis also revealed a 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, $p<0.01$) in the LOTUS group, and the rotarod test showed significant longer total run time (60.75±32.08 vs. 15.07±9.65, $p<0.01$) at 6 weeks after SCI in the LOTUS group (Figure 1). Electrophysiological analysis revealed significantly shorter latency and larger amplitude in the LOTUS group 8 weeks after SCI. Histological analyses revealed that the NF-H, 5-HT and p-GAP43 positive fibers increased significantly at the caudal sites in the LOTUS group compared to the control group (Figure 2). As for the 5-HT positive serotonergic fibers, a major contributor of motor function, a significant increase was seen in the LOTUS group 14 days after SCI and continued to increase up to 56 days. These results suggest that LOTUS protected nerve axons from injury during the acute phase and promoted axonal regeneration. The CST axons labeled with BDA significantly increased at the rostral sites in the LOTUS group compared to the control group, but not at the caudal sites of the lesion epicenter in both groups. On the other hand, reticular nucleus neurons retrogradely labeled with FG increased significantly.

Conclusion: Taken together, LOTUS showed beneficial effects for functional recovery in SCI by promoting axonal regeneration and nerve axonal protection. In the future, we plan to evaluate the efficacy of LOTUS by transplantation of LOTUS overexpressed neural stem cells in the injured spinal cord.

Fig. 1 LOTUS contributed to functional recovery

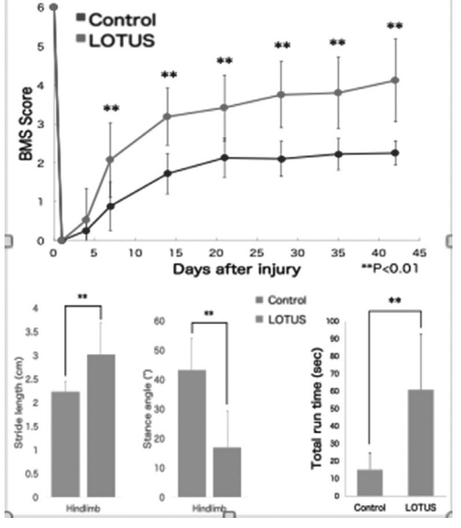
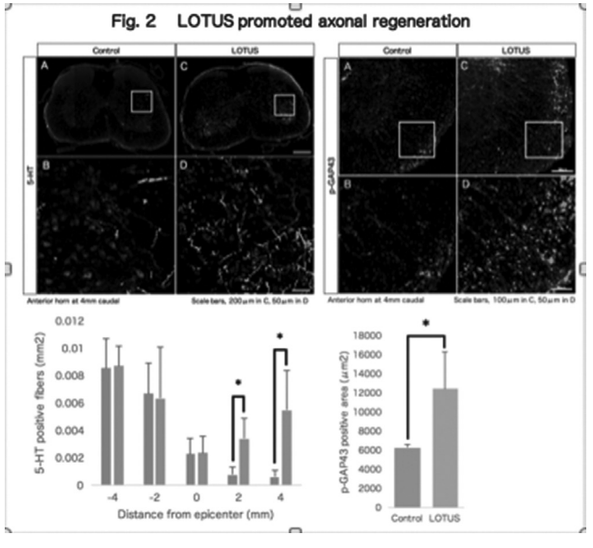


Fig. 2 LOTUS promoted axonal regeneration



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Using Suicide Genes for Selectively Ablating Tumorigenic Cells following Human Induced Pluripotent Stem Cell-Derived Neural Stem / Progenitor Cell Transplantation in Spinal Cord Injury

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Introduction: The issue of safety is one of the highest concerns when it comes to the clinical application of human induced pluripotent stem cell-derived neural stem / progenitor cell (hiPS-NS/PC) transplantation in treating spinal cord injury (SCI). When certain lines of hiPS-NS/PCs are transplanted into the injured spinal cord of murine models, significant improvements in the motor function is seen over a period of 4 to 5 weeks, which is then followed by an abrupt deterioration secondary to the mass effect of the tumor. With these cells, a significant proportion of the transplanted cells remain undifferentiated. The aim of this study is to selectively ablate the undifferentiated cells whilst preserving the fully differentiated cells and hence the motor function.

Materials / Methods: In order to establish the ablation system for targeting tumorigenic proliferating cells, we used the Herpes Simplex Virus 1 Thymidine Kinase (HSV-TK) gene which is a well-known suicide gene that is already in use in the clinical setting. Ganciclovir (GCV), the prodrug of HSV-TK, can be converted to cytotoxic GCV-triphosphate by HSV-TK, thereby killing HSV-TK-expressing cells. It is known to be cell cycle dependent and is only effective in cells that are multiplying.

In Vitro, we successfully introduced the HSV-TK gene into a line of hiPS-NS/PCs that is known to have tumorigenic properties (hiPSC-NS/PC-HSV-TK). We allowed these cells to differentiate over a period of 3 weeks and administered GCV in an attempt to ablate the undifferentiated cells.

In Vivo, hiPSC-NS/PC-HSV-TK was transplanted into the spinal cord of NOD/SCID mice nine days after a spinal cord contusion injury. Six weeks following the transplantation, GCV was administered for three weeks. Motor function was evaluated through weekly BMS scoring together with Rotor Rod Scoring and Digigait analysis 12weeks after the transplantation.

Results:
In Vitro: There was a significant decrease in the percentage of immature Nestin and Ki67 positive cells (60.0% to 18.6%, 30.0% to 3.1%, respectively; $p<0.01$) after GCV administration, but the Tuj1 positive neuronal cells were relatively well preserved (84.5% to 63.3%; $p>0.05$).

In Vivo: In the mice without GCV administration (GCV(-)), there was an initial improvement in motor function followed by an abrupt deterioration. In the mice with GCV administration (GCV(+)), however, the improved motor function was preserved throughout the 12 week follow up period. Immunohistochemistry staining revealed that the immature Nestin, SOX1 and Ki67 positive cells were more abundant in the GCV(-) mice compared to the GCV(+) mice (45.6% vs. 4.3%, 32% vs. 2.2%, 15.4% vs. 1.0%, respectively; $p<0.01$). For the matured post-mitotic NeuN positive neuronal cells, there were no significant differences between the 2 groups (19.5% vs. 23%; $p>0.05$).

Conclusion: We were successful in selectively ablating the immature potentially tumorigenic iPS-NS/PCs that had been transplanted into SCI model mice whilst preserving the motor function gained from the treatment. We believe that, by employing this system, we can minimize the risks of tumorigenesis and improve the safety of iPS-NS/PC transplantation in the treatment of SCI patients.

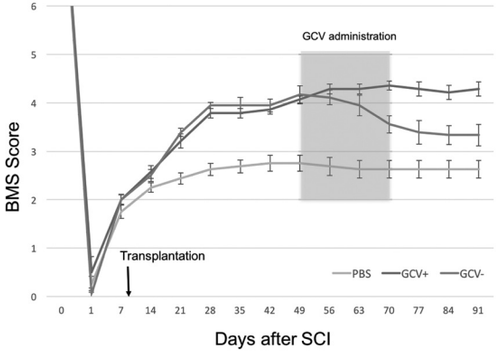

Figure 1. A graph illustrating the changes in motor function (BMS scores) following SCI. The drop in BMS score observed in the GCV(-) mice is not seen in the GCV(+) mice.

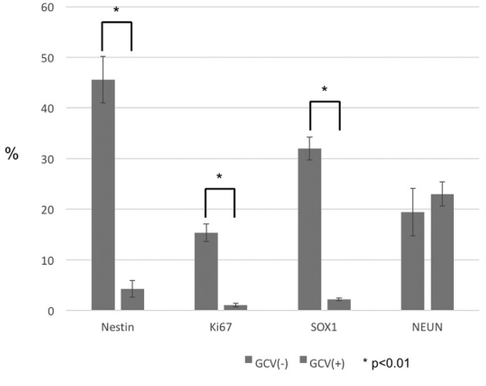

Figure 2. A graph comparing the percentage of cells at various stages of differentiation. There is a significant drop in the number of immature neuronal cells in the GCV(+) mice.

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Transplantion of Neural Stem / Progenitor Cell Derived from Human iPS Cells with Gamma-Secretase Inhibitor Treatment Promotes Motor Functional Recovery after Both Subacute and 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 whilst preventing tumorigenicity in tumorigenic 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 both subacute and chronic SCI.

Materials / Methods: Non-tumorigenic hiPSC (201B7)-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 9 days (subacute) and 42 days (chronic) after injury. The growth / survival and histological analyses of the transplanted cells were monitored with bioluminescence imaging and immunohistochemistry. Behavioral analyses were also performed using BMS scoring.

Results: Both GSI treated and untreated hiPSC-NS/PCs survived following transplantation in the subacute 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. There were also significantly more neuronal, serotonergic and growth-associated protein 43-positive fibers in the GSI group. Furthermore, in the GSI group, a significantly greater recovery in motor function was gained compared with the control group at 35 days after transplantation in the subacute phase (Figure 1).

With regards to transplantation in the chronic phase, the proportion of mature neurons in the GSI group also increased significantly; and we observed neuronal and serotonergic fibers suggesting that axonal regrowth was promoted. Quantitative analyses revealed that the transverse area of the spinal cord at the lesion epi-center was significantly larger in the GSI group compared with the control groups, suggesting that transplantation of cells with GSI treatment prevented atrophy of the injured spinal cord. Even though we performed the transplantation in the chronic phase, we observed significant improvements in functional recovery at 56 days after transplantation of hiPSC-NS/PCs with GSI treatment (Figure 2).

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 both subacute and chronic SCI. We believe that, by treating the cells for transplantation with GSI, they gain the ability to extend their axons despite the environment being disadvantageous in the chronic phase following a SCI. Therefore, transplantation of hiPSC-NS/PCs with GSI treatment can improve their safety and efficacy in the clinical setting.

Figure 1. Motor function analyses after transplantation of hiPSC-NS/PCs with or without GSI treatment in long-term observation of 'subacute' SCI.

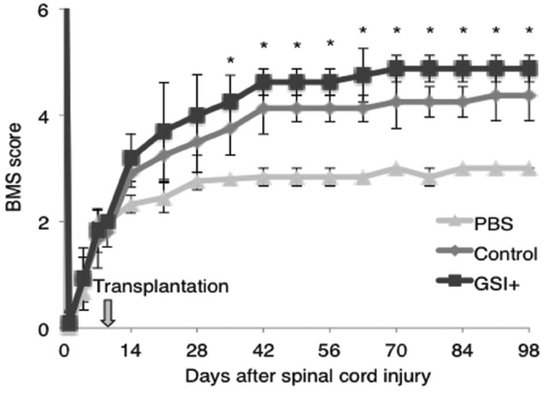
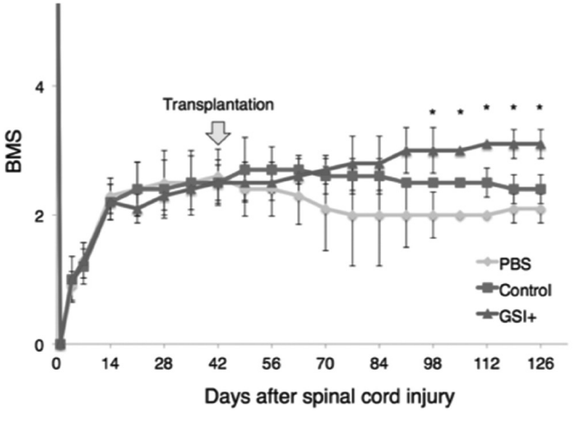


Figure 2. Motor function analyses after transplantation of hiPSC-NS/PCs with or without GSI treatment in long-term observation of 'chronic' SCI.



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Methylprednisolone Treatment Speeds Early Locomotor Recovery Following Surgical Decompression for Degenerative Cervical Myelopathy (DCM)

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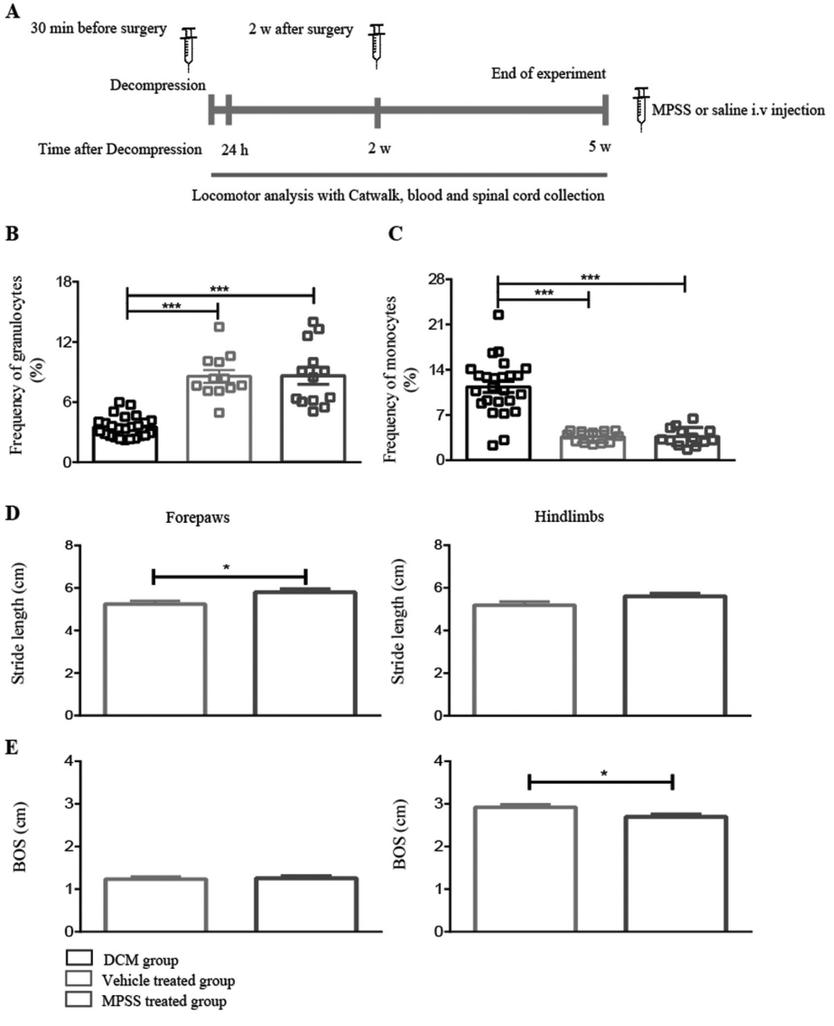
Introduction: Degenerative cervical myelopathy (DCM) is caused by age-related degeneration of the cervical spine, leading to chronic compression of the spinal cord. The current treatment consists of surgical decompression. Our laboratory has shown that after decompression, increased neuroinflammation and spinal cord reperfusion can contribute to diminish the beneficial neurological outcomes post-surgery. Sterioids, such as Methylprednisolone (MPSS), have been used to moderate inflammation in the spinal cord following traumatic spinal cord injury. However they have been shown to compromise the peripheral immune system. The primary objective of this study was to assess the effectiveness of MPSS as a neuroprotective treatment to reduce post-decompression inflammation and enhance neurological recovery.

Materials / Methods: Gradual compression of the spinal cord was induced in C57B/L mice by inserting a biomaterial underneath the C5-6 lamina. After 12 weeks of DCM, animals were randomized to receive one I.V (intravenous) dose of MPSS (30mg/kg) or vehicle 30 minutes before decompression and a second one at two weeks after decompression (Figure 1A). Composition of circulating white blood cells and secreted cytokines were analyzed by flow cytometry and ELISA. Locomotor outcomes were measured using the Catwalk system. Tissue preservation was analyzed with luxol fast blue and hematoxylin / eosin (LFB/HE) staining along with immunohistochemistry for glial and neuronal cell markers.

Results: At 24 hours after surgical decompression there were significant changes in the composition of circulating white blood cells. Granulocytes experienced a 2.5-fold increase, whereas monocytes had a 3.5-fold decrease (Figure 1B-C; ***$p<0.001$) compared with their baseline levels before surgery. No significant changes were observed between MPSS or vehicle group at 24 hours or at 2 weeks after decompression. However, at 2 weeks after surgery MPSS treatment speed locomotor recovery, specifically recovery of stride length and base of support (BOS) reached significant values compared with vehicle treated group (Figure 1D-E; *$p<0.05$). At this time point, MPSS treated group had reduced systemic IL-1b levels and an increase in the number of NeuN+ cells in the spinal cord. Histological assessment of the spinal cord, did not show significant changes in grey and white matter preservation by MPSS treatment.

Conclusions: Our data suggest that MPSS has an early neuroprotective effect in improving locomotion following decompression for degenerative cervical myelopathy without compromising the composition of circulating immune cells.

Figure 1.



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A Biomechanical Evaluation of Reinsertion and Revision Screw for Cervical Vertebrae Screw Fixation

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Study Design: Fresh-frozen human cadaveric biomechanical study.

Objective: To evaluate the biomechanical consequence of vertebrae screw reinsertion and revision in the cervical spine.

Summary of Background Data: During cervical vertebrae screw instrumentation, complete removal to reassess for screw malposition, screw fixation strength has never been evaluated biomechanically after reinsertion using a previous pilot hole and trajectory or revision screw for failed cervical vertebrae screw fixation.

Methods: Forty-five cervical individual fresh-frozen human cadaveric vertebral levels were instrumented bilaterally with 4.0-mm titanium cervical vertebrae screws, and insertional torque (IT) was measured with each revolution. A paired comparison was performed for each level. Screw reinsertion was performed by completely removing the cervical vertebrae screw, palpating the tract, and then reinserting along the same trajectory. Screws were tensile loaded to failure "in-line" with the screw axis, and pullout strength (POS) was measured, a paired comparison was performed for each level, and then a 4.5-mm revision screws reinserting along the same trajectory and insertional torque (IT) was measured with each revolution, and pullout strength (POS) was measured. The pullout strength and insertional torque results of the 4.0-mm vertebrae screws, and 4.5-mm revision screws groups were compared.

Results: There was no significant difference for cervical vertebrae screws pullout strength (POS) between reinserted and control screws. There was no significant difference in IT between initial insertion for the test group (INI) and control. IT for reinserted screws had significantly decreased compared with INI and control screws. The test group screws in the cervical vertebrae had significant correlations between initial IT and POS, and moderate correlations between reinsertion IT and POS in the cervical vertebrae. There was significant difference for screw pullout strength (POS) between 4.0-mm titanium vertebrae screws groups and 4.5-mm titanium revision screws groups. There was significant difference in IT between 4.0-mm titanium vertebrae screws groups (INI) and 4.5-mm revision screws groups. The 4.0-mm titanium vertebrae screws in the cervical spine had significant correlations between IT and POS, the 4.5-mm titanium revision screws in the cervical spine had significant correlations between IT and POS.

Conclusion: Despite a significant reduction in cervical vertebrae screw IT, there was no significant difference in cervical vertebrae screw POS with reinsertion. Therefore, when surgeons must completely remove cervical vertebrae screw for tract inspection, reinsertion along the same trajectory may be performed without significantly compromising fixation strength. 4.5-mm revision screw fixation cannot provide enough biomechanical fixation for failed 4.0-mm cervical vertebrae screws fixation.

How Does the Hardware Failure After Anterior Cervical Plate Fixation Affect the Radiographic and Clinical Outcomes?

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Introduction: Hardware failure (screw pullout, loosening or breakage) detected after anterior cervical discectomy/corpectomy and fusion (ACDF/ACCF) with plating is a worrisome condition that might cause various implant-related complications and reduce solid fusion rate. Since little is known about its long-term prognosis, surgeons could be wondering whether or not they need to perform revision surgery when they discover anterior cervical plating failure on postoperative x-rays. The purpose of this study is to elucidate the effect of hardware failure associated with anterior cervical plating on radiographic and clinical outcomes at long-term follow-up.

Methods: Medical records and radiographic data of 248 consecutive patients who underwent ACDF or ACCF with a dynamic plating system and were followed-up for ≥2 years were retrospectively reviewed. Among them, 25 patients showed anterior migration of >2mm, or breakage of at least one screw on x-ray before postoperative 1 year (Hardware failure group, HF group, n=23). The Non-failure (NF) group included the other 223 patients without any radiological evidence of hardware failure until final follow-up. Solid union was defined as interspinous space motion of <1mm on magnified dynamic lateral x-rays. Fusion rates were compared between HF vs. NF groups at 1 year, 2 years, and final follow-up period, respectively. To assess clinical outcomes, visual analogue scales (VAS) of neck pain/arm pain and neck disturbance index (NDI) were also compared between the two groups pre- and post-operatively. We investigated the locations of screw failure and reviewed complications requiring revision surgeries.

Results: There were no baseline differences in age, gender, or follow-up period between the two groups; however, the patients with hardware failure underwent significantly longer fusion levels (2.2±0.5 vs. 1.6±0.7 levels, $p<0.01$). Among the 25 patients in HF group, 15 (60%) had screw pullout, 4 (16%) had screw breakage, and 6 (24%) had both screw pullout and breakage. Even with the hardware failure, 13 of the 25 patients achieved solid fusion at final follow-up. However, fusion rates were significantly lower in the HF group than in the NF group at each follow-up period consistently until the last visit (52% vs. 86%, $p<0.01$). Most failures developed at the lowermost-instrumented vertebra (23 out of 25, 92%). Despite the fractured implants and a higher nonunion rate, the patients of the HF group showed a similar degree of neck pain, arm pain, and NDI score as those in the NF group postoperatively (Table 1). There were no serious hardware migrations or related complications requiring revision surgery; however, 1 patient showed persistent arm pain, which was associated with pseudarthrosis.

See Disclosure Index pages 41–95.

Conclusion: Our study demonstrated that screw pullout or breakage is not a rare condition, occurring in 10.1% (25 out of 248) of patients who underwent ACDF or ACCF with a dynamic plating system. Although hardware failure was associated with a higher rate of pseudarthrosis, it did not aggravate postoperative arm pain, neck pain, and neck disability. Since the migration of failed implants rarely progresses to the extent that endangers tracheoesophageal structures, immediate removal would not be necessary (Figure 1).

Table 1. Comparison between hardware failure group and non-failure group

Variables	Hardware failure group (n=25) Mean±SD	Non-failure group (n=223) Mean±SD	p value
Gender			
Female	7 (28%)	104 (47%)	0.09
Male	18 (72%)	119 (53%)	
Age	59.1±8.4	58.0±10.4	0.61
Follow up(m)	32.4±10.1	30.7±10.9	0.44
Fusion Level	2.2±0.5	1.6±0.7	**<0.01**
Fusion			
1 year	8 (32%)	164 (73%)	**<0.01**
2 year	10 (40%)	193 (86%)	**<0.01**
Final f/u	13 (52%)	193 (86%)	**<0.01**
Neck pain			
Preop	4.3±3.4	3.6±2.9	0.24
Postop	1.8±2.1	1.5±1.9	0.38
Improvement	2.4±4.2	2.0±3.2	0.61
Arm pain			
Preop	5.1±2.9	4.9±2.9	0.76
Postop	2.0±2.3	2.0±2.5	0.98
Improvement	3.1±3.9	2.9±3.5	0.92
NDI			
Preop	16.6±8.5	16.2±8.3	0.80
Postop	6.0±5.2	6.4±6.4	0.77
Improvement	10.7±9.5	9.9±9.0	0.67
Location of failure			
Uppermost instrumented vertebra	2 (8%)		
Lowermost instrumented vertebra	23 (92%)		
Other levels	0 (0%)		
Age, level: chi-square test			
Other variables: T-test			

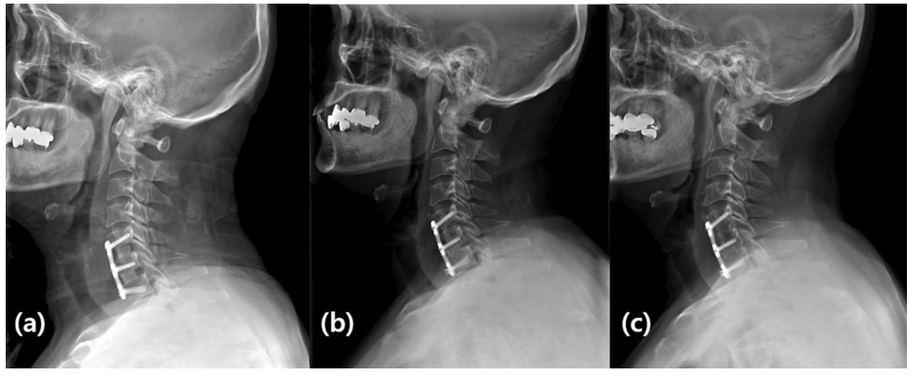

Figure 1. A case of a 57 year old male with cervical myelopathy caused by hard disk who underwent ACDF, C5-6-7. (a) Immediate postop (b) Postop 6m (c) Postop 4y

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ACDF Procedures Performed In Ambulatory Centers Compared to the Hospital Inpatient Setting: Length of Stay, Cost Data, and Complications in Two National Databases

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a common procedure used to treat cervical herniated discs and degenerative disc disease. Though recent care pathways have increased interest in performing ACDF procedures in the outpatient setting at ambulatory surgery centers (ASC), few studies have drawn direct comparisons with the inpatient hospital setting. Large databases can offer several advantages in this type of analysis with their ability to capture a broader geographical distribution with substantially larger statistical power. There exists no studies using large cohort databases comparing ACDF procedures performed in an outpatient vs. hospital setting. Our purpose, therefore, was to compare length of stay, cost, and complications between patients undergoing ACDF in outpatient ASC and inpatient hospital settings.

Methods: The New Jersey State Ambulatory Surgery Database (NJSASD) and National Inpatient Sample (NIS) databases were queried for patients age ≥18 with a primary cervical diagnosis that underwent anterior cervical discectomy and fusion (ACDF) procedures (1–2 levels) between the years 2005–12. Patients from the NJSASD databases constituted the outpatient ASC cohort and patients from the NIS database constituted the hospital cohort. NJSASD and NIS patients were propensity score matched based on age, gender, diabetes, coronary artery disease, and chronic kidney disease. Patient demographics, length of stay, total charges, and complications (dysphagia, nervous system, cardiac, respiratory, digestive, urinary, PVD, device-related, shock, hematoma, puncture, infection, anemia, ARDS, PE, and DVT) were recorded and analyzed for significant differences between the two cohorts using Student's t-tests and Pearson's chi-squared tests.

Results: 2,205 outpatients were compared with 2,205 matched inpatients. Average age was 52.13, 51.9% were female, 82.2% white race, and 87.1% performed as elective cases. Due to matching, there were no significant difference in baseline demographics or comorbidities, however, there was a larger proportion of two-level ACDFs in the NIS cohort (NIS 10.8% vs. NJSASD: 7.6%, $p<0.001$). NIS had overnight stays 98.6% of the time, as opposed to NJSASD cases who stayed overnight 17.7% ($p<0.001$). Inpatient procedures incurred significantly higher charges compared to outpatient procedures ($44,233.08 vs. $34,729.82, $p<0.0001$). Complications were much more frequent in the hospital setting (4.9% inpatient versus 0.5% outpatient). Complications that were more prevalent in hospitals as compared to outpatients included dysphagia, nervous system, cardiac, respiratory, digestive, urinary, device-related, hematoma, puncture, infection, anemia, ARDS, PE, and DVT (all $p<0.05$).

Conclusions: Patients undergoing ACDF procedures performed between 2005 and 2012 were matched in two large databases to analyze operative and post-operative data in the inpatient hospital setting compared with the outpatient ASC setting. Within the limitations inherent to database studies, we found that hospital based ACDF surgery had a higher length of stay, incurred greater charges, and experienced a greater number of complications, despite controlling for comorbidities, age, and gender. These disparities are tempered by a slightly higher frequency of two-level ACDFs in the hospital setting and possible differences in database reporting. These results suggest significant advantages for outpatient ACDF procedures including an acceptable safety profile.

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Complications Associated with Surgical Management of Cervical Myelopathy: An Analysis of Risk Factors and HRQOL Outcomes Using Baseline Characteristics

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Introduction: Cervical disk herniation and degenerative disease are frequently associated with spinal stenosis and cervical myelopathy. Though surgical intervention is associated with favorable outcomes overall, the risk factors for complications and their ultimate impact on surgical outcomes is poorly understood. The purpose of this study was to analyze baseline patient characteristics and surgical data to identify risk factors for complications in patients undergoing surgical intervention for cervical myelopathy. Identified risk factors and complications were then compared to changes in health related quality of life (HRQOL) outcomes from baseline to 2 years post-operatively.

Materials / Methods: A restrospective review was performed on a prospectively collected multi-center database of patients surgically treated for cervical myelopathy. Data collected included baseline patient demographics and co-morbidities, baseline clinical information, surgical procedures (decompression / discectomy / fusion, anterior / posterior, instrumentation, and bone graft), and complication rates. Complications included cervical cord injury, cerebral spinal fluid (CSF) leak, excessive bleeding, ineffective fixation, infection, intra-operative monitoring alteration, nerve root injury, postoperative radiculopathy, soft tissue injury, vascular injury, and other complications. Health-related quality of life (HRQOL) outcomes were assessed by SF-36 physical component score (PCS), mental component score (MCS), and Neck Disability Index (NDI) at baseline and 2 years post-operatively and compared between patients with and without complications. Statistical analyses included multivariate logistic regression, controlling for age, gender, and BMI, to investigate risk factors for complications. Paired sample t-tests were used to compare treatment effects (TE) defined as change in HRQOL outcomes from baseline to 2 years post-operatively with and without complication.

Results: A total of 203 patients were included in the analysis. The total rate of complications was 7.4%. Notable complications included CSF leak (2.5%), post-operative radiculopathy (1.0%), excessive bleeding (1.0%) and other complications (2.5%). The only significant risk factor for developing a complication was previous cervical spine surgery (OR:9.22, p=0.034). No other baseline patient characteristics, comorbidities, or surgical procedures were associated with a significantly increased risk for developing complications. Comparison of TE with and without complications shows no significant differences between the groups (p>0.05)

Conclusions: For patients undergoing surgical management of cervical myelopathy, the total rate of complications was 7.4%. In this cohort, baseline clinical information, comorbidities, and use of non-operative treatment modalities were not found to be significantly associated with an increased risk of developing a complication, however, previous cervical spine surgeries increased the risk of complications by nine times. Treatment effects of surgical intervention were not significantly effected by the occurrence of complications with two year outcomes using SF-36 PCS, MCS, and NDI scores.

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Perioperative Catheter Use as a Risk Factor for Surgical Site Infection Following Cervical Surgery: An Analysis of 39,893 Patients

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Background: The association between surgical site infection (SSI) and the use of arterial catheters (AC) or central vein catheters (CVC) is well established in cardiac surgery; one study demonstrated that 9.0% of patients with SSI had a catheter related infection. We hypothesized that perioperative use of catheters can increase the incidence of SSI after cervical spine surgery.

Methods: We retrospectively analyzed the Humana private insurance database using PearlDiver. The incidence of SSI within 1 month postoperatively and the crude odds ratio (cOR) were calculated based on the use of catheters. Perioperative catheter use was defined as the patients with corresponding codes for catheter use on the day or within 7 days preoperatively. Subsequently, subgroups were divided based on patient's Charlson Comorbidity Index (CCI) and analyzed for the incidence of SSI and OR. Finally, logistic regression analysis was performed to identify risk factors for SSI. Patient's CCI (≥3 or 2≥), use of catheters, surgical type (anterior or posterior) and the presence of instrumention were included as the independent factors.

Results: A total of 39,893 patients received cervical surgery between 2007 and 2015; 14.1 % of patients had AC and 2.0% had CVC on the day of operation or within 7 days preoperatively. In total 631 (1.6%) patients had postoperative SSI. The incidence of SSI of patients treated with and without AC was 3.2% and 1.3%, with cOR of 2.44 (p<0.001). Likewise, SSI incidence in patients with and without CVC was 5.8% and 1.5%, with cOR of 2.61 (p<0.001). In subgroup analysis, perioperative use of a CVC or AC was a risk factor for SSI regardless of the patients' CCI (Table1). Multivariate logistic regression analysis demonstrated that the adjusted OR was 1.227 in AC use (p=0.086), and 1.649 in CVC use (p=0.017) (Table2).

Conclusion: The incidence of SSI was significantly higher in patients with perioperative catheter use compared to patients without catheters, regardless of patients' comorbidities. Furthermore, the use of CVC was a significant risk factor regardless of the severity of comorbidity, surgical approach, and presence of instrumention. While the essential benefits of AC and CVC are undisputed, our study demonstrates that perioperative catheters must be used cautiously to prevent SSI following cervical surgery.

Table 1. SSI ratio based on the patients' CCI

CCI	variables		SSI		Incidence of SSI	Crude OR	95%CI	P value
			Positive	Negative				
0	AC	w/o	108	10,618	1.0%	ref	-	-
		w/	27	1,009	2.6%	2.61	1.72–4.03	<0.001
	CVC	w/o	129	11,514	1.1%	ref	-	-
		w/	6	113	5.0%	4.74	2.05–10.97	0.002
1 or 2	AC	w/o	130	11,908	1.1%	ref	-	-
		w/	51	1,692	3.0%	2.82	2.03–3.91	<0.001
	CVC	w/o	164	13,423	1.2%	ref	-	-
		w/	17	177	8.7%	8.59	5.09–14.45	<0.001
≥ 3	AC	w/o	217	11,364	1.9%	ref	-	-
		w/	98	2,671	3.5%	1.92	1.51–2.45	<0.001
	CVC	w/o	293	13,596	2.1%	ref	-	-
		w/	22	439	4.8%	2.33	1.49–3.62	0.001

Table 2. Logistic regression analysis to predict SSI

Variables	Reference	Univariate analysis		Multivariate analysis	
		Crude OR (95%CI)	P value	Adjusted OR (95%CI)	P value
AC use	Without AC	2.44 (2.05–2.99)	<0.001	1.23 (0.97–1.54)	0.086
CVC use	Without CVC	4.06 (2.97–5.55)	<0.001	1.66 (1.08–2.46)	0.016
CCI≥3	2≥CCI	1.53 (1.31–1.80)	<0.001	1.41 (1.16–1.70)	<0.001
Posterior surgery	Anterior surgery	3.98 (3.40–4.65)	<0.001	1.32 (1.01–1.74)	0.047
Instrument	Without instrument	2.32 (1.90–2.83)	<0.001	3.99 (3.20–4.98)	<0.001

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National Short-Term Outcomes Following Single-Level Cervical Disc Arthroplasty vs. Anterior Cervical Discectomy and Fusion

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Objective: To compare the differences in the thirty-day postoperative outcomes between cervical disc arthroplasty (CDA) and anterior cervical discectomy and fusion (ACDF).

Summary of Background Data: Although ACDF and CDA can be performed for similar preoperative cervical pathologies, it is unclear whether procedure type impacts perioperative patient outcomes.

Materials / Methods: This retrospective cohort included patients undergoing primary single-level ACDF and CDA from 2010–2014 who were identified by unique Current Procedural Terminology codes within the American College of Surgeon's National Surgical Quality Improvement Program (NSQIP) database. Cases including concomitant posterior cervical, thoracic or lumbar surgery, fractures, emergent cases and patients with preoperative compromised wounds were excluded from analysis. Primary outcomes of interest included both surgical and medical complications, length of hospital stay, unplanned readmission, return to operating room, and mortality all occurring within 30 days of the initial procedure. Patients undergoing ACDF and CDA were propensity score-matched to reduce selection bias and differences in preoperative patient characteristics. Multivariate logistic regression models were utilized to determine odds ratios and associations between covariates and primary outcomes of interest.

Results: Overall, 3,322 (83.6%) patients undergoing primary single-level ACDF and 653 (16.4%) patients that underwent single-level CDA were identified. Propensity score-matching produced a cohort of 1,305 patients with 652 (50.0%) in the ACDF group and 653 (50.0%) in the CDA group. ACDF procedures were performed more often for patients with myelopathy (71.6% vs. 14.7%, p<0.001). There were no statistically significant differences in the development of major surgical or medical complications between the groups. The ACDF patients on average experienced a significantly longer hospital length of stay (LOS) (2.3+14.8 days vs. 1.1+1.0 days, p=0.034) and unplanned hospital readmission (1.8% vs. 0.2%, p=0.002). The increased LOS for ACDF patients (Odds Ratio [OR], 4.21; 95% Confidence Interval [CI], 1.29–13.73, p=0.017) persisted in the multivariate analysis after controlling for preoperative patient characteristic differences. Elevated American Society of Anesthesiologists (ASA) physical status classification, preoperative anemia and elevated white blood cell count were also associated with a significantly increased LOS. Similarly, the increase in ACDF patient unplanned readmission persisted in the multivariate model (OR, 12.17; 95% CI, 1.16–127.23, p=0.037).

Conclusion: Although ACDF and CDA can be indicated for similar cervical pathologies, the latter can be performed safely and effectively with comparable perioperative risk of major complications. The unplanned readmission rate and LOS were increased in patients undergoing ACDF, which may have significant impact on patient cost and outcomes.

Level of Evidence: Therapeutic Level III

Univariate Analysis of Propensity-score Matched ACDF vs. CDA

Patient Characteristics n(%)	ACDF	CDA	p-Value
Number of Procedures	652 (50.0)	653 (50.0)	-
Age	46.9 ± 11.3	44.6 ± 9.7	**<0.001**
Female	291 (44.6)	301 (46.1)	0.596
Total Number of Patients with Myelopathy	467 (71.6)	96 (14.7)	**<0.001**
ASA Category, n(%)			
ASA 1	71 (10.9)	90 (13.8)	0.177
ASA 2	454 (69.6)	453 (69.4)	
ASA 3	127 (19.5)	110 (16.8)	
Comorbidities, n(%)			
Diabetes	37 (5.7)	27 (4.1)	0.198
Hypertension	153 (23.5)	128 (19.6)	0.089
COPD	7 (1.1)	5 (0.8)	0.560
Corticosteroid Use	14 (2.1)	6 (0.9)	0.071
Bleeding Disorder	1 (0.2)	2 (0.3)	1.000
Current Smoker	215 (33.0)	146 (22.4)	**<0.001**
Preoperative Lab Abnormalities, n(%)			
Elevated Creatinine > 1.5	8 (1.5)	4 (0.8)	0.300
Elevated White blood cell count > 12	35 (6.2)	14 (2.7)	**0.005**
Low Albumin <3	1 (0.5)	1 (0.6)	1.000
Low Hematocrit < 33	12 (2.1)	9 (1.7)	0.602
Low Platelets < 100	1 (0.2)	3 (0.6)	0.358

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Perioperative Outcomes			
	ACDF	CDA	p-Value
Length of Stay (days)	2.3 ± 14.8	1.1 ± 1.0	**0.034**
Unplanned Readmission	12 (1.8)	1 (0.2)	**0.002**
30-Day Return to OR	5 (0.8)	2 (0.3)	0.288
Mean Operation Time (minutes)	117.9 ± 64.8	107.5 ± 47.0	**0.001**
Major In-hospital Complications, n (%)			
≥ 1 Major Complication	10 (1.5)	6 (0.9)	0.313
Pulmonary Embolism	0 (0.0)	1 (0.2)	1.000
Deep Venous Thrombosis	1 (0.2)	0 (0.0)	0.500
Myocardial Infarction	1 (0.2)	0 (0.0)	0.500
Deep Incisional SSI Occurrences	2 (0.3)	0 (0.0)	0.249
Pneumonia	1 (0.2)	0 (0.0)	0.500
Unplanned Re-intubation	1 (0.2)	3 (0.5)	0.624
Mortality	0 (0.0)	0 (0.0)	-
Stroke	0 (0.0)	0 (0.0)	-
Cardiac Arrest Requiring CPR	0 (0.0)	0 (0.0)	-
Sepsis Postoperatively	0 (0.0)	0 (0.0)	-
Septic Shock	0 (0.0)	0 (0.0)	-
Organ/Space Infection Occurrences	0 (0.0)	0 (0.0)	-
Ventilator > 48hr	0 (0.0)	0 (0.0)	-
Hospital Stay > 30days	0 (0.0)	0 (0.0)	-
Acute Renal Failure Postoperatively	0 (0.0)	0 (0.0)	-
Progressive Renal Insufficiency	0 (0.0)	0 (0.0)	-
Minor In-hospital Complications, n (%)			
Perioperative Blood Transfusion	4 (0.6)	1 (0.2)	0.218
Superficial Incisional Infection	3 (0.5)	2 (0.3)	0.687
Urinary Tract Infection	4 (0.6)	0 (0.0)	0.062
Hematoma	1 (0.2)	0 (0.0)	0.500

Multivariate Analysis of Predictors for Increased Length of Stay					
Coefficient	Odds Ratio	SE	95% CI		p-Value
CDA	(reference)				
ACDF	4.21	0.60	1.29	13.73	**0.017**
Myelopathy Category					
Absence of Myelopathy	(reference)				
Myelopathy Diagnosis	1.32	0.54	0.46	3.79	0.605
ASA Category					
ASA 1&2	(reference)				
ASA 3&4	2.85	0.41	1.28	6.37	**0.011**
Age					
<60	(reference)				
≥ 60	0.68	0.66	0.19	2.49	0.566
Sex					
Male	(reference)				
Female	0.61	0.39	0.28	1.32	0.213
Comorbidities					
Lack of Specified comorbidity	(reference)				
Diabetes	2.33	0.58	0.75	7.18	0.142
Hypertension	0.64	0.47	0.25	1.61	0.342
Corticosteroid use	2.57	0.74	0.60	11.06	0.205
Current Smoker	0.40	0.49	0.15	1.04	0.060
Preoperative Lab Abnormalities					
Normal Specific Lab	(reference)				
Elevated White blood cell count > 12	4.34	0.54	1.49	12.62	**0.007**
Low Hematocrit < 33	6.82	0.78	1.49	31.30	**0.013**
Elevated Creatinine > 1.5	0.98	1.28	0.08	12.09	0.989

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Multivariate Analysis of Predictors for Unplanned Readmission					
Coefficient	**Odds Ratio**	**SE**	**95% CI**		**P**
CDA	(reference)				
ACDF	12.17	1.20	1.16	127.23	**0.037**
Myelopathy Category					
Absence of Myelopathy	(reference)				
Myelopathy Diagnosis	0.71	0.87	0.13	3.91	0.695
ASA Category					
ASA 1&2	(reference)				
ASA 3&4	1.18	0.76	0.27	5.26	0.823
Age					
<60	(reference)				
≥ 60	1.98	0.77	0.44	8.94	0.377
Sex					
Male	(reference)				
Female	1.10	0.64	0.31	3.84	0.884
Comorbidities					
Lack of Specified Comorbidity	(reference)				
COPD	8.78	1.47	0.49	157.16	0.140
Hypertension	2.06	0.70	0.52	8.20	0.305
Diabetes	1.23	0.98	0.18	8.31	0.834
Corticosteroid use	3.73	1.17	0.37	37.21	0.262
Current Smoker	0.54	0.82	0.11	2.68	0.449
Preoperative Lab Abnormalities					
Normal Hematocrit	(reference)				
Hematocrit < 33	2.76	1.38	0.18	41.67	0.463

Can Machine-Learning Algorithms be Used to Improve Prediction of Short-Term Severe Adverse Events, Readmission, and Mortality Following Elective, Single-Level Anterior Cervical Discectomy and Fusion?

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Introduction: Single-level, anterior cervical discectomy and fusion (ACDF) is a potential target for future bundled payment initiatives, necessitating accurate preoperative risk stratification and prediction. In other specialties such as cardiology and oncology, machine-learning techniques have been shown to improve risk prediction for post-procedural complications and to minimize data collection burden via more parsimonious models. The purpose of this study was to assess the ability of four machine-learning algorithms to 1) improve prediction of 30-day readmission, severe adverse events (SAEs), and morality following elective single-level ACDF, and 2) to do so using risk models containing only the most predictive data elements.

Materials / Methods: We identified 28,326 patients in the American College of Surgeons Nation Surgical Quality Improvement Database (NSQIP) who underwent single-level, elective ACDF between 2011 and 2015. Predictors included demographics, comorbidities, laboratory, and intraoperative variables. Outcomes of interest included 30-day unplanned readmission and 30-day SAEs. Four machine-learning algorithms–logistic regression (LR), random forest (RF), an adaptive boosting algorithm (AB), and a neural network (NN)–were trained on the derivation cohort (2011–2014 ACDF patients) to predict for the outcomes mentioned above, and then applied to the validation cohort (2015 ACDF patients). The c-statistic was used as a measure of predictive value of each model. A threshold-based selection method was then used to select the most predictive variables that individually accounted for at least 0.10 of full-model risk prediction. The algorithms were retrained using only those variables above this threshold to determine the predictive ability of algorithms trained on limited-set models.

Results: The derivation and validation cohorts were comprised of 19,738 and 8,588 ACDF patients, respectively, with similar demographics, comorbidities, and rates 30-day SAE (2.4% vs. 2.7%, p=0.21), 30-day unplanned readmission (2.8% vs. 3.0%, p=0.37), and 30-day mortality (0.21% vs. 0.23%, p=0.67) (Table 1). The machine-learning algorithms achieved acceptable risk prediction for 30-day SAEs (c-statistic for LR: 0.70, RF: 0.83, AB: 0.83, NN: 0.61), 30-day readmissions (LR: 0.67, RF: 0.64, AB: 0.64, NN: 0.63), and for 30-day mortality (LR: 0.69, RF: 0.68, AB: 0.68, NN: 0.66). Across all three outcomes, body mass index (SAE prediction contribution: 0.34, 30-day readmission prediction contribution: 0.42, 30-day morality prediction contribution: 0.30) and age (0.26, 0.18, 0.20 respectively) passed the prediction threshold (≥0.10). Algorithms trained on only these variables achieved lower risk prediction for 30-day SAEs (LR: 0.60, RF: 0.58, AB: 0.56, NN: 0.54), yet similar risk prediction for 30-day readmissions (LR: 0.60, RF: 0.62, AB: 0.57, NN: 0.61) and 30-day mortality (LR: 0.60, RF: 0.58, AB: 0.82, NN: 0.61).

See Disclosure Index pages 41–95.

Conclusion: Machine-learning techniques achieve useful and often improved predictive accuracy for short-term adverse events, unplanned readmission, and mortality following ACDF with multiple algorithms outperforming logistic regression. Limited-variable risk models are similarly predictive for short-term adverse events and unplanned readmission while greatly minimizing data collection burden.

Table 1. Variables included in machine-learning algorithms and comparison of derivation/validation ACDF cohorts

	Derivation (2011-2014) 19738 (100%)	Validation (2015) 8588 (100%)	*p* value
Age (mean)	53.4 (SD 11.6)	54.0 (SD 11.6)	<0.0001
Male gender	9687 (49.1%)	4317 (50.3%)	0.07
Dependent functional status	326 (1.7%)	123 (1.4%)	0.33
BMI > 40	1483 (7.5%)	665 (7.7%)	0.50
History of smoking	5887 (29.8%)	2310 (26.9%)	<0.0001
History of diabetes	2874 (14.6%)	1361 (15.9%)	0.01
History of pulmonary disease	810 (4.1%)	351 (4.1%)	0.95
History of chronic heart failure	42 (0.21%)	17 (0.20%)	0.80
Hypertension	8508 (43.1%)	3878 (45.2%)	<0.01
History of renal disease	64 (0.32%)	21 (0.24%)	0.26
Steroids for chronic condition	595 (3.0%)	291 (3.4%)	0.10
Bleeding-causing disorders	212 (1.1%)	103 (1.2%)	0.36
ASA class >2	7606 (38.5%)	3560 (41.5%)	<0.0001
Regional anesthesia	49 (0.25%)	39 (0.45%)	<0.01
Operative time (mean)	123.4 (SD 67.6)	122.7 (SD 65.2)	0.45
Hospital LOS (mean)	2.0 (SD 7.1)	1.9 (SD 3.6)	0.19
Complications within 30 days			
Severe adverse event	479 (2.4%)	230 (2.7%)	0.21
Unplanned readmission	548 (2.8%)	255 (3.0%)	0.37
Mortality	41 (0.21%)	20 (0.23%)	0.67
Laboratory results within 90 days preop. (%)			
Low WBC count (<4500/mcL)	968 (4.9%)	406 (4.7%)	0.52
High WBC count (>10,000/mcL)	2312 (11.7%)	996 (11.6%)	0.78
Low hematrocrit (<30%)	157 (0.80%)	60 (0.70%)	0.39
Low platelets (<150,000/mcL)	703 (3.6%)	335 (3.9%)	0.16
High INR (>1.1)	589 (3.0%)	221 (2.6%)	0.06
Low sodium (<135 mEq/L)	703 (3.6%)	296 (3.5%)	0.63
High sodium (>145 mEq/L)	130 (0.66%)	61 (0.71%)	0.63
High creatinine (>1.3 mg/dL)	682 (3.5%)	327 (3.8%)	0.14
High blood urea nitrogren (>30 mg/dL)	329 (1.7%)	168 (2.0%)	0.09
High bilirubin (>1.9 mg/dL)	44 (0.22%)	19 (0.22%)	0.98
Low albumin (<3.4 g/dL)	323 (1.6%)	148 (1.7%)	0.60

BMI = Body Mass Index, ASA Class = American Society of Anesthesiology Classification System; LOS = Length of Stay; WBC = White Blood Cell Count; INR = International Normalized Ratio

Development and Validation of Risk-Adjustment Models for Elective One- and Two-Level Anterior Cervical Discectomy and Fusions

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Introduction: Risk-adjustment models are crucial in bundled payment by accounting for differences in case mix when comparing outcomes across providers. However, the adequacy of risk adjustment must be balanced against the burden of collecting data from clinical records. The aim of this study was to develop and validate risk-adjustment models specific to 30-day severe adverse events (SAE) and unplanned readmissions (UR) for elective, one- and two level anterior cervical discectomy and fusion (ACDF), in order to allow surgeons to make informed decisions regarding tradeoffs between risk-adjustment performance and the difficulty of data collection.

Materials / Methods: Data from the ACS-NSQIP national surgical database was used to identify patients that underwent one- and two-level ACDFs. Derivation cohorts were created with patients from 2011–2013 (n=13,969) while the validation cohort was created with patients from 2014 (n=7,155). Logistic regression models were developed using age, sex, American Society of Anesthesiologists (ASA) classification, comorbidities, laboratory values, intraoperative variables, and outcomes as covariates. Model performance (c-statistic) and goodness-of-fit (Hosmer-Lemeshow test) was verified with the validation cohort. Each covariate's relative contribution to the full model was determined via stepwise addition of the variable to limited risk-adjustment models until full-model performance was reached.

Results: Eleven and seven data elements were included in the full model for SAE and UR, respectively. Model performance was comparable between derivation and validation cohorts (c-statistic 76.1% vs. 73.4% for SAE and 70.1% vs. 66.3% for UR). Age, ASA classification, and laboratory variables (low hematocrit, high INR, high BUN, low albumin) accounted for the greatest proportion of explained variation in the full model for SAE (26%, 16%, 36% in the derivation cohort; 18%, 31%, and 28% in the validation cohort). In the UR full model, age and ASA class had the greatest explanatory value (31%, 28% in the derivation cohort; 23%, 50% in the validation cohort)(Table 1). Sequential addition of variables revealed that age and ASA class were sufficient to achieve similar predictive ability (c-statistic 72% vs. 76%) as the full model (eleven variables). Similarly, for UR prediction, age and ASA class produced nearly equivalent values to the full model (c-statistic 65% vs. 66%, two versus seven variables)(Table 2).

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Conclusions: Risk-adjustment models using data from health records demonstrated good discrimination (c-statistics up to 76%) for assessing the risk of severe adverse events and unplanned readmission in patients undergoing ACDFs, with advanced age and ASA class 3-4 contributing the majority of discrimination for both models. For both models, gender, comorbid conditions, laboratory values, and operative time conferred negligible improvements to model performance. By measuring the relative contribution of each variable to the full model performance, this study not only helps care providers identify the risk factors associated with adverse events and unplanned readmissions, but also identifies a limited set of "most predictive" variables that with similar performance a full model, demonstrating that it is possible to develop risk-adjustment models using only the most parsimonious methods.

Table 1. Partial Risk-Adjustment Model Performance and Relative Contribution of Predictor

	Severe Adverse Event		Unplanned readmission	
	Derivation Cohort N = 13,969	Validation Cohort N = 7,155	Derivation Cohort N = 13,969	Validation Cohort N = 7,155
C-Statistic (Full Model)	76.1%	73.4%	70.1%	66.3%
Pr x2 for Hosmer-Lemeshow goodness-of-fit test†	0.99	0.78	0.59	0.21
Relative Contribution of predictors‡				
Age	0.26	0.18	**0.31**	0.23
Sex	0.03	0.06	-	-
ASA classification (3/4 vs 1/2)	0.16	**0.31**	0.28	**0.50**
Comorbid conditions	0.09	0.05	0.14	0.16
Laboratory values	**0.36**	0.28	0.21	0.08
Intraoperative variables	0.10	0.12	0.06	0.03

*ASA Classification = American Society of Anesthesiology Classification System

†Pr x2 = probability of chi-squared statistic, and df = degrees of freedom. A p value of >0.05 for the Hosmer-Lemeshow goodness-of-fit test demonstates good model calibration; a p value of <0.05 for the Hosemer-Lemeshow goodness-of-fit test suggests a poor model fit. ‡We assessed the relative contribution of variables grouped into different categories by examining changes in the model fit log- likelihood value when each variable category was retained and then removed from the full model. Such an analysis measures adequacy, which is the measure of the explanatory value of each variable category relative to the entire set, or full model.

Table 2. Any Adverse Outcome or Unplanned Readmission Model Performance with Sequential Addition of Variable Groups and Measures of Prediction Increment

	No. of Data Elements	C-Statistic (%)	Event NRI(>0) (%)	Nonevent NRI (>0) (%)	Combined NRI (>0)	P Value, HL Test
Severe Adverse Event - Models§ (Derivation Cohort)						
Age	1	0.69	-	-	-	0.19
+ ASA class 3/4	2	0.72	31	25	0.56	0.32
+ Intraoperative Variables	3	0.73	-6	37	0.31	0.80
+ Gender	4	0.74	19	4	0.24	0.99
+ Comorbid Conditions	6	0.75	-69	89	0.20	0.98
+ Laboratory Values (Full Model)	11	0.76	-30	60	0.30	0.99
Severe Adverse Event - Models§ (Validation Cohort)†						
Age	1	0.63	-	-	-	0.25
+ ASA class 3/4	2	0.69	39	22	0.61	0.70
+ Intraoperative Variables	3	0.72	3	34	0.37	0.86
+ Gender	4	0.73	28	1	0.29	0.95
+ Comorbid Conditions	6	0.73	-73	80	0.07	0.66
+ Laboratory Values (Full Model)	11	0.73	-52	70	0.18	0.78
Unplanned Readmission - Models§ (Derivation Cohort)						
Age	1	0.64	-	-	-	0.33
+ Gender	-	-	-	-	-	-
+ ASA class 3/4	2	0.68	23	25	0.48	0.20
+ Comorbid Conditions	3	0.68	-34	1	-0.33	0.29
+ Laboratory Values	6	0.70	-42	66	0.24	0.39
+ Intraoperative Variables (Full Model)	7	0.70	-11	29	0.18	0.59
Unplanned Readmission - Models§ (Validation Cohort)†						
Age	1	0.60	-	-	-	0.64
+ Gender	-	-	-	-	-	-
+ ASA class 3/4	2	0.65	28	21	0.49	0.97
+ Comorbid Conditions	3	0.65	-58	49	-0.09	0.99
+ Laboratory Values	6	0.66	-60	72	0.12	0.96
+ Intraoperative Variables (Full Model)	7	0.66	-8	25	0.17	0.21

§As groups of variables were sequentially added. A p value of >0.05 for the Hosmer-Lemeshow goodness-of-fit test demonstates good model calibration; a p value of <0.05 for the Hosemer-Lemeshow goodness-of-fit test suggests a poor model fit.

† Validation models utilized the same variables for full model as determinied by multivariate linear regression for the derivation cohort

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Intelligently Predicting Surgical Complications in Adult Patients Undergoing Anterior Cervical Discectomy and Fusion (ACDF) Using Machine Learning

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Introduction: Much of current clinical research relies on statistical models to identify independent risk factors surrounding complications. However, complex interplay between risk factors is rarely accounted for, which can lead to inaccurate patient morbidity and mortality prognosis. Artificial neural networks (ANNs) are a supervised machine learning (ML) classification system inspired by the mammalian brain. Each network contains a large cluster of neurons which collectively, but uniquely weigh the importance of critical input variables. Training artificial intelligence (AI) algorithms allows for the model to "learn" complex patterns from patient data through repetitive epochs and can be used as a powerful tool for predicting surgical outcomes.

Methods: Patients undergoing anterior cervical discectomy and fusion (ACDF) from 2010 to 2014 were identified from a national database and were separated into training and testing cohorts for ML randomly. Patients with missing data were excluded. 70% of the initial data was used for AI training while 30% was set aside for blinded evaluation of our models. To overcome the low sample size for positive complication cohorts, the adaptive synthetic sampling (ADASYN) approach for imbalanced learning was utilized and L2 regularization was implemented to prevent AI overfitting. Feature selection was performed using logistic regression to identify the top six demographic, preoperative, and intraoperative variables as features to use for the models. AI was trained to predict mortality, venous thromboembolism (VTE), cardiac complications, and wound complications. Performance of the ANN was compared to traditional logistic regression that was trained and tested on the same data that the ANN was evaluated on. Furthermore, ASA classification system was used as an additional comparison. Lastly, the patient dataset was randomized and re-partitioned and training and testing was performed again, iteratively five times. Model efficacy was assessed with area under the receiver-operator curve (AUC) and accuracy.

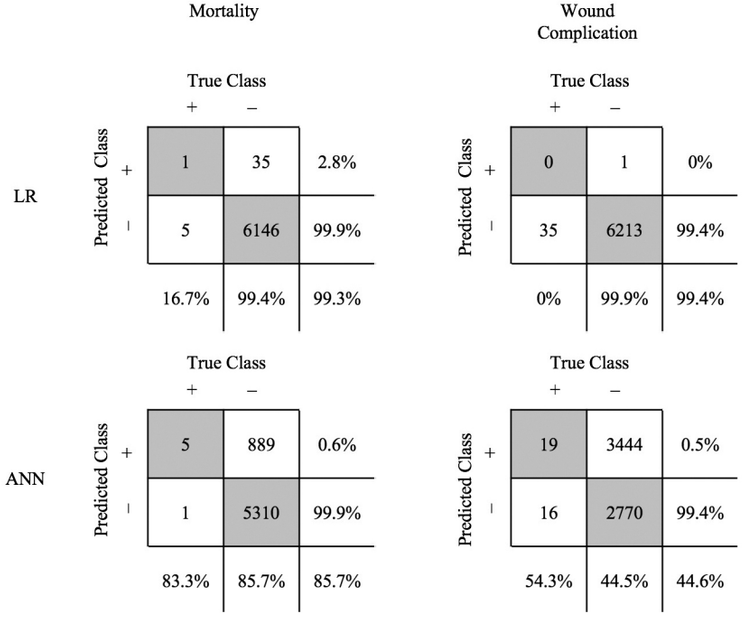
Results: A total of 20,879 patients met the inclusion criteria, with a 0.1% rate of mortality, 0.5 % rate of wound complication, 0.3% rate of VTE, and 0.2% rate of cardiac complication. The ANN performed with an AUC of 0.772 for cardiac complications, 0.656 for VTE, 0.518 for wound complications, and 0.979 for mortality. In contrast, the LR performed consistently better than ASA as a classifier with an AUC of 0.759 for cardiac complications, 0.639 for VTE events, 0.501 for wound complications, and 0.974 for mortality. The ASA classifiers performed least effectively for all target outcomes with an AUC of 0.566 for cardiac complications, 0.397 for VTE, 0.455, and 0.346 for mortality (Table 1). ANN had greater sensitivity than LR in mortality and wound complication (Figure 1).

Conclusion: We show here that ANNs can accurately forecast major postoperative complications following ACDF. Although ML often succeeds as classifiers, interpretability of its decision-making process is obscured by its complexity. The power of this network lies in its ability to learn complex patterns. The combination of interpretability and classification accuracy suggests these algorithms can be applied to preoperative care in a real time clinical workflow.

Table 1. Comparison of AUC of a Logistic Regression, Artificial Neural Network, and ASA Evaluated on Blinded Data

	LR (95% CI)	ANN (95% CI)	ASA (95% CI)
Cardiac	0.759 (0.738 - 0.781)	0.772 (0.766 - 0.778)	0.566 (0.544 - 0.587)
VTE	0.639 (0.632 - 0.645)	0.656 (0.653 - 0.658)	0.397 (0.388 - 0.407)
Wound	0.501 (0.500 - 0.503)	0.518 (0.510 - 0.527)	0.455 (0.449 - 0.461)
Mortality	0.974 (0.973 - 0.976)	0.979 (0.978 - 0.981)	0.346 (0.342 - 0.350)

Figure 1. Confusion matrices of trained ANN and LR machine learners evaluated on hold-out a) mortality and b) wound complication data sets to demonstrate real-world performance.



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Number of Levels Fused Does Not Affect C5 Palsy Rate After Anterior Cervical Discectomy and Fusion

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Introduction: Post-operative C5 nerve root palsy is a known complication after decompressive cervical surgery, most commonly reported after posterior cervical decompression and fusion (PCDF). However, while the rate of C5 palsy after anterior cervical decompression and fusion (ACDF) is lower, the effect of increasing number of levels fused on the prevalence of C5 palsy is unclear. Therefore, we set out to examine the rate of C5 palsy after one-, two- and three-level ACDF including the C4-5 level.

Materials / Methods: We performed a retrospective review of ACDFs performed at one institution by multiple surgeons between September 2015 and June 2016. Patient demographic and surgical information was reviewed, including post-operative motor examination results in the immediate post-operative period. C5 palsy was defined as motor decline of the deltoid muscle function by at least 1 level in a standard manual muscle test. Patients were excluded if no preoperative motor strength was available. Fisher's exact test was used to compare categorical variables between groups.

Results: We identified 194 patients undergoing ACDF involving the C4-5 level. After excluding patients without a documented preoperative motor examination, 185 patients were included in the study: twenty-two undergoing single-level fusion, sixty-six undergoing two-level fusion, and 97 undergoing three-level fusion. Average age was 59.0 years, with no difference in age between groups. Average follow up was 7 months. The overall rate of C5 palsy was 3.78%. We identified one C5 palsy in the single-level group (4.5%), one in the two-level group (1.5%), and 5 in the three-level group (5.2%). These rates were not statistically significant between groups ($p>0.05$). Three patients had complete recovery of final deltoid strength, and all but one patient had some improvement in deltoid function by final follow up.

Conclusion: To our knowledge, no prior study has specifically compared the risk of C5 palsy between single- and multi-level ACDF. We found an overall C5 palsy rate of 3.78% for all patients undergoing one-, two- or three-level ACDF that included the C4-5 level at our institution. The rate of post-operative deltoid motor strength decline was lowest in the patients undergoing two-level ACDF and highest in the three-level group, but this finding did not reach statistical significance. Our rate of C5 palsy appears comparable to published literature.

Hypoalbuminemia as an Independent Risk Factor for 30-Day Morbidity and Mortality in Cervicothoracic Spinal Tumor Excision

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Background: Malnutrition has been shown to be associated with post-operative morbidity and mortality. It is a particularly prevalent comorbidity in cancer patients. This study aims to explore the prognostic implication of hypoalbuminemia in patients undergoing laminectomy and excision for thoracic and lumbar spinal tumors.

Methods: This was retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database between 2010 and 2014 for patients undergoing laminectomy and excision of thoracic spinal tumors. CPT codes 63276 and 63275 were used to query patients undergoing laminectomy for thoracic and cervical spinal tumors. These patients were then divided into two cohorts, malnourished (<3.5g/dL preoperative albumin) and nourished. Patient baseline factors, perioperative data, and postoperative course were analyzed by univariate analysis. Multivariate logistic regression was used to compare the two albumin cohorts to determine the effect of malnourishment on short term postoperative morbidity and mortality.

Results: A total of 1,138 patients with thoracic and cervical tumors were identified. Of these patients 404 (35.5%) were malnourished (albumin <3.5g/dL). Multivariate logistic regression (Table 1) found malnutrition to be an independent risk factor for 30-day mortality (OR=4.34, CI: 2.70-6.97, $p<0.001$), discharge to a facility other than home (OR=2.45, CI: 1.84–3.25, $p<0.001$), length of stay greater than or equal to five days (OR=3.11, CI: 2.11–4.59, $p<0.001$), transfusion (OR=5.57, CI: 1.10–1.87, $p=0.008$), and sepsis (OR=4.07, CI: 2.28–7.24, $p=0.002$).

Conclusion: Hypoalbuminemia in the preoperative setting is a risk factor for 30-day mortality, non-home discharge, prolonged LOS, pulmonary complications, bleeding requiring intra or postoperative transfusion, and sepsis. Albumin levels can be used as a prognostic tool and for risk stratification for adverse outcomes.

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Complications	Odds Ratio	Lower CI	Upper CI	P Value
30-day Mortality	4.34	2.70	6.97	<0.001
Non-home discharge	2.45	1.84	3.25	<0.001
Prolonged LOS	3.11	2.11	4.59	<0.001
Transfusion	1.43	1.10	1.87	0.008
Sepsis	4.07	2.28	7.24	<0.001

Table 1. Multivariate Regression for Preoperative Hypoalbuminemia as an Independent Risk Factor for 30-Day Morbidity and Mortality

McGregor's Slope and Slope of Line of Sight: Two Surrogate Markers for Chin-Brow Vertical Angle in the Setting of Cervical Spine Pathology

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Introduction: The Chin Brow Vertical Angle (CBVA) is a parameter that assesses horizontal gaze. The purpose of this study is to evaluate whether the slope of McGregor's line (McGS) and the slope of line of sight (SLS) are useful surrogates for CBVA in patients with cervical spine pathology. CBVA is less accessible due to the technical requirements of the radiograph. Its relationship and conversion to McGS and SLS may prove beneficial in the assessment of patients undergoing surgery for cervical spine pathologies.

Methods: We conducted a retrospective review of patients with full-body standing stereoradiographs. Inclusion criteria were age ≥18 years and a primary cervical diagnosis. A subanalysis of cervical deformity (CD) patients was performed if they had any of the following: cSVA>4cm or T1 Slope minus cervical lordosis (TS-CL)>20°. The CD diagnosis included patients with: iatrogenic, TL-PJK, ankylosing spondylitis, degenerative de novo, dropped head, or post-traumatic causes. Independent samples and paired t-tests were used to compare radiographic alignment with significance set at $p<0.05$. Pearson correlations characterized linear relationships between variables and linear regression analysis identified predictive relationships between the parameters.

Results: 329 patients were identified with primary cervical spine diagnoses. The mean age was 56.8±14.5 years. There were 183 females (55.6%) and the average BMI was 27.8±6.2. CBVA was visible in 171 patients (52.0%), whereas McGS was visible in 281 patients (85.4%) and SLS in 259 (78.7%).

Of the 171 patients with CBVA visible, the mean CBVA was 2.30±7.7, mean McGS was 5.02±8.1 and mean SLS was -1.588±2.03. CBVA strongly correlated with McGS (r=0.83) and SLS (r=0.89), all p£0.001. Similarly, McGS positively correlated with SLS (r=0.89, p=0.001).

Patients were stratified into those with CD (n=119) and those without (n=108). In the CD group, 63 (52.9%) had CBVA visible, whereas 113 (95.0%) and 99 (83.2%) had McGS and SLS visible, respectively. These patients were then separated into those with horizontal gaze disruption (McGS>10°), and those without (McGS<10°) The mean McGS was 17.5±8.0 for the gaze disruption group compared to 0.37°±6.38. Radiographic parameters differed significantly between these groups including greater subaxial sagittal malalignment (cSVA, small vs. large MGS: 25.49 vs. 38.58, $p<0.001$), greater TS-CL mismatch (18.71 vs. 39.25, p=0.001), and less upper cervical compensation (C2S, 14.37 vs. 33.63, $p<0.001$). There were no significant differences for TPA, T2-T12 TK, SVA, PT, PI-LL. Age, gender, and BMI differences were not significant between these subsets.

See Disclosure Index pages 41–95.

Conclusion: The role of CBVA as an assessment of horizontal gaze has previously been limited to specific pathologies such as ankylosing spondylitis. CBVA is not widely accessible in radiographic analysis of cervical pathologies, due to the technical requirements of the radiograph. This study demonstrates that McGS and SLS serve as strong, positive correlates for CBVA. Furthermore, we have provided the mean difference for these measurements, allowing an ease of conversion between these parameters, broadening CBVA's use as a radiographic assessment of horizontal gaze in all cervical pathologies.

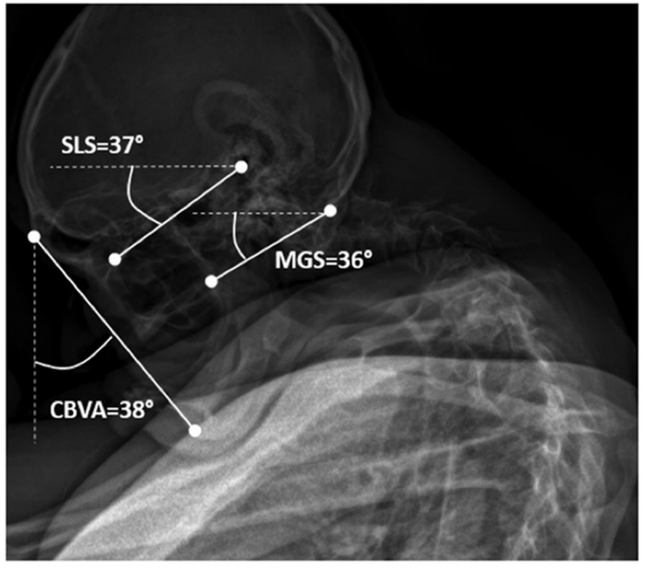

Figure 1. Chin-Brow Vertical Angle (CBVA) and its proposed surrogates, Slope of Line of Sight (SLS) and McGregor's Slope (MGS).

Cluster Analysis Describes Constellations of Cardiac Anomalies Presenting in Spinal Anomaly Patients

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Introduction: Vertebral anomalies occur early in development during the formation of the mesoderm, and may occur alongside other deformities. These deformities can affect a multitude of other organ systems. Estimates of vertebral anomalies in those with VACTERL association range as high as 60 to 80%. However, Literature discussing the incidence of bony congenital anomalies of the spine is usually methodologically limited by small sample sizes. The Kid's Inpatient Database (KID) was created to yield national estimates of rare pediatric conditions such as congenital disorders. The purpose of this study was to utilize a cluster analysis to examine patterns of concurrent anomalies in patients with congenital vertebral anomalies.

Materials / Methods: This is a retrospective analysis of the prospectively collected KID from the years 2003, 2006, 2009, and 2012. KID supplied hospital- and year-adjusted weights allowed for accurate assessment of incidence of bony spinal anomalies, as well as, cardiac, gastrointestinal and urinary anomalies. The aforementioned were queried using HCUP-CCS coding. K-means clustering analysis was run to discover relationships between these anomalies within a cohort of patients with hemivertebra, block vertebra and missing vertebra diagnoses; k was set to n-1 where n=first incidence of significant drop / little gain in Sum of Square error within clusters.

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Results: 12,039,432 patients age 0–20 were identified. Incidence per 100,000 newborns was as follows: 2.5 block vertebra, 10.4 hemivertebra, 7.0 missing vertebra. There was no significant difference in gender between those with and without vertebral anomalies. 49% of those with a vertebral anomaly had at least one additional VACTERL characteristic. Cardiac malformations were the most frequent co-occurring congenital anomaly in those with vertebral anomalies (30.7%). This was much more common than the incidence of 2.5% found in the general population. The most common cardiac malformation was atrial septal defect followed by patent ductus arteriosus (PDA), with ASD occurring 55.9% of the time in patients with PDA. Renal anomalies occurred in 20.3% of patients with renal agenesis being the most frequent diagnosis.

In those with vertebral anomalies:

55.9% of patients with PDA also had ASD, 34.2% of those with VSD also had PDA, 23.8% of those with large intestinal atresia also had ASD, 37.0% of those with a ureter obstruction also had large intestinal atresia, 54.0% with a cystourethral anomaly also had large intestinal atresia, 35.3% of those with renal dysplasia also had large intestinal atresia.

Conclusions: In patients with vertebral anomalies, concomitant anomalies in other organ systems occur much more frequently than the general population. When these anomalies arise, specific clusters of anomalies often occur.

Visualization of the Cervicothoracic Junction with EOS Imaging Is Superior to Conventional Lateral Cervical Radiographs

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Introduction: The cervicothoracic junction plays an important role in the biomechanics of cervical spinal deformity but is typically difficult area to visualize using traditional radiographs. Whole-body stereoradiography (EOS) allows for imaging of the entire axial skeleton in a weight-bearing position without parallax error and with lower radiation doses. EOS image quality has been shown to be superior to conventional radiographs (XR) for lateral spine imaging but can vary depending on the region of the body being imaged. To our knowledge no prior study has evaluated the visibility of the cervicothoracic junction on EOS. In this study we sought to compare the visibility of the vertebra of the cervicothoracic junction on lateral EOS images to that of conventional cervical lateral radiographs.

Materials / Methods: Two fellowship-trained spine surgeons evaluated the images of 50 patients who had both lateral cervical spine radiographs and EOS images acquired within a 12 month period. The number of visible cortices of the vertebral bodies of C6-T2 were scored 0–4. Presence of spondylolisthesis >2 mm at each level was also recorded. Patient BMI was also recorded. Visibility scores were compared using a paired samples t-test. Cohen's kappa was calculated to judge inter-rater reliability. Linear regression analysis was performed to detect any effect of patient BMI on visibility.

Results: On average, there were more visible cortices with EOS vs. XR at T1 (2.8 vs. 2.3, $p=0.02$) and T2 (2.5 vs. 1.1 $p<0.001$); whereas visible cortices were equal at C6 (3.9 vs. 3.9, p-value not significant) and C7 (3.6 vs. 3.6, p-value not significant). Patient BMI was inversely correlated with cortical visibility on XR at T2 ($r=-0.35$, $p=0.013$) and on EOS at T1 ($r=-0.29$, $p=0.04$) and T2 ($r=-0.33$, $p=0.02$). There was moderate interobserver agreement for visible cortices from C6 to T2 for EOS and XR (Cohen's kappa=0.42, 0.44). There were no statistically significant differences when comparing the visibility of spondylolisthesis between EOS vs. XR at C6-7 (5% vs. 6%), C7-T1 (9% vs. 8%) and T1-2 (1% vs. 0%).

Conclusions: EOS imaging is superior at imaging the vertebra of the cervicothoracic junction. This has significant implications for preoperative evaluation of patients with spinal deformity of the cervical and upper thoracic spine. While advanced imaging modalities (computed tomography, magnetic resonance imaging) are capable of generating high quality images of the cervicothoracic region they are also accompanied by disadvantages either high cost (MRI) or significant radiation exposure (CT). Furthermore, these studies are usually performed in the supine position and thus cannot simulate weight-bearing spinal alignment, an important consideration in pre-operative planning for spinal deformity correction. EOS imaging deserves further consideration as a diagnostic tool in the evaluation of patients with cervical spinal deformity given its ability to produce high quality images of the cervicothoracic junction with very low radiation exposure.

See Disclosure Index pages 41–95.

Anomalous Vertebral Artery Course: MRI Findings of At-Risk Anatomy During Anterior Cervical Surgery Exposure

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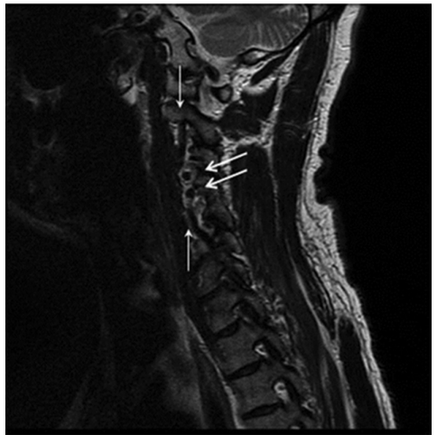
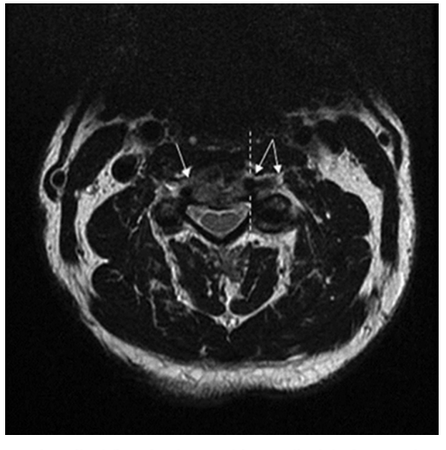
Introduction: Subaxial anterior cervical spinal exposures can result in unintended vertebral artery (VA) injury with a reported injury incidence of up to 2%. Studies have reported a 1% prevalence of anomalous at-risk medial loop (ML) anatomy of the VA on axial contrast-enhanced computed tomography (CE-CT). In typical pre-operative planning, MRI is the commonly utilized study, whereas CE-CT is typically an elective secondary imaging modality. The current study presents unique characteristics of at-risk ML anatomy of the VA on pre-operative MRI imaging.

Materials / Methods: Single provider, consecutive review of pre-operative MRI imaging of electively scheduled cervical surgery cases. At-risk anatomy was defined as VA transit medial to the sagittal plane of the medial pedicle wall intersection with the posterior vertebral cortex [lateral most point of prospective epidural canal decompression] on axial MRI imaging.

Results: 80 cases of electively planned cervical surgery were reviewed (2015–2016). Two (2) cases met the at-risk criteria (2.5%). Of the cases meeting at-risk criteria, imaging review demonstrated a unique and distinctive finding of ML of the VA on sagittal plane MRI images characterized by paired circular shapes interposed in the VA path, henceforth termed – the 'viper sign' – given the visual similarity to the puncture of a venomous snake bite. This was resultant from the anomalous transverse circuitous course of the normally longitudinally-oriented vertebral artery transit (Figure 1 and 2). No cases demonstrated the described finding without meeting the at-risk criteria; all cases meeting the at-risk criteria demonstrated the described finding [viper sign: sensitivity 100%; specificity 100%].

Conclusion: The reported distinctive MRI finding of ML of the VA, termed 'viper sign', alerts the surgeon to at-risk VA anatomy and the consideration of ancillary pre-operative imaging and intra-operative prudence.





Spinal Cord Swelling in Patients with Cervical Compression Myelopathy

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Introduction: Intramedullary hyperintense lesion associated with spinal cord edema on T2-weighted MR imaging is a rare finding in in patients with cervical spondylosis. Such lesions are liable to be misinterpreted as neoplastic or inflammatory lesions in the spinal canal and cause delay in appropriate treatment. However, intramedullary hyperintense lesions with spinal cord edema are not well characterized in literature. The purpose of this study was to investigate the clinical characteristics of spinal cord edema due to cervical spondylosis (SCECS).

Materials / Methods: A total of 272 patients with cervical spondylosis who underwent surgery between April 2007 and March 2017 at our institute were enrolled. We defined SCECS as follows; 1) intramedullary signal changes (ISI) of the cervical spinal cord in sagittal T2-weighted MRI extending to more than one vertebral body height; 2) "fuzzy" ISI, recognized as a faint intramedullary change with a largely indistinct and hazy border; and 3) larger sagittal diameter of the spinal cord segment with ISI just above or below the cord compression area, as compared to that in areas of the cervical spine without ISI. Radiographic parameters, demographic characteristics of patients, and surgical outcomes were compared between the SCECS (group E) and non-SCECS (group C) groups.

Results: Fifteen patients (5.5%) were diagnosed as SCECS (Table1). The disease duration (months) from onset to operation in group E was significantly shorter than that in group C [median (interquartile range), 6(8) vs. 16(51), respectively]. On the other hand, no significant between-group difference was observed with respect to sex [male, number (%): 13 (87%) vs. 194 (75%), respectively], preoperative cervical lordosis [median (interquartile range), 9.5 (11.6) vs. 13 (18.3), respectively], preoperative JOA score [median (interquartile range), 10.5 (4) vs. 10 (4), respectively], postoperative JOA score [median (interquartile range), 13 (4) vs. 13 (4), respectively], and JOA recovery rate [median (interquartile range), 38.1 (30) vs. 40 (42.8), respectively]. Patients in group E tended to be older than those in group C, although the difference was not statistically significant. None of the patients in group E showed dynamic instability on x-ray lateral functional view. Postoperatively, 10 (67%) patients in group E exhibited regression of SCECS.

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Conclusion: The present study showed that the disease duration from onset to operation in patients with SCECS was significantly shorter than that in patients with non-SCECS. Although further studies and longer follow up are necessary, we believe that SCECS was attributable to venous hypertension caused by disturbance of venous circulation as previously reported, rather than to dynamic instability or chronic degenerative change.

Table 1. Collected data of the patients in spinal cord edema due to cervical spondylosis (SCECS) group (group E) and non-SCECS group (group C)

	group E (n=15)	group C (n=257)	p value
Age (y)	67 (17)	68 (11)	0.084
Male	13 (87%)	194 (75%)	0.64
Disease duration from onset to operation (months)	6 (8)	16 (51)	0.001*
Preoperative cervical lordosis (degrees)	9.5 (11.6)	13.0 (18.3)	0.64
Preoperative JOA score	10.5 (4.0)	10.0 (4.0)	0.69
Postoperative JOA score	13.0 (4.0)	13.0 (4.0)	0.73
JOA recovery rate (%)	38.1 (30)	40 (42.8)	0.52

Data presented as median (interquartile range) or frequencies (%).
*Significant difference between two groups.

Can C7 Slope Substitute the T1 Slope? An Analysis Using Cervical Radiographs and Weight-Bearing MRIs

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Introduction: Although the T1 slope is one of the key factors in cervical balance, it is not always visible due to the anatomical interference on cervical radiography. Therefore, several studies have used C7 slope instead of T1 slope. However, it is still unclear whether the C7 endplate is more visible on radiographs than T1, as well as whether C7 slope has similarity with T1 slope. Therefore, the aim of the present study was to assess the visibility of C7 and T1 endplates on radiographs, and to verify the correlation between C7 or T1 slope and cervical balance parameters using weight-bearing magnetic resonance imaging (MRI).

Materials / Methods: We retrospectively reviewed 45 consecutive radiographs and 120 consecutive MRIs. The endplate visibility was determined using weight-bearing radiographs and were defined as "Visible": the endplate could be seen clearly, "Unclear": the shape of vertebra could be observed, but not the endplate or "Invisible". Subsequently, using weight-bearing MR images, the C7 slope of the upper endplate, the C7 slope of the lower endplate, T1 slope, C1 inclination, C2 slope, atlas-dens interval (ADI), C2-C7 cobb angle, cervical sagittal vertical axis (cSVA), cervical tilt, cranial tilt, neck tilt, thoracic inlet angle (TIA) were measured. Chi square test and the residual analysis were used to analysis the endplate visibility, and linear regression and Pearson correlation coefficient were used to verify the correlation of parameters on MRI.

Results: 82% of the upper endplate of C7, 51% of the lower endplate of C7 and 18% of upper endplate of T1 were clearly visible. In contrast, 18% of the upper C7, 31% of the lower C7 and 62% of upper T1 endplate were invisible. The residual analysis demonstrated that the upper C7 endplate was significantly visible, whereas T1 endplate was significantly invisible ($p<0.01$ respectively). Linear regression analysis showed high correlation between the upper C7 slope and T1 slope ($r^2=0.818$, $p<0.01$) and, lower C7 slope and T1 slope ($r^2=0.840$, $p<0.01$). Additionally, T1 slope significantly correlated with Neck Tilt, TIA, C2-C7 angle, cSVA, cervical and cranial tilt, but not with the C1 inclination, C2 slope, ADI. Upper and lower C7 slopes showed the close resemblance with T1 slope in terms of correlation with those parameters (Table 1).

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Conclusions: Both, upper and lower C7 slope correlated strongly with T1 slope and showed similar relationship with cervical sagittal balance parameters as T1 slope. Therefore, C7 slope could potentially substitute T1 slope, especially upper C7 slope due to the good visibility.

Figure 1. Visibility of endplate for measuring the vertebral slope

Table 1. Correlation between slopes and each parameter

	Thoracic parameters		Cervical parameters				Upper cervical parameters		
	Neck tilt	TIA	Cervical tilt	Cranial tilt	cSVA	Cobb angle	C2 slope	C1 incl	ADI
uC7s	-0.341**	0.380**	0.506**	0.470**	0.407**	0.599**	0.015	-0.094	-0.028
lC7s	-0.358**	0.374**	0.501**	0.466**	0.402**	0.583**	0.027	-0.083	-0.049
T1s	-0.350**	0.469**	0.421**	0.545**	0.316**	0.545**	0.030	-0.053	-0.094

**: p>0.01, uC7s: upper C7 slope, lC7s: lower C7 slope, T1s: T1 slope, TIA: thoracic inlet angle, cSVA: cervical sagittal vertical axis, ADI: atlas-dens interval, C1 incl: C1 inclination

Tandem Spinal Stenosis in Patients with Symptomatic Cervical Ossification of the Posterior Longitudinal Ligament (OPLL)

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Introduction: Concurrent cervical and lumbar spinal canal stenosis is recognized as tandem spinal stenosis (TSS). Previously, several studies have investigated TSS in patients with cervical spondylotic myelopathy (CSM). However, to date, no studies have focused on the presence of TSS in patients with ossification of the posterior longitudinal ligament (OPLL). While previous studies have used magnetic resonance imaging to evaluate the TSS, computed tomography after myelography (CTM) offers advantages for visualizing bony compressive lesions, such as OPLL. In this study, we investigated the presence of TSS in cervical OPLL patients using CTM, and compared the characteristics of these patients to TSS in CSM patients.

Methods: We investigated 97 consecutive cervical OPLL patients (72 males and 25 females, 60.1±10.9 years old) who received surgery in 2010–2015 and followed for more than 1 year. Neurological status was evaluated by JOA scoring system (Table 1). We performed CTM for all these patients before surgery and evaluated both the cervical spine and the lumbar region. A compressive lesion was defined as a lesion in contact with the anterior or posterior aspect of the spinal cord or cauda equina, morphological deformity of the spinal cord, or the disappearance of the subarachnoid space in CTM images. Two independent spinal surgeons evaluated the images: the kappa coefficient of inter-observer agreement was 0.71. The rate of TSS in OPLL and patients' characteristics were compared with those of CSM patients (N=200, 128 males, 72 females, 65.3±9.8 years old). Further, the rate of TSS evaluated by CTM and surgical outcomes in OPLL patients were compared between TSS and non-TSS patients.

Results: The CTM findings indicated 61 cases (62.9%) with radiological lumbar canal stenosis among the cervical OPLL patients. The TSS rate in cervical OPLL was not significantly higher than that in CSM (55.5%). However, the incidence of TSS was significantly higher in the C-OPLL cases in the young patients (<65 years old), while in the older patients (≥65 years old), the incidence of TSS was similar for the non-OPLL and OPLL groups (Table 1). Compared with the CSM patients, the OPLL cases included younger patients and more patients who possessed DM, obesity, coexisting lumbar OPLL and lumbar ossification of the yellow ligament (OYL) (Table 1).

In comparison of TSS and non-TSS cases in patients with cervical OPLL, no significant differences were found in patients' demographics, except patients' age. While preoperative JOA score was similar in TSS and non-TSS cases, postoperative JOA score was significantly lower in the TSS-group. In the TSS cases, 10 patients (16.4%) required additional lumbar surgery (Table 2).

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Conclusion: Cervical OPLL patients frequently have co-existing lumbar spinal stenosis (62.9%). The high ratio of TSS was seen even in young patients, while the TSS is more common in older patients in CSM patients. The lumbar stenosis in cervical OPLLL patients was partly caused by lumbar OPLL and OYL. Because neurological score after cervical surgery was significantly lower in TSS patients, a care should be taken to the presence of co-existing lumbar stenosis before surgical treatment of cervical OPLL.

Table1. Demographics and presence of tandem canal stenosis (TSS) in patients with CSM and OPLL

	CSM (n=200)	OPLL (n=97)	p
Sex, female/male, No	72/128	24/73	NS
Age, average (range)	66.8 ± 11.9 (27-89) *	63.3 ± 10.5(40-93)	<0.05
Tandem canal stenosis (TSS)	111 (55.5%)	61 (62.9%)	NS
TSS ≥65 years old	77(65.7%)	32(60.4%)	NS
TSS <65 years old	34(41.0%)	29(65.9%)*	<0.05
L-ossification of the posterior longitudinal ligament (OPLL)	0 (0%)	8 (8.2%)*	0.0001
L-ossification of the yellow ligament (OYL)	4 (2.0%)	14 (14.4%)*	<0.0001
Hypertension	95 (47.5%)	42 (43.3%)	NS
Hyperlipidemia	26 (13.0%)	15 (15.5%)	NS
Diabetes mellitus	49 (24.5%)	35 (36.1%)*	<0.05
Smoking	78 (39.0%)	41 (42.3%)	NS
Heart disease	29 (14.5%)	15 (15.5%)	NS
Renal failure	8 (4.0%)	1 (1.0%)	NS
Collagen disease	11 (5.5%)	1 (1.0%)	NS
Obesity, body mass index (BMI)>25	65 (32.5%)	47 (48.5%)*	<0.01
Artificial joint in knee or hip	8 (4.0%)	2 (2.1%)	NS
Osteoporosis	13 (6.5%)	2 (2.1%)	NS

Table 2. TSS vs Non-TSS in patients with OPLL

	TSS (n=61)	Non-TSS (n=36)	p
Sex, female/male, No	18/43	7/29	NS
Age, average (range)	65.3 ± 9.8 (40-93) *	60.1 ± 10.9 (36-80)	<0.05
Hypertension	30 (49.2%)	12 (33.3%)	NS
Hyperlipidemia	10 (16.4%)	5 (13.9%)	NS
Diabetes mellitus	24 (39.3%)	11 (30.6%)	NS
Smoking	25 (41.0%)	15 (41.7%)	NS
Heart disease	10 (16.4%)	5 (13.9%)	NS
Renal failure	1 (1.6%)	0 (0%)	NS
Collagen disease	1 (1.6%)	0 (0%)	NS
Obesity, body mass index (BMI)>25	29 (47.5%)	19 (52.8%)	NS
Artificial joint in knee or hip	2 (3.3%)	0 (0%)	NS
Osteoporosis	2 (3.3%)	0 (0%)	NS
Anterior/ posterior surgery (cervical)	25/36	15/21	NS
Operative time, average (range), min	300.8 ± 149.6 (74-732)	250.5 ± 98.2 (102-469)	0.0767
Blood loss, average (range), grams	368.2 ± 545.6 (little-3400)	238.7 ± 223.5 (little-998)	NS
Preoperative C-JOA score, average (range), points	10.8 ± 2.8 (4.5-16.5)	11.1 ± 2.4 (5-15.5)	NS
Postoperative C-JOA score, average (range), points	13.9 ± 2.4 (8-17)	14.8 ± 1.6 (11.5-17) *	0.0388
Additional lumbar operation	10 (16.4%)*	0 (0%)	0.0012

Do Motor Evoked Potentials (MEPs) Improve Neuromonitoring Accuracy During Posterior Cervical Spine Surgery in Adults? Intraoperative Neuromonitoring Findings and Outcomes in 5,987 Procedures

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Introduction: Transcranial electric motor evoked potentials (tceMEP) have been widely adopted as an important component of multimodality neuromonitoring (IONM) during spinal deformity surgery, but their usage is not standard in other spinal procedures. In posterior cervical spine surgery, monitoring with somatosensory evoked potentials (SSEPs) alone has good specificity but demonstrably low sensitivity.

The first goal of the present study was to determine if combined SSEP and tceMEP monitoring improves diagnostic accuracy for evolving neurologic injury over SSEP monitoring alone during posterior cervical spine surgery. A second goal was to determine if successful intraoperative resolution of adverse neuromonitoring changes is associated with improved neurologic outcomes in these procedures.

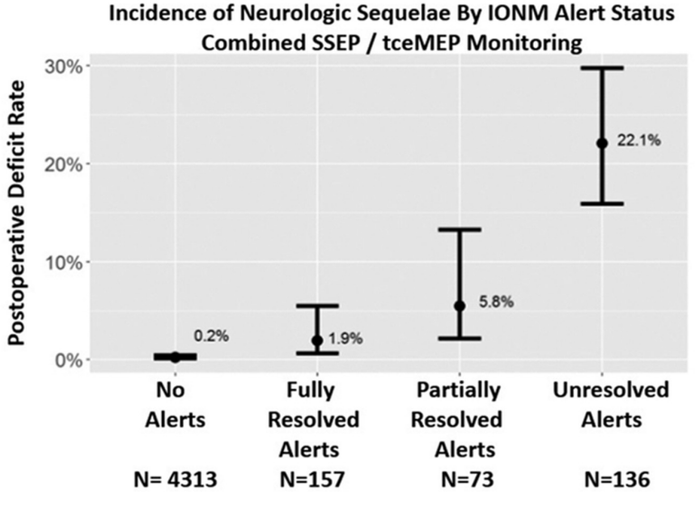
Materials / Methods: We retrospectively reviewed a multi-institutional database of 9,719 consecutive posterior cervical spine surgeries conducted with IONM between May-2013 and April-2017. Procedures were screened to determine if they met inclusion criteria for one of two IONM cohorts: monitoring with SSEPs alone vs. monitoring with both SSEPs and tceMEPs. Procedures were excluded from analysis if baseline signals could not be obtained for testing of both upper and lower extremities or if monitoring records did not include documentation of neurologic status upon emergence from anesthesia. True positive cases were defined as those with unresolved IONM changes and postoperative neurologic sequelae. True negative cases had either no or fully resolved IONM changes and no neurologic sequelae. Binary logistic regression and post-hoc Tukey HSD tests were used to assess inter-cohort comparisons of IONM sensitivity and specificity, as well as to investigate the relationship between degree of IONM alert resolution and postoperative outcome.

See Disclosure Index pages 41–95.

Results: There were 1,308 procedures that met inclusion criteria for the SSEP cohort and 4,679 procedures that met criteria for combined SSEP/tceMEP monitoring. Sensitivity for new onset neurologic deficit was 0.286 (95% CI=0.082–0.641) for SSEP monitoring alone compared to 0.723 (95% CI=0.582–0.831) for combined SSEP/tceMEP monitoring (p=0.037). The odds of a true positive IONM finding in cases with postoperative sequelae were 6.5 times higher for combined SSEP/tceMEP monitoring than for SSEP monitoring alone (95% CI=1.12–38). Specificities for monitoring with SSEP alone vs. combined SSEP/tceMEP monitoring were 0.985 (95% CI=0.976–0.990) and 0.962 (95% CI=0.956–0.967), respectively (p<0.001). Intraoperative neuromonitoring changes and their resolution were quantitatively predictive of postoperative neurologic outcome, as summarized in Figure 1 for the combined SSEP/tceMEP cohort. Rates of neurologic sequelae ranged from 0.2% in procedures with no IONM changes to 22.1% when IONM changes did not resolve prior to the end of surgery (p<0.001). The odds ratio for new onset deficits in cases with unresolved alerts was 121.7 (95% CI=58–255.6) compared to cases with no alerts. This ratio decreased to 8.4 (95% CI=2.3–30.8) when IONM changes resolved prior to the end of surgery.

Conclusion: Combined SSEP/tceMEP monitoring during posterior cervical spine surgery provides superior diagnostic accuracy for evolving neurologic injury compared to SSEP monitoring alone. Successful resolution of IONM changes is associated with improved neurologic outcomes. Assessment of IONM value should take into account both the type of monitoring utilized and effectiveness of intraoperative interventions to reverse identified adverse neurophysiologic change.

Figure 1.



Clinical Assessment using MRI/^{18}F-FDG PET Fusion Imaging for Patients with Cervical Compressive Myelopathy

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Introduction: ^{18}F-FDG PET is used to investigate neural tissue metabolic activity. MRI is used to visualize morphological changes, but the relationship between intramedullary signal changes and clinical outcome remains controversial. We reported that patients with cervical myelopathy have a variable degree of glucose utilization rate in the cervical spinal cord, and that impaired metabolic activity in these patients at the affected spinal cord level correlated closely with the severity of preoperative neurological dysfunction. It is also known how difficult it is to define the specific level of lesion in the cervical spinal cord using ^{18}FDG-PET alone, becoming a main problem to be addressed. The present study was designed to evaluate the use of three dimensional (3D)-MRI/^{18}F-FDG PET fusion imaging to define intramedullary signal changes on MRIs and local glucose metabolic rate measured on ^{18}F-FDG PET in relation to clinical outcome and prognosis.

Materials/Methods: We studied 24 patients who underwent decompressive surgery for cervical compressive myelopathy. All patients underwent 3D-MRI and ^{18}F-FDG PET before surgery. Quantitative analysis of intramedullary signal changes on MRIs included calculation of the signal intensity ratio (SIR) between increased signal intensity of the lesion and C7-T1 disc level. Using the Advantage Workstation, the same slices of cervical 3D-MRI and ^{18}F-FDG PET images were fused. On fusion images, the maximal count at the lesion was adopted as the standardized uptake value (SUV_{max}). The SUV ratio (SUVR), similar to SIR, was also calculated. Neurological assessment was conducted using the Japanese Orthopaedic Association (JOA) scoring system for cervical myelopathy.

Results: The SIR on T1-weighted images (WIs), but not SIR on T2-WIs, correlated with preoperative JOA score and postoperative neurological improvement. Lesion-SUV_{max} correlated with SIR on T1-WIs, but not with SIR on T2-WIs, and also with postoperative neurological outcome. The SUVR correlated better than SIR on T1-WIs and lesion-SUV_{max} with neurological improvement. Longer symptom duration correlated negatively with SIR on T1-WIs, positively with SIR on T2-WIs, and negatively with SUV_{max}.

Conclusion: 3D-MRI/^{18}F-FDG PET fusion imaging is useful for mapping the exact level of cervical spinal cord lesion on ^{18}F-FDG PET. Our results suggest that low-intensity signal on the T1-WIs, but not that on T2-WIs, correlates with poor postoperative neurological outcome. SUV_{max} measured at lesions with increase signal intensity and SUVR measured on fusion MRI/PET, are more sensitive parameters for prediction of clinical outcome than signal intensity on the MRI. Although the present study is limited due to the small sample size, we believe that glucose metabolism measured by MRI/PET fusion is suitable for visualization of neural tissue metabolic activity, and that is a more sensitive tool for assessment of the clinical outcome and prognosis of patients with cervical compressive myelopathy.

See Disclosure Index pages 41–95.

Prospective Validation of the NIH PROMIS CAT in Cervical Spine Patients: Preliminary Results

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Introduction: Patient reported outcome measures used in the cervical spine have several limitations. The National Institutes of Health (NIH) Patient Reported Outcomes Measurement Information System (PROMIS) offers the potential for improved psychometric properties with reduced questionnaire burden through computer adaptive testing (CAT). We designed a prospective study to investigate the Physical Function (PF) and Pain Interference (PI) PROMIS CATs against the Neck Disability Index (NDI) and Short Form 36 (SF-36) Physical Component Score (PCS). We hypothesized that the NIH PROMIS would have equivalent or superior psychometric properties compared to the SF-36 and NDI.

Methods: Adult patients undergoing cervical spine surgery were prospectively enrolled. Patients with a diagnosis of cervical trauma or instability were excluded. SF-36, NDI, PROMIS-PI and PROMIS-PF were administered via assessmentcenter.net in a random order at enrollment and 1–2 weeks after enrollment (if surgery was scheduled >1wk after enrollment). Test-retest reliability was calculated using the intraclass correlation coefficient (ICC) based on a mixed-effects linear model. A Rasch Analysis of the NDI and SF-36 was performed.

Results: A total of 125 patients were included. The average age was 56.9 with 58.4% males. The most common diagnoses were radiculopathy (n=47, 37%), myeloradiculopathy (n=37, 29.9%) and myelopathy (n=35, 28.3%). The PROMIS PF (PPF) required 4.1 questions (range 4-12) with average time to completion (TTC) of 43±38s. The PROMIS PI (PPI) required 4.3 questions with TTC of 36±34s. Both required significantly less time than the NDI (124±70s) and SF-36 PCS (171±72s). Test retest reliability was excellent for NDI (ICC:0.874), PCS (0.874), PPF (0.829) and PPI (0.826). Histograms with the pre- and post-operative distributions are shown (Figure 1). Rasch Analysis of the NDI and SF-36 revealed good person- and item reliability >0.9. Pre-operative floor effect for the NDI was low (4.8%); we did not observe any ceiling effects. There were no large differences in item and person reliability based on diagnosis (e.g., patients with myelopathy). There was a strong correlation between the Rasch-derived measures of the NDI, PPI ($r=0.751$, $p<0.001$) and PPF ($r=-0.609$, $p<0.001$). The Rasch-derived measures of the PCS were well correlated with the PROMIS-PI ($r=-0.550$, $p<0.001$) and PPF ($r=0.722$, $p<0.001$).

Seventy-four patients completed 6 months post-op questionnaires (86% of eligible). There was a significant change in all measures post-operatively (Table 1). Rasch Analysis of the NDI post-operatively revealed significant floor effects (22.9%) with poor coverage for individuals with low NDI (Figure 2). Patients reaching the floor of the NDI most commonly had a diagnosis of myelopathy pre-operatively (n=7, 41.1%).

Conclusions: The PPF and PPI are correlated to existing PROs with PPF being most closely correlated to the SF-36 and PPI to the NDI. The PPF and PPI CATs can be completed in ~10q and 75s; saving over 3.5 min per patient compared to the NDI and PCS. The NDI demonstrates significant floor-effects post-operatively, particularly in patients with myelopathy. The PPF and PPI are both responsive to changes in surgery. Further work is needed to determine the clinically important differences in PPF and PPI.

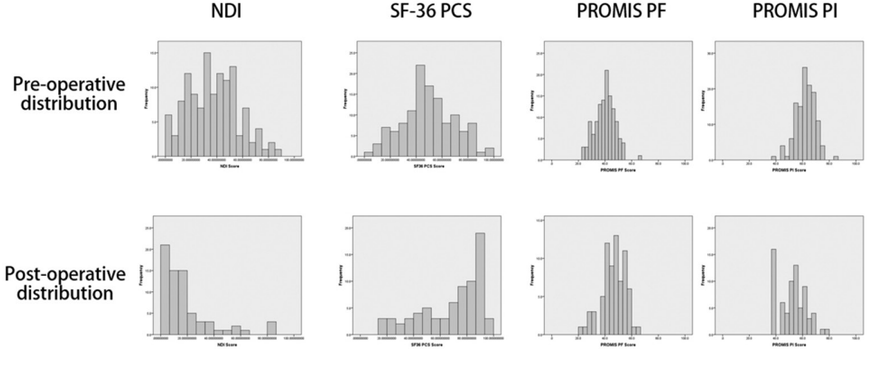

Figure 1. Pre- and Post-operative histograms (all graphs scaled from 0-100 on the x-axis).

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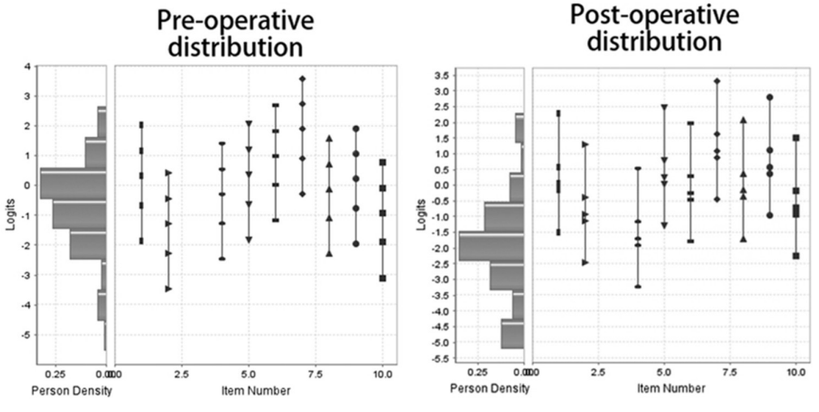
Table 1. Pre- and post-operative mean scores and change in scores for all instruments

	Mean	Standard Deviation	Minimum	Maximum
Pre-operative NDI Score	37.9	18.6	2.0	86.0
Post-Op NDI Score	20.5	21.3	0.0	86.0
NDI Change (p<0.001)	-17.4	20.4	-70.0	43.8
Pre-op PCS	46.6	18.0	5.0	86.0
Post-op PCS	68.9	23.8	14.0	98.8
PCS Change (p<0.001)	21.7	23.6	-72.4	60.2
Pre-op PPI	62.9	6.5	46.6	83.8
Post-op PPI	53.1	10.1	38.7	77.8
PPI Change (p<0.001)	-11.6	13.7	-75.3	14.7
Pre-op PPF	39.3	7.1	23.5	54.0
Post-op PPF	46.2	8.9	22.2	66.4
PPF Change (p<0.001)	6.4	11.1	-42.3	42.9

Figure 2. Item-person maps for pre- and post-operative NDI



- **The FDA has not cleared the drug and/or medical device for the use described (i.e., the drug and/or medical device noted with an * is being discussed for an "off label" use). See inside back cover for information.**

The Epidemiology of Cervical Spine Injuries in 25 NCAA Sports from 2004–2014 Academic Years

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Introduction: Sports injuries are the second most common cause of spine injuries in the first 30 years of life. To our knowledge, no study has been conducted to determine the incidence of cervical spine injuries (CSI) in a large sample of National Collegiate Athletic Association (NCAA) athletes. The objective of our study is to evaluate the incidence of CSIs in the athlete population of 25 NCAA sports.

Methods: We conducted a retrospective study of injury surveillance data collected via the NCAA Injury Surveillance Program (ISP) from 2004–2014. Using exposure and injury information supplied by Datalys, inferences were made on the total number of NCAA CSIs by year, including 95% confidence intervals. R statistical software version 3.2.5 was used for the analyses. National Estimates were produced by the survey package in R utilizing a validated weighting method.

Results: CSIs include: brachial plexus syndrome (Stinger), cervical disc Injury, cervical facet syndrome, cervical spinal fracture, cervical spinal stenosis, cervical strain/whiplash, cervical spine contusion, torticollis. During the 2004–2014 academic years, there were an estimated 27,276 CSIs. 15,524 were football-related, 2,445 being men's wrestling-related and 9307 being non-football or wrestling related. For the 2004–2014 academic years, the rate of cervical spine injuries for all sports was 1.15 per 10,000 athlete exposures (AEs) from 2004–2009 and 1.52 per 10,000 AEs for 2009–2014. Men's wrestling had the highest rate per individual sports with a rate of 4.26 per 100,00 AEs from 2004–2009 and 4.95 per 10,000 AEs from 2009–2014. Severity of injuries was also measured and recorded as time loss from competition.

Discussion and Conclusion: CSIs can have devastating results for athletes. Rule changes such as the "targeting rule" have been put into place recently to combat head and neck injuries in NCAA men's football and adjustments to injury timeouts, specifically concussion timeouts, in men's wrestling to allow medical personnel to make a more complete evaluation. An understanding of the sports which have the highest rate and most severe of injuries will allow us to ensure proper protocols are in place as well as have appropriately trained medical staff at events to ensure the safety of participating student-athletes.

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Characteristics of Rheumatoid Arthritis with No Development of Cervical Spine Instabilities: A Prospective Multicenter Over 10-Year Cohort Study

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Introduction: We previously conducted a prospective multicenter >10-year cohort study of patients with established rheumatoid arthritis (RA), reporting the increased incidence and predictive risk factors of cervical spine instabilities. In this study, there were a substantial number of patients who did not develop cervical spine involvement consistently, despite their apparent RA. Understanding of these patients possibly provides insight into RA treatment targeting no development of cervical spine instabilities. Therefore, a sub-population analysis was designed.

Materials / Methods: Three types of cervical spine instability were radiographically categorized into "moderate" and "severe" based on atlantoaxial subluxation (atlantodental interval >3 mm vs. ≥10 mm), vertical subluxation (Ranawat value <13 mm vs. ≤10mm), and subaxial subluxation (irreducible vertebral translation ≥2 mm versus ≥4 mm or at multiple levels). Between 2001 and 2002, 634 outpatients with "definite" or "classical" RA were enrolled, and 292 of 634 were identified as those without baseline cervical spine instability. Between 2006 and 2008, 140 of 292 patients (47.9%) were prospectively followed for >5 years. Between 2012 and 2013, 84 of 140 patients (60.7%) were followed throughout >10 years. The incidence of instabilities was examined. Characteristics of patients without any development of instabilities were analyzed by multivariable logistic regression.

Results: In 84 patients who underwent >10-year clinical follow-up throughout,>5-year incidence of cervical spine instability and "severe" instability was 45.2% ($p<0.01$) and 13.1% ($p<0.01$), respectively; meanwhile, 54.8% did not develop any instability (Figure 1). Then,>10-year incidence of overall and "severe" instabilities was 60.7% ($p=0.045$) and 17.9%, respectively, resulting in 33 patients (39.3%) without instability at endpoint (Figure 1). Compared to 51 patients with the development of instabilities, 33 without the development tended to have the duration of RA<5 years ($p=0.047$), CRP value<1 mg/dl ($p=0.03$), no peripheral joints surgically treated ($p=0.02$), no administration of corticosteroids ($p=0.01$), and Steinbrocker stages I–II in the hands ($p=0.02$) at baseline. Then, a multivariable logistic regression model including these variables identified no corticosteroid administration ($p=0.03$, odds ratio [OR]=3.39) and Steinbrocker stages I–II ($p=0.04$, OR=4.05) as significant characteristics of no instability (Table 1). Furthermore, to make these differences clearer, the comparison between patients who did not develop instability and who developed "severe" instabilities was performed. Patients without the development of instabilities showed baseline<5-year RA duration ($p=0.04$), no previous joint surgery ($p=0.03$), no use of corticosteroids ($p<0.01$), and Steinbrocker stages I–II ($p=0.03$). A multivariable model ultimately determined no corticosteroid use ($p<0.01$, OR=9.36) as the significant predictor for no development of instabilities (Table 1).

Conclusion: The prevalence of no cervical spine instability significantly declined but still remained after>10 years. Characteristics of patients without cervical spine instability throughout were no requirement of corticosteroids to relieve RA symptoms and non-advanced hand destruction by RA. These are in line with the current treatment algorithm aiming the remission of RA. This study highlights that the maintenance of reduced symptoms and preserved peripheral joints is essential to prevent the development of cervical spine instabilities, suggesting the importance of early and intensive interventions for RA, e.g. biologic therapies.

Figure 1. Over 10-year incidence of cervical spine instability and "severe" cervical spine instability in 84 RA patients without baseline cervical spine instability

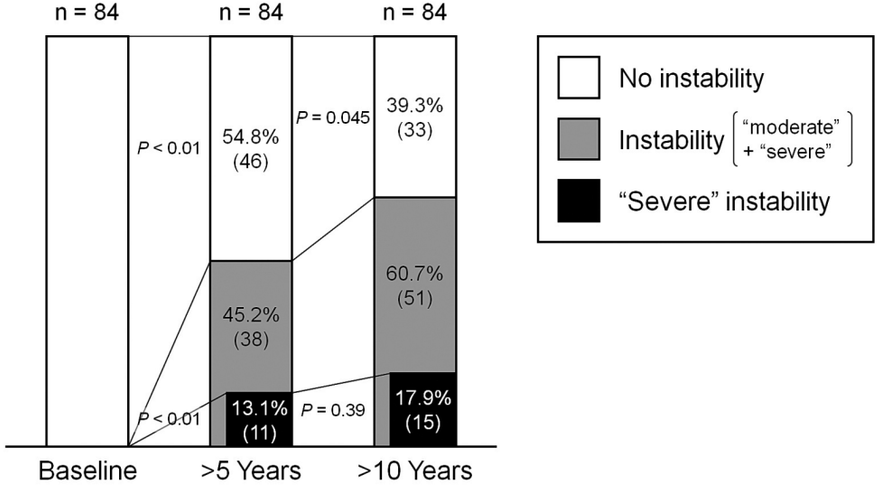

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Table 1. Odds ratios (ORs), 95% confidence intervals (95% CIs), and P values for no development of cervical spine instability by multivariable logistic regression analysis

	No instability vs. Instability development			No instability vs. "Severe" instability development		
Variable	OR	95% CI	p Value	OR	95% CI	p Value
Demographic and clinical characteristics						
Age <55 years		Not included			Not included	
Age ≥65 years		Not included			Not included	
Female sex		Not included			Not included	
RA duration <5 years	1.47	0.42–5.18	0.55	2.56	0.19–35.28	0.48
CRP<1.0 mg/dl	2.11	0.73–6.08	0.17		Not included	
RF negative	2.01	0.55–7.41	0.29		Not included	
No previous joint surgery	1.96	0.66–5.84	0.22	3.05	0.62–15.05	0.17
Medications						
No corticosteroids	3.39	1.16–9.91	0.03†	9.36.	1.77–49.62	<0.01‡
No MTX		Not included			Not included	
No other DMARDs		Not included			Not included	
No biologic agents	3.33	0.71–15.58	0.13		Not included	
RA stages and mutilating changes						
Steinbrocker stages I–II	4.05	1.03–15.86	0.04†	7.63	0.52–112.52	0.14

†p<0.05. ‡p<0.01.
CRP, C-reactive protein; DMARD, disease modifying anti-rheumatic drug; MTX, methotrexate; RA, rheumatoid arthritis; RF, rheumatoid factor.

Pathological Process and the Expression of Susceptibility Genes for Ossification of the Posterior Longitudinal Ligament of the Spine in Human and Hereditary Spinal Hyperostotic Mouse *(ttw/ttw)*

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Introduction: Ossification of the posterior longitudinal ligament of the spine (OPLL) is a multi-factorial disease that involves genetic and environmental factors. In a previous genome-wide association study (GWAS), six loci associated with OPLL were reported. However, susceptibility genes in these loci have not been identified yet. In this study, we investigated serial histological changes in the longitudinal ligaments leading to the ossification and the expression of susceptibility genes (STK38L, RSPO2, HAO1, CCDC91, RSPH9) using sections of the posterior longitudinal ligament were obtained from patients who underwent anterior decompressive surgery and the spinal hyperostotic mouse *(ttw/ttw)* as a suitable model of human OPLL.

Materials / Methods: Sections of the posterior longitudinal ligament were obtained from patients who underwent anterior decompressive surgery. Cultured posterior longitudinal ligament cells were subjected to 24 hours of cyclic tensile strain and then analyzed by microarray. Immunohistochemistry analysis of the harvested sections was performed to evaluate the expression of susceptibility genes; STK38L, RSPO2, HAO1, CCDC91, RSPH9. The pathological process was assessed in dissected en bloc vertebral column in 6-, 18- and 22-weeks old *ttw/ttw* mice by immunohistochemical analysis (PCNA, S-100, Chondroitin 4 sulfate proteoglycan, ALP). The expression of susceptibility genes was also assessed in 6-8-weeks old *ttw/ttw* mice.

Results: The human OPLL samples were imunopositive for RSPO2 and HAO1 in the ossification front of OPLL, but the individual difference was seen in degree of the expression. In the microarray analysis, HAO1 showed increased expression levels compared with controls and RSPO2 and CCDC91 showed increased expression levels after the 24-hour cyclic tensile strain. In *ttw/ttw* mice, we observed that enlargement of the nucleus pulposus followed by herniation, disruption and regenerative proliferation of annulus fibrosus cartilaginous tissues participated in the initiation of ossification of the posterior longitudinal ligament. The expression of RSPO2 and HAO1 was observed posteriorly at the C1-C2 vertebral level in 6-8-weeks old *ttw/ttw* mice.

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Conclusion: The individual difference of the immunoreactivity for RSPO2 and HAO1 was seen in the human OPLL because these susceptibility genes were expressed in the initiation of ossification of OPLL and the activity of progression may be influenced. In *ttw/ttw* mice, high reproducible results were obtained, the cells of the protruded hyperplastic annulus fibrosus invaded the longitudinal ligament and induced neovascularization and metaplasia of primitive mesenchymal cells to osteoblasts in the spinal ligaments. Since genetic mechanisms could play a role in human OPLL, the age-related enlargement of the nucleus pulposus in the *ttw/ttw* mouse may primarily occur as a result of overproduction of mucopolysaccharide matrix material induced by certain genetic abnormalities. Our histological and pathological date indicate that RSPO2 and HAO1is a susceptibility gene for OPLL.

Trends in Opioid Utilization During Hospitalization for Cervical Spinal Fusion: A Large Scale Multicenter Epidemiological Study

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Introduction: While opioids are the cornerstone of postoperative pain control, they have come under increased scrutiny given the current epidemic of opioid overuse in the US. Indeed, a substantial proportion of patients with a dependence on opioids initiated opioid use during a hospitalization for a surgical procedure. Patients undergoing spinal surgery in particular have a relatively high opioid consumption during hospitalization and may be at increased risk. Despite the current focus on prudent use of opioids, there is a lack of large-scale data on trends in utilization and how this relates to resource utilization and hospital characteristics. Using a large national claims database, we specifically focused our analysis on trends in opioid utilization during hospitalizations for cervical fusion patients as this data is lacking in the literature.

Methods: We extracted claims data on patients undergoing a cervical fusion using ICD-9 procedure codes 81.02 (anterior) and 81.03 (posterior); 2006–2014 (n=183,400 procedures). Trends in median per-patient annual opioid utilization (extracted from billing; expressed in oral morphine equivalents, OME) as well as total cost of hospitalization (TCOH) were assessed for the full cohort as well as stratified by hospital characteristics: teaching vs. non-teaching, urban vs. rural, and hospital size measured by number of beds (<300, 300–400, >499). Significance of trends was assessed using linear regression.

Results: Overall, median opioid utilization increased slightly from 227.5 to 237.5 OMEs ($P<0.0001$), while median cost of hospitalization increased from $11473 in 2006 to $14,802 in 2014 ($P<0.0001$). With regard to hospital location: median opioid utilization for urban hospitals increased from 230.0 to 240.0 OMEs from 2006-2014 ($P<0.0001$), however this trend was not seen in rural hospitals (200.0 to 210.0 $P>0.05$). Despite this, the median cost of hospitalization in rural hospitals increased from $9,978 to $14,189 ($P<0.0001$) and urban hospitals increased from $11,649 to $14,850 from 2006–2014($P<0.0001$). In terms of hospital size, median opioid usage increased in all three-bed sizes from 2006-2014:<300 beds increased from 228.04 to 235 OMEs; 300–400 beds 225.0 to 230.0 OMEs;>499 beds 232.5 to 242.65 OMEs ($P<0.0001$). The median cost of hospitalization also increased across all hospital sizes from 2006–2014:<300 beds increased $10,634 to $14,974; 300–400 beds $11,359 to $14,373;>499 beds $11,924 to $14,997 ($P<0.0001$). The median opioid usage in teaching hospitals increased from 218.0 to 248.0 OMEs ($P<0.0001$), but a decreased trend was seen in non-teaching hospitals, decreasing from 240.0 to 227.5 OMEs from 2006–2014 ($P<0.0001$) shown in Figure 1. The median cost of hospitalization for teaching and non-teaching hospitals showed a similar trend to the other hospital characteristics: non-teaching hospital costs increased from $11,403 to $14,184 ($P<0.0001$); teaching hospital costs increased from $11,535 to $15,371 ($P<0.0001$).

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Conclusion: The most interesting and clinically relevant trend elicited from this study was the differences in median opioid utilization among different hospital characteristics. A general increase in median opioid use was seen for urban and teaching hospitals, but rural hospitals experienced no change and non-teaching hospitals actually decreased median opioid usage from 2006–2014. This analysis opens up epidemiological questions discussing opioid utilization patterns between urban and teaching hospitals vs. rural and non-teaching hospitals.

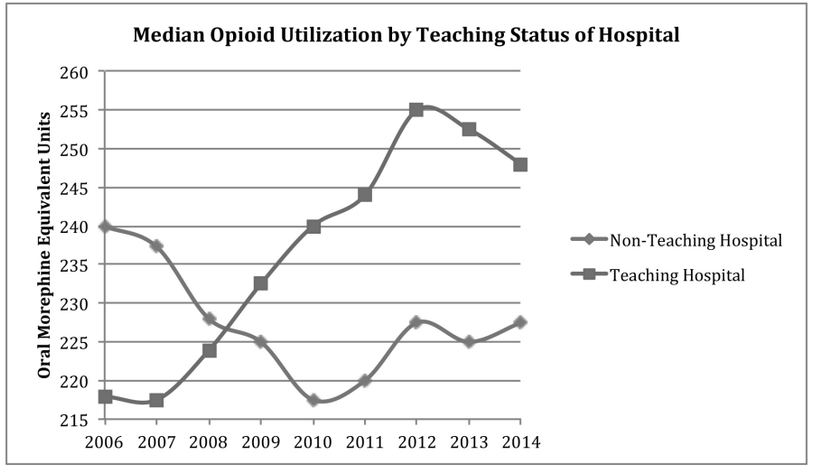

Figure 1. Median Opioid Utilization Stratified by Teaching Status of Hospital showing the increasing trend in median opioid utilization seen in teaching hospitals compared to that seen in non-teaching hospitals from 2006–2014.

Table 1. Opioid Utilization and Cost of Hospitalization by Teaching Status of Hospital

	Median Opioid Utilization (OME)		Median Cost of Hospitalization	
Teaching Status Hospital	Non-Teaching Hospital	Teaching Hospital	Non-Teaching Hospital	Teaching Hospital
2006	240.0	218.0	$11,403	$11,535
2007	237.3	217.5	$11,904	$12,647
2008	228.0	223.9	$13,206	$13,530
2009	225.0	232.5	$13,057	$13,421
2010	217.5	240.0	$13,610	$14,242
2011	220.0	244.0	$13,904	$14,506
2012	227.5	255.0	$13,525	$14,489
2013	225.0	252.5	$13,332	$14,736
2014	227.5	248.0	$14,185	$15,371

Table 2. Opioid Utilization and Cost of Hospitalization by Hospital Size (Number of Beds)

	Median Opioid Utilization (OME)			Median Cost of Hospitalization		
Hospital Bed Size	<300	300–400	>499	<300	300–400	>499
2006	228.0	225.0	232.5	$10,634	$11,359	$11,924
2007	237.5	220.0	229.7	$11,509	$12,389	$12,587
2008	235.0	220.0	225.0	$12,878	$13,547	$13,507
2009	240.0	225.0	225.0	$12,532	$13,103	$13,908
2010	220.2	220.0	240.0	$13,292	$13,637	$14,626
2011	226.0	225.0	240.0	$13,528	$14,049	$14,845
2012	236.0	230.0	250.0	$13,761	$13,690	$14,486
2013	240.0	230.0	242.7	$14,016	$13,833	$14,175
2014	235.0	234.1	242.5	$14,974	$14,373	$14,997

Table 3. Opioid Utilization and Cost of Hospitalization by Hospital Location

	Median Opioid Utilization (OME)		Median Cost of Hospitalization	
Hospital Location	Rural	Urban	Rural	Urban
2006	200.0	230.0	$9,978	$11,649
2007	210.0	228.0	$10,949	$12,447
2008	192.0	227.5	$12,748	$13,440
2009	210.0	230.0	$12,950	$13,292
2010	204.5	230.0	$13,473	$13,937
2011	210.0	232.5	$14,441	$14,165
2012	215.0	241.2	$14,151	$14,012
2013	200.4	240.0	$13,912	$14,017
2014	210.0	240.0	$14,189	$14,850

See Disclosure Index pages 41–95.

The Seven-Year Cost-Effectiveness of Anterior Cervical Discectomy and Fusion vs. Cervical Disc Arthroplasty

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Introduction: Anterior cervical discectomy and fusion (ACDF) and cervical disc replacement (CDR) are both acceptable surgical options for the treatment of an acute disc herniation with associated cervical myelopathy / radiculopathy. Studies have demonstrated at least equal effectiveness of CDR when compared with ACDF in large randomized investigational device exemption (IDE) studies. Furthermore, analysis of the cost-effectiveness of the two procedures in the short term has demonstrated that CDR may be the preferred treatment option. The purpose of this study is to determine the seven year cost-effectiveness of single-level ACDF versus CDR.

Materials / Methods: A Markov-state transition model was used to evaluate data from the MobiC IDE study. Data from the 12-item Short Form Health Survey were converted into utilities suing the SF-6D algorithm for 179 CDR patients and 81 ACDF patients. Costs were calculated from the payer perspective using 2017 Medicare reimbursement for diagnosis related groups (DRG) and current procedural terminology (CPT) codes. Transition probabilities in the model were determined from complication rates as well as index / adjacent segment re-operation rates from their IDE study. Quality adjusted life years (QALYs) were used to represent effectiveness. For the base case analysis, incremental cost effectiveness ratios (ICERs) were used to compare treatments. A willingness-to-pay threshold of $50,000 / QALY was used. A probabilistic sensitivity analysis was performed using a Monte Carlo simulation of 10,000 cycles to validate the input variables in the model. Confidence intervals (CI) were reported at 95%.

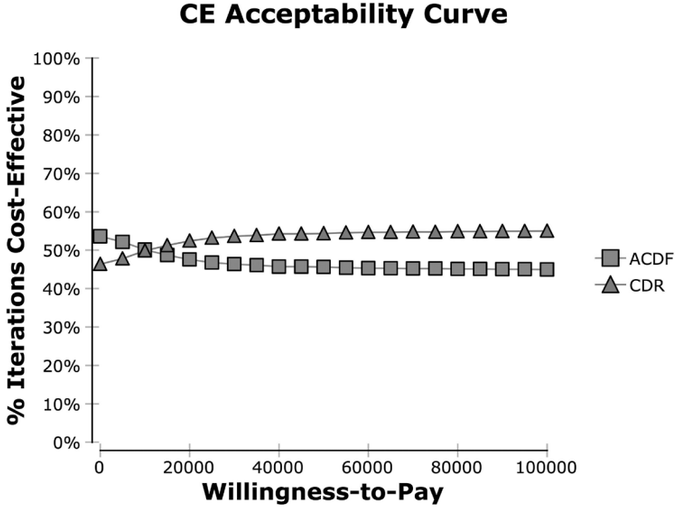
Results: The base case assumed an ideal operative candidate of 40 years old who has failed appropriate conservative care. The base case analysis generated a seven-year cost of $105,332 for CDR and $103,911 for ACDF. CDR resulted in a generation of 5.33 QALYs while ACDF resulted in 5.16 QALYs. The ICER was calculated to be $8,111 / QALY for CDR, which was less than the $50,000 / QALY WTP threshold. CDR and ACDF were both cost-effective procedures ($20,133 / QALY vs. $19,738 / QALY). The Monte Carlo simulation validated the base case scenario. CDR had a mean cost of $105,637 (CI: $79,665–$131,609) with an average effectiveness of 5.33 (CI: 3.21–7.45). ACDF had a mean cost of $103,924 (CI: $78,694–$122,884) and an average effectiveness of 5.16 (CI: 3.08–7.24) (Table 1). Assuming a WTP $50,000 / QALY; the cost-effectiveness acceptability curve indicated that CDR would be chosen 54% of the time based on 10,000 simulations (Figure 1).

Conclusions: CDR and ACDF are both cost-effective strategies at seven years. Based on the results of this model, CDR was found to be to the more cost-effective strategy with an ICER less than the $50,000 / QALY WTP threshold. Furthermore, the assumptions used in the base case analysis were strongly validated with the results of the probabilistic sensitivity analysis. Additional long-term studies (>10 years) evaluating the clinical and quality-of-life outcomes of these two strategies are needed to further validate the findings in this model.

Table 1. Comparison of ACDF and CDR and their relative cost and effectiveness as well as the ICER.

Strategy	Cost ($)	Incremental Cost ($)	Effectiveness (QALY)	Incremental Effectiveness (QALY)	Incremental Cost Effectiveness (ICER) ($/QALY)	Average Cost Effectiveness ($/QALY)
ACDF	103,911 (CI: ($78,694–$122,884)		5.16 (CI: 3.08–7.24)			20,133
CDR	105,332 (CI: $79,665–$131,609)	1,421	5.33 (CI: 3.21–7.45)	0.17	**8,111**	19,738

Figure 1. 54% of scenarios at a $50,000 willingness to pay threshold were in favor of CDR with respect to ACDF in a Monte Carlo probabilistic sensitivity analysis.



See Disclosure Index pages 41–95.

How Much Does the Surgeon Make for the Hospital from Cervical Fusion? Time Trends and Regional Variation from 10-Year Medicare Data

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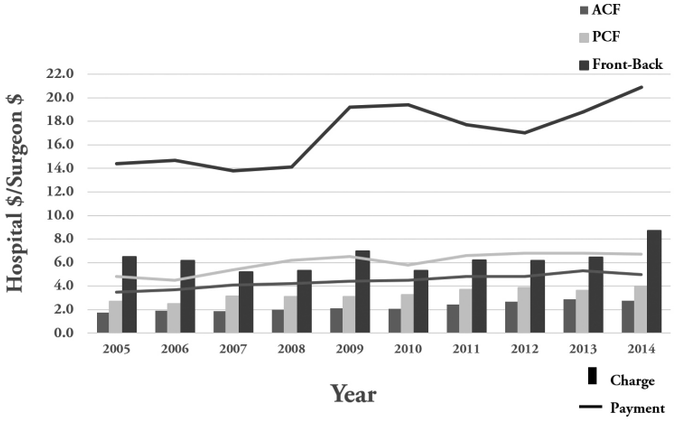
Introduction: Hospital costs not only constitute majority share for spinal fusion but are also the source of maximum variation. Previous studies have reported trends and variation in hospital charges and payments after cervical fusion, but none have incorporated surgeon data in analyzing trends. Knowledge of the fiscal relationship between hospitals and surgeons over time and between regions will be important for stakeholders as we move towards bundled payments. Therefore, the objective of our study was to analyze hospital charges and payments adjusted to corresponding surgeon charges and payment for cervical fusion, and to report their trends and geographic variation from Medicare data.

Material / Methods: A 5% Medicare sample was used to study hospital and surgeon charges and payments related to cervical fusion for degenerative disease between 2005 and 2014. For our analysis, hospital Charge and Payment Multipliers (CM, PM) were defined by hospital dollars / surgeon dollars for charges and payments, respectively. In addition to giving estimates of how much the hospital charges and nets per surgeon dollar, this ratio helps neutralize effect of hospital expensiveness when we compare regions. We studied anterior, posterior, and front-back cervical fusions separately. For each procedure type, patient's charlson comorbidity index (CCI) and fusion levels were weighed between regions to ensure uniformity in magnitude of surgery. The yearly trend in CM and PM was studied from 2005 to 2014. Geographic variation (Northeast, Midwest, South and West) was studied using one-way analysis of variance and post-hoc analysis.

Results: A total of 15,854 patients with a mean age of 63.4 years were included. The hospital charge and payment per surgeon dollar had a rising trend for all cervical fusions (maximum for front-back fusions) (Figure 1). The average hospital charge for front-back cervical fusions was $6.4 to each dollar surgeon charge. In turn hospitals were paid an average $17.4 for each dollar earned by the surgeon. The increase in hospital charges and payment between 2005 and 2014 had an inverse relation to the length of hospital stay (LOS) **(r=-0.6 and -0.8)**. Hospitals in the West had significantly ($p<0.01$) more charges per surgeon dollar than hospitals in other regions. Hospitals in the Northeast had the lowest charge, but were paid the most per dollar earned by the surgeon ($p<0.01$ for anterior and front-back fusions). Hospitals in the South were paid the least per dollar earned by the surgeon.

Conclusion: Hospital charges and payments for cervical fusion continue to rise despite a decreasing length of hospital stay. A more complex procedure such as front-back cervical fusion seems to favor the hospital rather than the surgeon in terms of revenue generated. In addition to increased use of resources, implants, and biologics, changes to the payment system in 2008 enabled hospitals to receive higher payments for sicker patients. This effect has not trickled down to surgeon payments. These findings have important implications from a risk-sharing and bundled payments perspective. Hospital charges do not seem to correlate with regional cost-index and bear little relationship to actual payments from Medicare.

Figure 1. Hospital Charge and Payment Multiplier for Cervical Fusions: Trend from 2005 to 2014



ACF – Anterior Cervical Fusion, PCF – Posterior Cervical Fusion

See Disclosure Index pages 41 – 95.

Advanced Age is Not a Predictor for Distal Junctional Kyphosis in Operative Cervical Deformity Patients

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Introduction: Aging creates changes in bone mineral content, intervertebral disk elasticity, and joint flexibility, which contribute to alteration of spine biomechanics. Age-specific alignment for thoracolumbar deformity correction results in low disability with less PJK. There is a lack of information concerning the effect of age on cervical deformity correction and on the incidence of Distal Junctional Kyphosis (DJK). The purpose of this study is to determine if there is age specific cervical alignment and if elderly patients have a higher rate of DJK than younger patients.

Methods: This study is a retrospective review of a prospective, multicenter database of adult cervical deformity patients. Inclusion criteria for the database were cervical kyphosis (CK)>10°, cervical scoliosis (CS)>10°, C2-7 SVA (cSVA)>4cm or chin-brow vertical angle (CBVA)>25°. Patients were grouped by age (younger<65 vs. elderly≥65). Patients were analyzed for DJK (change in kyphosis>10° in LIV to LIV-2). HRQL were correlated with alignment. Elderly and Younger patients were compared in each group with respect to demographic, surgical, established radiographic parameters and novel measures, C2-T1 Tilt and C2-LIV Tilt, to assess alignment within the fusion construct. Categorical variables were compared using Chi-Squared Tests. Comparisons between radiographic parameters were performed using paired and independent samples t-tests.

Results: 123 CD patients (mean age 60.6 yrs, 59.3% female, 11.4% revisions) were included. 79 younger and 44 elderly patients were included. There were no differences in BMI, gender, smoking status or CCI between these groups (p>0.05). The elderly patients had more baseline deformity by TPA (16.6 vs. 11.9, p=0.034), TS-CL (41.5 vs. 33.2, p=0.014), and cSVA (52.6 vs. 42.2, p=0.026). Both groups underwent significant correction of their deformity (TPA, TS-CL, CL, cSVA; all p<0.01). DJK occurred 9.8% of all patients (8.9% of younger patients and 11.4% of the elderly cohort). Postoperatively, younger patients with DJK had larger cSVA (54.1 vs. 32.0, p=0.007), C2-Slope (33.0 vs. 23.3, p=0.025) and MGS (4.80 vs. -4.35, p=0.001) than those without DJK.There were no significant correlations between alignment and HRQL measures at baseline (NDI, NSR neck, EQ5D, mJOA) for the whole cohort or either age group. Comparing patients with DJK to those without, Elderly patients had worse alignment within the fusion (C2-T1 Tilt: 2.24 vs. -12.1, p=.034), which was also true for younger patients (C2-LIV Tilt: 16.6 vs. 2.41, p<.05).

Conclusions: Both younger and elderly patients had similar alignment, HRQL outcomes and DJK rate following corrective cervical deformity surgery. The nonlinear relationship between postoperative HRQL metrics and radiographic alignment did not demonstrate that there is an optimal age-specific alignment. Regardless of age, patients who were fused in a forward alignment had higher rates of DJK.

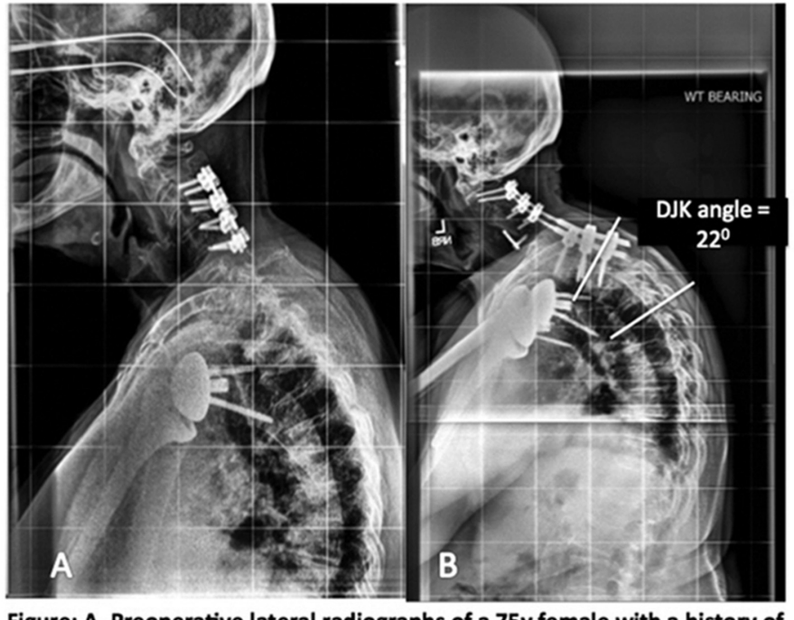

Figure: A. Preoperative lateral radiographs of a 75y female with a history of laminectomy and fusion with iatrogenic kyphosis and cervical sagittal deformity. B. Following C2-T2 anterior/posterior fusion, distal junctional kyphosis occurred with further loss of sagittal alignment.

See Disclosure Index pages 41–95.

Impact of Cervical Scoliosis on Radiological and Clinical Parameters: Retrospective Study of 258 Patients

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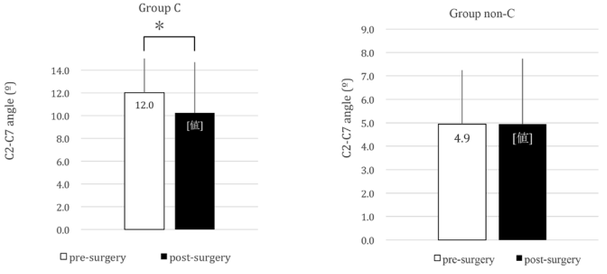
Introduction: Lumbar coronal imbalance has been considered as important because it may cause clinical symptoms. However, cervical coronal balance has received insufficient attention, in contrast to degenerative lumbar scoliosis. The aim of this study was to demonstrate the impact of cervical coronal balance on radiological and clinical parameters.

Materials / Methods: Since 2008, 258 patients with cervical myelopathy who underwent selective laminectomy in a single institute have completed a minimum of 2 years of follow-up. The reasons of myelopathy were spondylosis (n=189, 73.3%), ossification of the posterior longitudinal ligament (n=64, 24.8%), and disc herniation (n=5, 1.9%). The average age of patients was 63.0±11.7 (years) and gender was 177 males and 81 females. Preoperative and postoperative coronal balance were calculated by Cobb method and cervical scoliosis (CS) was determined as Cobb angle exceeding 10º. Patients with CS (group C) and those without CS (group non-C) were compared by following parameters; postoperative cobb angle, age, gender, number of decompressed laminae, JOA score, C2–C7 angle, range of motion, sagittal vertical axis, T1 slope, kyphosis, and signal intensity changes in the spinal cord on T2-weighted MRI. Kyphosis was defined as local kyphosis exceeding 5° on lateral x-ray. Student's-t test was adopted for statistical analysis and $p<0.05$ was considered as statistically significant.

Results: The prevalence of CS was 22.1% (n=57). In group C, Cobb angle became significantly smaller at the final follow-up (pre-surgery 12.0 vs. post-surgery 10.2º; p=0.00), whereas there was no significant change of Cobb angle in group non-C (pre-surgery 4.9º vs. post-surgery 4.9º; p=0.97) (Figure.1). Patients in group C have significantly higher C2-C7 angle (group C 16.1° vs. group non-C 12.0°; p=0.035) and T1 slope (group C 27.1° vs. group non-C 24.4°; p=0.037) without significant differences in other radiological and clinical parameters (Table 1).

Conclusion: Relatively higher prevalence of DCS were detected in this study. Surprisingly, Cobb angle among patients with CS became significantly smaller at the final follow-up. This result suggests that scoliosis of myelopathic patients is frequently nonstructural and this improved by relief of pain following surgery. Interestingly, CS has significantly higher correlation with other radiological parameters of sagittal alignment such as C2-C7 angle and T1 slope. Although this reason is unknown, we speculate that imbalance of cervical soft tissues due to cervical scoliosis affects the result.

Figure 1. In group C, Cobb angle became significantly smaller at the final follow-up (pre-surgery 12.0º vs. post-surgery 10.2º; p=0.00) (*left*). On the other hand, there was no significant change of Cobb angle in group non-C (pre-surgery 4.9º vs. post-surgery 4.9º; p=0.97) (*right*).



Group C indicates group of patients with degenerative cervical scoliosis, Group non-C; group of patients without degenerative cervical scoliosis. Cervical scoliosis was defined by Cobb angle exceeding 10º. *Statistically significant.

Table 1. Comparative study of demographic, clinical, and radiographic features between patients with cervical scoliosis and those without cervical scoliosis

Variables	Group C	Group non-C	p Value
Age (y/o)	65.0±12.2	62.2±11.6	0.120
Follow-up period (months)	38.6±14.9	36.2±13.7	0.250
Number of decompressed laminae (n)	2.9±0.8	2.6±1.0	0.100
JOA			
Pre (pts)	11.0±2.8	11.6±2.6	0.130
Post (pts)	13.6±2.0	13.9±2.2	0.330
Recovery rate (%)	39.4±33.9	40.6±37.6	0.830
Cobb angle (°)	12.0±14.6	5.0±12.0	0.000
C2-C7 angle (°)			
Neutral	16.1±11.2	12.0±16.1	0.035*
Flex	-7.1±14.4	-8.1±7.1	0.590
Extension	28.6±12.8	26.3±28.6	0.270
ROM (°)	35.7±15.5	34.2±13.2	0.930
SVA (°)	20.2±15.8	18.9±20.2	0.560
T1slope (°)	27.1±7.5	24.3±27.1	0.037*
Signal intensity change on spinal cord (n)	42 (73.7%)	157 (78.1%)	0.560

Group C indicates group of patients with cervical scoliosis, Group non-C; group of patients without cervical scoliosis. Cervical scoliosis was defined by Cobb angle exceeding 10º. JOA, Japan Orthopedics Association; ROM, Range of Motion; SVA, Sagittal Vertical Axis.
*Statistically significant.
Numerical variables have been expressed as mean±standard deviation or number (proportion)

See Disclosure Index pages 41–95.

PROMIS Physical Functioning Correlation with NDI and mJOA in the Surgical Cervical Myelopathy Patient Population

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Introduction: Legacy patient reported outcome measures such as NDI (Neck Disability Index) and mJOA (modified Japanese Orthopedic Association score) have become essential for analyzing treatment interventions in orthopedic spine surgery for cervical myelopathy. Despite their usefulness, significant associated administrative burdens impose limits on completion of these measures. The Patient Reported Outcomes Measurement Information System (PROMIS) group developed a patient outcome measure based on Item Response Theory in order to improve reporting of patient symptoms, function, and health and to reduce administrative burden and improve outcome measure reliability. Despite early positive results of PROMIS in orthopedic specialties including spine, NDI and mJOA scores have not been compared with PROMIS in the spondylotic cervical myelopathy patient population. The aim of this study is to compare NDI and mJOA with PROMIS to determine their correlations in a surgical patient population longitudinally.

Materials / Methods: 60 patients with a primary diagnosis of cervical spondylotic myelopathy that went on to surgery were identified and included in the study. Patients were excluded who were less than 18 years old, were having revision surgery, and any patient who lacked baseline preoperative data. All patients were treated at the same tertiary university based spine center by four different spine surgeons. Patients were seen and PROMIS, NDI, and mJOA measurements were collected preoperatively and during initial postoperative follow up in the first 6 months. Data from the mentioned outcome measures was extracted from a central Redcap database. Correlations between NDI, mJOA and PROMIS were quantified using Pearson correlation coefficient measurements. Two tailed student's T-tests were used to demonstrate correlation significance with alpha set at 0.05.

Results: All 60 (100%) of patients completed baseline preoperative questionnaires. 55 (92%) of patients completed all questionnaires during initial follow up in the first 6 months. PROMIS, mJOA and NDI scores all improved significantly from preoperative assessment to initial follow up (Table 1). PROMIS physical function and NDI demonstrated a strong negative correlation at baseline and in initial follow up (R=-0.69, -0.76) (Table 2). PROMIS and mJOA demonstrated a strong positive correlation at baseline and in initial follow-up (R=0.61, 0.72). Students T-test demonstrated a P value of <0.0001 for all Pearson correlation calculations.

Conclusions: PROMIS physical function scores have a strong negative correlation with NDI scores both at baseline and in the early postoperative course in patients undergoing surgery for cervical myelopathy. PROMIS physical function scores have a strong positive correlation with mJOA scores both at baseline and in the early postoperative course in patients undergoing surgery for cervical myelopathy. Surgeons may factor these outcomes into the delivery and interpretation of patient reported outcome measures in patients with cervical myelopathy, both at baseline and in the postoperative course. Use of PROMIS physical function assessments for this patient population may improve completion of outcome measures in the office and reduce administrative burden while still providing reliable outcomes data.

Table 1. Outcomes Data

Event	n	PROMIS PF	NDI	mJOA
Baseline	60 (100%)	36.11	40.42	12.28
Follow-up	55 (92%)	38.41	28.91	13.62
P value		0.006	<0.0001	0.002

PROMIS PF=Patient Reported Outcomes Measurement Information System Physical Function, NDI=Neck Disability Index, mJOA=Modified Japanese Orthopedic Association score

Table 2. Correlation Data

	NDI+PROMIS PF		mJOA+PROMIS PF	
	Baseline	**Follow-up**	**Baseline**	**Follow-up**
R	-0.69	-0.76	0.61	0.72
R squared	0.48	0.58	0.37	0.51
95% interval	(-0.82 / -0.50)	(-0.86 / -0.61)	(0.36 / 0.78)	(0.53 / 0.84)
P value	<.0001	<.0001	<.0001	<.0001

PROMIS PF=Patient Reported Outcomes Measurement Information System Physical Function, NDI=Neck Disability Index, mJOA=Modified Japanese Orthopedic Association score

See Disclosure Index pages 41–95.

PROMIS Physical Function and Pain Correlation with NDI and VAS in the Surgical Patient Population with Cervical Disc Herniations and Cervical Radiculopathy

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Background Context: Legacy patient reported outcome measures such as NDI (Neck Disability Index) and VAS (Visual Analog Score) have become essential for analyzing treatments in orthopedic spine surgery for cervical disc herniations with radiculopathy. Despite their usefulness, significant administrative burdens impose limits on completion of such measures. The Patient Reported Outcomes Measurement Information System (PROMIS) developed a patient outcome measure based on Item Response Theory in order to improve reporting of patient symptoms and function and to reduce administrative burden and improve reliability. Despite early positive results of PROMIS in orthopedic specialties including spine, NDI and VAS scores have not been compared with PROMIS in patients with cervical disc herniations with radiculopathy. The aim of this study is to compare NDI and VAS with PROMIS physical function and pain respectively in to determine their correlations in a surgical patient population longitudinally.

Methods: 65 patients with a primary diagnosis of cervical disc herniation with radiculopathy that went on to surgery were identified and included in the study. All patients were treated at the same tertiary university based spine center by four different spine surgeons. Patients were seen and PROMIS, NDI, and VAS scores were collected preoperatively and at two postoperative time points (initial follow up at 1-4 months, 6 months). Correlations between NDI, VAS and PROMIS were quantified using Pearson correlation coefficient measurements. Two tailed student's T-tests were used to demonstrate correlation significance with alpha set at 0.05.

Results: All 65 (100%) of patients completed all baseline preoperative questionnaires (Table 1). 47 (72%) of patients completed all questionnaires at the 1–4 month follow up. 21 (32%) of patients completed questionnaires at 6 month follow up. PROMIS physical function and NDI demonstrated a strong negative longitudinal correlation, with Pearson r values of (-0.82, -0.79, -0.82) at baseline, initial follow up and 6 months respectively (Table 2). PROMIS pain and VAS neck pain demonstrated a moderately positive correlation, with Pearson r values of (0.52, 0.59, 0.76) at baseline, initial follow up and 6 months. PROMIS pain and VAS arm pain demonstrated a weak positive correlation, with Pearson r values of (0.49, 0.57, 0.54) at baseline, initial follow up and 6 months. Students T-test showed a P value of <0.0001 for all Pearson correlation calculations.

Conclusions: PROMIS physical function scores have a strong negative correlation with NDI scores at baseline and in the postoperative course in patients undergoing surgery for cervical disc herniations with radiculopathy. PROMIS pain scores have a moderate positive correlation VAS neck pain and a weak positive correlation with VAS arm pain scores at baseline and in the postoperative course. Surgeons may factor these outcomes into the delivery and interpretation of patient reported outcome measures in patients with cervical disc herniations with radiculopathy. Use of PROMIS physical function for this patient population may improve completion of outcome measures in the office and reduce administrative burden while still providing reliable outcomes data, while use of PROMIS pain scores may not represent a consistent reliable alternative for pain assessment in this patient population.

Table 1. Outcomes Data

Event	n	PROMIS PF	NDI	VAS neck	VAS arm
Baseline	65 (100%)	39.66	40.27	5.42	4.72
1-4 mo	47 (72%)	44.07	25.03	2.45	1.83
6 mo	21 (32%)	45.66	28.84	2.67	1.52

PROMIS PF=Patient Reported Outcomes Measurement Information System Physical Function, NDI=Neck Disability Index, VAS=visual analog scale

Table 2. Correlation Data

	PROMIS PF+VAS arm			PROMS PF+VAS neck			PROMIS PF+NDI		
	Baseline	**1-4 mo**	**6 mo**	**Baseline**	**1-4 mo**	**6 mo**	**Baseline**	**1-4 mo**	**6 mo**
R	0.48	0.57	0.54	0.52	0.59	0.75	-0.82	-0.79	-0.81
R squared	0.23	0.32	0.29	0.27	0.34	0.57	0.67	0.63	0.67
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

PROMIS PF=Patient Reported Outcomes Measurement Information System Physical Function, NDI=Neck Disability Index, VAS=visual analog scale

See Disclosure Index pages 41–95.

Are Patients Who Undergo Multi-Level Anterior Cervical Discectomy and Fusion at a Higher Risk of Developing Adjacent Segment Degeneration Compared to Single-Level Procedures?

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Introduction: Historically, some have proposed that fusion of cervical spinal segments led to excessive stress on the unfused adjacent levels; instigating or exacerbating the pathologic process of adjacent segment disease (ASD). Furthermore, others have proposed that a longer fusion in the setting of an anterior cervical discectomy and fusion may result in elevated risks of ASD. We sought to compare the rates of radiographic ASD as well as the sagittal alignment parameters in patients who underwent multi-level versus single-level ACDF.

Methods: A retrospective cohort analysis was performed on patients who underwent a single-level or multi-level ACDF by one of two senior surgeons between 2008 and 2015 for cervical radiculopathy or myelopathy. The number/location of levels fused was recorded and radiographs were reviewed preoperatively, immediately postoperative, and at final follow up. Radiographic diagnosis of ASD was determined by the presence of disc space narrowing>50%, new or enlarged osteophytes, endplate sclerosis, and/or increased calcification of the anterior longitudinal ligament (ALL). The sagittal parameters measured included change in C2-C7 lordosis, T1 angle, levels fused, sagittal vertical axis (SVA), fusion mass lordosis, proximal and distal adjacent segment lordosis. Appropriate statistical tests were performed to calculate relationships between the variables and the development of ASD.

Results: Of the 404 that underwent an ACDF with a minimum of 6 months follow-up (average 21 months), 130 underwent a single-level procedure, while 192 underwent a 2-level procedure, and 82 underwent a 3-4 level surgery. There was no significant difference in the rate of radiographic ASD overall (single-level 26.2%; 2-levels 25.5% p=0.863; 3–4 levels 24.4%, p=0.903), or in the proximal or distal adjacent segments on multivariate analysis (Table 1). Secondarily, the multi-level fusions appear to restore significantly greater amounts of lordosis compared to single-level procedures (single-level 1.2±8.4 degrees; 2-levels 2.9±7.2 degrees p=0.025; 3–4 levels 6.4±8.5; p<0.001), and are able to maintain the corrected cervical lordosis and fusion segment lordosis over time (Table 2). Additionally, from the immediate post-operative period to final follow-up, the single-level ACDFs show continuing lordosis improvement (single-level 2.8±5.0 degrees; 2-levels 2.4±5.5 degrees p=0.025; 3–4 levels -0.1±5.1; p=0.005) that is significantly greater than that of the multi-level constructs. Re-operation rates were low in all groups (single-level 4.6%; 2-levels 4.2% p=0.898; 3–4 levels 6.1%, p=0.757), with no significant differences were observed.

Conclusions: At just under 2 years after an ACDF, patient who underwent multi-level procedures may not be at a significantly greater risk of developing radiographic evidence of ASD compared to those who underwent a single-level procedure. Additionally, multi-level fusions appear to restore significantly greater amounts of lordosis compared to single-level procedures. Although all constructs appear to maintain the corrected cervical lordosis and fusion segment lordosis over time, the single-level ACDFs show significantly greater amounts of lordosis improvement compared to the multi-level constructs over time.

Table 1. Multivariate analysis of ASD and reoperation rates (one level used as reference)

					Two levels*		3–4 Levels*	
	One level	**Two Levels**	**3–4 Levels**	**All patients**	OR	p-value	OR	p-value
Overall ASD	26.2%	25.5%	24.4%	25.5%	1.0	0.863	1	0.903
Proximal	10.8%	17.7%	17.1%	15.4%	1.9	0.074	1.8	0.172
Distal	6.9%	11.5%	11.0%	9.9%	1.8	0.18	1.4	0.525
Reoperations	4.6%	4.2%	6.1%	4.7%	0.9	0.898	1.2	0.757

See Disclosure Index pages 41–95.

Table 2. Multivariate analysis for change in parameters at different time points

	One level	Two Levels	3–4 Levels	All patients	Two levels*		3-4 Levels*	
					Beta	p-value	Beta	p-value
Change Preoperative to Postoperative								
Lordosis (deg)	1.2+8.4	2.9 +7.2	6.4+8.5	3.1+8.1	**2.2**	**0.025**	**5.4**	**<0.001**
SVA (mm)	1.5+7.0	2.8+7.4	3.0+9.6	2.4+7.8	1.2	0.212	0.9	0.485
Fusion seg lordosis (deg)	4.3+4.9	6.6+6.2	9.2+8.1	6.4+6.5	**3.0**	**<0.001**	**5.6**	**<0.001**
T1 slope (deg)	0.3+4.8	2.7+5.2	4.6+6.4	2.2+5.5	**2.5**	**0.006**	**4.0**	**0.001**
Proximal lordosis (deg)	-0.5+3.7	-0.2+4.0	-0.8+4.2	-0.4+4.0	0.1	0.816	-0.6	0.327
Distal lordosis (deg)	-1.3 +3.8	-0.8+5.0	-2.1+2.9	-1.2+4.3	0.3	0.621	-1.1	0.207
Change Postoperative to Final								
Lordosis (deg)	2.8+5.9	1.4+5.5	-0.1+5.1	1.5+5.6	**-1.5**	**0.025**	**-2.3**	**0.005**
SVA (mm)	-2.2+7.5	-3.6+7.4	-2.0+6.3	-2.8+7.3	-1.6	0.051	-0.7	0.546
Fusion seg lordosis (deg)	-0.3+3.6	-0.6+3.5	-0.9+4.3	-0.6+3.7	-0.2	0.693	-0.3	0.630
T1 slope (deg)	1.5+4.2	-1.2+6.6	-0.2+4.8	-0.1+5.7	**-2.6**	**0.006**	-1.6	0.200
Proximal lordosis (deg)	0.5+4.1	1.3+3.7	0.9+3.3	1.0+3.8	**0.9**	**0.039**	0.7	0.192
Distal lordosis (deg)	1.3+4.2	1.2+3.7	-0.1+3.5	1.0+3.9	-0.1	0.921	-1.3	0.098
Change Preoperative to Final								
Lordosis (deg)	3.9+8.0	4.4+7.6	6.4+7.8	4.7+7.8	1.0	0.292	**3.6**	**0.003**
SVA (mm)	-0.3+7.7	-0.6+7.9	0.5+8.7	-0.3+8.0	-0.7	0.486	-0.7	0.549
Fusion seg lordosis (deg)	4.1+5.4	6.0+6.3	8.2+8.5	5.8+6.7	**2.8**	**<0.001**	**5.4**	**<0.001**
T1 slope (deg)	2.3+4.5	1.8+7.6	3.2+7.9	2.2+6.8	-0.8	0.507	0.7	0.674
Proximal lordosis (deg)	0.2+4.7	1.2+4.3	0.0+4.8	0.6+4.6	1.0	0.076	0.0	0.950
Distal lordosis (deg)	0.2+4.1	-0.1+4.5	-2.2+4.5	-0.3+4.4	-0.4	0.526	**-2.6**	**0.003**

*One level ACDF used as reference

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. 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: 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 were 105 months (minimum 60 months) on average. We divided those 17 patients into two groups whether C2 was included in the range of fixation. We evaluated their neurological status and radiographic findings retrospectively.

Results: There were nine cases whose range of fixation was from C2 to C7 (Th1) (L group) and eight cases whose range of fixation was below C3 to lower (S group). All C2 anchors in L group were performed at least one pedicle screw fixation. 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 recovery rate was 40% in the L group and 39% in the S group at a year follow-up, and was 24% in the L group and 35% in the S group at final follow-up. Both groups showed relatively good surgical outcome at a year follow-up, however L group showed deterioration of the neurological symptom at midterm follow-up. The data of the C2-7 angle and CGH-C7 SVA (center of the gravity of the head to C7 sagittal vertical axis) showed slightly increase of kyphosis in the S group, whereas no progression of kyphosis was seen in the L group at the final follow-up. The range of motion at the maximal spinal cord compression level controlled during the follow-up period in both groups.

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Conclusion: Relatively good surgical outcome could be obtained by posterior decompression with instrumented fusion for patients with K-line (-)-type cervical OPLL. The addition of posterior instrumented fusion eliminated the dynamic factor and preserved local stabilization in both two groups. Instrumented fusion from C2 to C7(Th1) with C2 pedicle screw fixation preserved the cervical sagittal balance and prevented the progression of cervical kyphosis in L group, whereas slight progression of cervical kyphosis was observed in S group. C2 pedicle screw fixation is the strong anchor for preserving the cervical sagittal alignment with PDF.

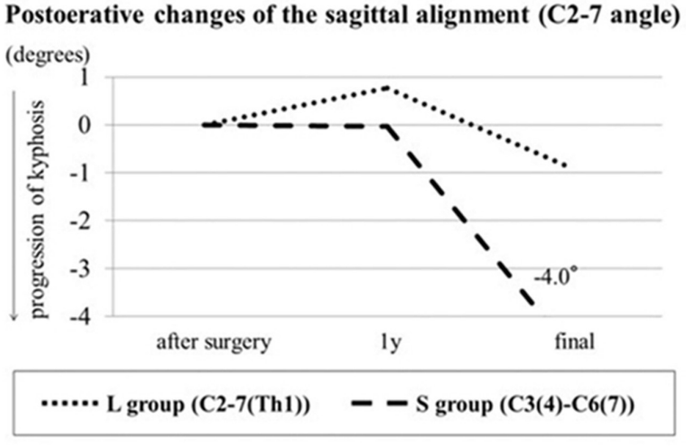

Fig. 1

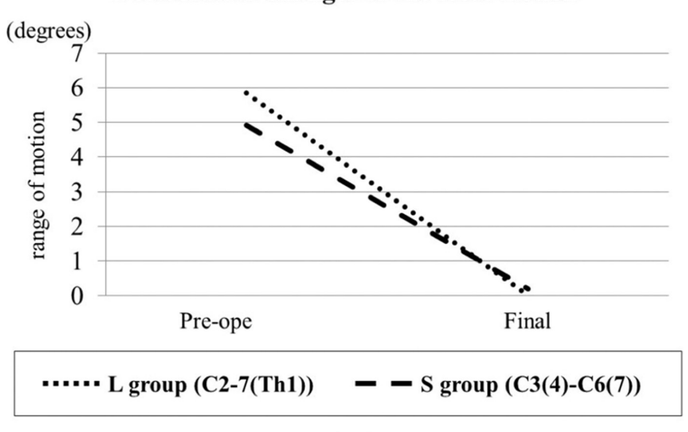

Fig. 2

Do Cervical Surgeries for Degenerative Pathologies Generate Sagittal Deformity?

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Introduction: Patients with degenerative pathologies of the cervical spine commonly undergo fusions to address their neck pain and neurologic compression. Sagittal deformity of the cervical spine is associated with increased pain and disability. It is unclear how and when cervical deformities can be generated from commonplace degenerative cervical surgeries. This study aims to examine regional and segmental alignment changes within fused and adjacent segments after short- and long-segment cervical fusions for degenerative pathologies.

Materials / Methods: This study is a retrospective analysis of a prospectively collected database of full-body standing stereoradiographs. Patients were included if they underwent a cervical fusion procedure and had pre- and post-operative radiographic imaging with at least 3 months follow-up. Patients' records were examined for number of levels fused (1–2 or 3–4 levels) and approach (anterior or posterior). Radiographs were analyzed for cervical deformity measurements (regional / segmental lordosis deficits, T1-Slope minus Cervical Lordosis (TS-CL) mismatch). Lordosis deficit was defined as the difference between regional and segmental postoperative lordosis and the accepted normative values. An identical subanalysis was performed on patients with baseline deformities (cSVA>4 cm, TS-CL>20°).

Results: Radiographs from 37 patients were analyzed (mean age: 53.2 years, 48.6% female). The mean number of levels fused was 2.4. All patients showed significant CL correction at follow-up, (-6.11° to -11.2°, p=0.001) and the proportion of TS-CL mismatch patients (TS-CL>20) decreased (52.8% vs. 22.9%, p=0.040). The greatest improvements in segmental lordosis deficit occurred at levels C4-C5 (Δ3.4°, p<0.001) and C5-C6 (Δ2.2°, p=0.011). No change in lordosis at unfused levels was observed at follow-up. In comparing 1-2 and 3-4 level fusions, longer fusions resulted in greater lordosis deficits (5.4° vs. 3.1°, p=0.017). 37% of patients with normative baseline radiographic alignment exhibited cervical deformity postoperatively. Of these patients whose cervical surgery resulted in a postoperative deformity, 38.5% had significant postoperative forward alignment as defined by cSVA>4 cm and had significantly less postoperative lordosis (-2.80 vs. -11.82, p=0.040) than patients who did not exhibit post-operative deformity.

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Conclusion: All fusions resulted in an improvement in cervical lordosis, but longer fusions resulted in greater lordosis deficits, and many non-CD patients at baseline developed CD postoperatively. These results highlight a pressing need for an increased intraoperative focus on maintaining spinal alignment during cervical fusions, particularly when performed on 3 or more levels. Cervical fusion procedures for degenerative pathologies may not create enough lordosis to allow for ideal cervical curvature, and can generate fixed sagittal deformity.

Table 1: Comparison of 1–2 and 3–4 level fusions

	1-2 Level Fusion	3-4 Level Fusion	P-Value
Pre-op C2-C7 lordosis	-10.64±11.2	1.538±21.6	**0.035****
Post-op C2-C7 lordosis	-14.22±10.8	-5.380±10.1	**0.021****
Post-op C2-7 Lordosis Deficit	-3.052±2.33	-5.400±3.24	**0.017****
Proportion of pts with Post-op TS-CL>20	26.1%	16.7%	0.429
Proportion of pts with Pre-Op cSVA>4cm	13.6%	23.1%	0.392
Proportion of pts with Post-Op cSVA>4cm	13.0%	15.4%	0.605

Cervical Spondylolisthesis Is a Risk Factor for Poor Clinical Outcome After Selective Laminectomy

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Introduction: Selective laminectomy (SL) that allows maximum preservation of cervical extensor muscles has been performed for cervical myelopathy. However, there are no studies analyzing risks associated with poor outcomes after SL. We investigated clinical and radiological outcomes of SL and analyzed associated risk factors.

Materials / Methods: We included a total of 162 patients who were treated at our institute from 2006 to 2012, with a minimum 2-year-follow-up. Recovery rate predefined by the Japan Orthopedic Society (JOA) score was adopted for clinical assessment. Pre- and post-operative C2–C7 angle, cervical range of motion (ROM), sagittal vertical axis (SVA), T1 slope, local kyphosis, and spondylolisthesis (vertebral slip >3.5 mm on lateral x-ray) were measured for radiological studies; their impact on clinical results was examined. Sex, age, ossification of the posterior longitudinal ligament (OPLL) presence and decompressed laminae number were also studied. Patients were divided into two groups based on JOA recovery rates. Group A [patients with postoperative recovery rate>50% (n=78)] and group B [patients with recovery rate<50% (n=84)]. These factors were investigated as risk factors associated with poor outcomes after SL. Student's test and multiple logistic regression analysis were used for statistical analysis and $p<0.05$ was considered as significant.

Results: The average preoperative and postoperative JOA scores were 11.1±2.6 and 13.6±1.74, respectively, with a JOA recovery rate of 40.6±20.1% ($p<0.01$). Multivariate analysis identified preoperative cervical spondylolisthesis (odds ratio: 3.599; 95% confidence interval: 1.440–8.997; $p=0.004$) as an independent risk factor for poor clinical results following SL. There were no significant differences in the other factors (Tables 1 and 2).

Conclusion: Previous studies have reported various potential risk factors that may affect outcomes after conventional laminoplasty, including the age of patients, presence of diabetes, severity of preoperative myelopathy, length of preoperative symptoms, presence of OPLL, number of levels with compression, alignment of the cervical spine, and presence of signal changes in the spinal cord on MRI. In this study, we analyzed these factors and identified preoperative cervical spondylolisthesis as the significant prognostic indicator via multivariate logistic regression analyses. Several studies recently reported that cervical spondylolisthesis may be more common than previously believed and could affect clinical symptoms due to the instability. There have been few studies that revealed the surgical indication for cervical myelopathy with spondylolisthesis. This study illustrated that the correction and fixation of slip should be considered for myelopathic patients with horizontal displacement exceeding 3.5 mm.

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Table 1. Comparison of perioperative characteristics between two groups based on clinical outcomes following selective laminectomy

Potential Risk Factors	Group A: Good outcome(n=78) JOA 50%≦	Group B: Poor outcome(n=84) JOA 50%>	P value
Sex			0.22
Man	58 (74.4%)	55 (65.5%)	
Woman	20 (25.6%)	29 (34.5%)	
Age (years)	64.5 ± 11.3	63.1 ± 11.6	0.44
Follow-up period (months)	36.4 ± 14.2	38.6 ± 13.9	0.33
Decompressed laminae number (n)	2.6 ± 0.86	2.7 ± 0.96	0.39
Diabetes	7 (9.0%)	9 (10.7%)	0.71
Preoperative JOA (pts)	11.2 ± 28.2	11.1 ± 23.4	0.77
Duration of symptoms (months)	37.3 ± 46.9	47.6 ± 50.0	0.26
C2–C7 angle (°)			
neutral	13.2 ± 12.4	14.9 ± 13.9	0.42
flexion	-6.5 ± 13.8	-7.7 ± 12.8	0.59
extension	26.1 ± 11.7	29.7 ± 13.4	0.07
Cervical ROM(°)	32.2 ± 13.8	37.4 ± 13.5	0.017*
SVA (mm)	25.8 ± 14.4	22.7 ± 13.6	0.17
T1 slope (mm)	25.6 ± 9.0	23.5 ± 8.6	0.13
Presence of kyphosis	25 (32.1%)	17 (20.2%)	0.086
Presence of spondylosisthesis	7 (9.0%)	22 (26.2%)	0.004*
Presence of high intensity on MRI T2W	69 (88.5%)	70 (83.3%)	0.47
Presence of OPLL	27 (34.6%)	38 (45.2%)	0.17

SL: Selective Laminectomy, JOA: Japanese Orthopedic Association, ROM: Range of Motion, SVA: Sagittal Vertical Axis, OPLL: Ossification of the Posterior Longitudinal Ligament,

"Numerical variables have been expressed as mean±standard deviationor number (proportion)" * statistically significant

Table 2. Multivariate Poisson regression results showing the risk factor of poor clinical results following selective laminectomy

Potential Risk Factors	OR	95%CI	P value
Cervical ROM(°)	1.021	0.996–1.046	0.065
Presence of spondylosisthesis	3.599	1.440–8.997	0.004*

SL: Selective Laminectomy, ROM: Range of Motion, OR: Odds Ratio, CI: Confidence Interval, * statistical significance

The Effect of Uncinate Process Resection on Subsidence Following Anterior Cervical Discectomy and Fusion

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Introduction: Subsidence is a frequent complication of anterior cervical discectomy and fusion (ACDF). Postoperative segmental micro-motion, thought to be a causative factor of subsidence, has been speculated to increase with uncinate process resection area (UPR). (Figure 1) To evaluate the effect of UPR on micro-motion, we designed a method to measure UPR area based on pre- and postoperative CT images and analyzed the relationship between UPR and subsidence as a proxy of micro-motion.

Materials / Methods: We retrospectively collected clinical and radiological data from January 2011 to June 2016. All procedures included bilateral UPR and anterior plate fixation. UPR area was evaluated with reformatted coronal computer tomography images. To reduce level-related bias, we converted UPR area to the proportion of UPR to the pre-operative UP area (pUPR). (Figure 2) Subsidence was defined as a total intervertebral height (TIH) decrease ≥ 3 mm into the adjacent vertebral body.

Results: In total, 38 patients (53 segments) were included in this study. Segments were divided into two groups: subsidence (group S; n = 18) and non-subsidence (group N; n = 35) (Table 1). No significant differences in age, sex, diabetes mellitus (DM) status, body mass index (BMI), or history of smoking were observed between the groups. Subsidence was positively correlated with right-side pUPR, left-side pUPR, and the sum of bilateral pUPR (sum pUPR) (R= 0.310, 301, 364; p=0.024, 0.029, 0.007, respectively.). Multiple linear regression analysis revealed that subsidence could be estimated with the following formula: subsidence = 1.522 + 2.7 * sum pUPR (R^2=0.133, p=0.007). ROC analysis determined that sum pUPR ≥ 0.38 could serve as a threshold for significantly increased risk of subsidence (p=0.005, AUC=0.737, sensitivity=94%, specificity=51%). This threshold was confirmed by logistic regression analysis for subsidence (p=0.009, OR=8.471) Psuedarthrosis occurred in eight patients (15.1%) and there was no difference in pseudarthrosis incidence according to subsidence.

Conclusions: The UPR measurement method confirmed that UPR was correlated with subsidence. Particularly when sum pUPR exceeded 0.38, the possibility of subsidence increased.

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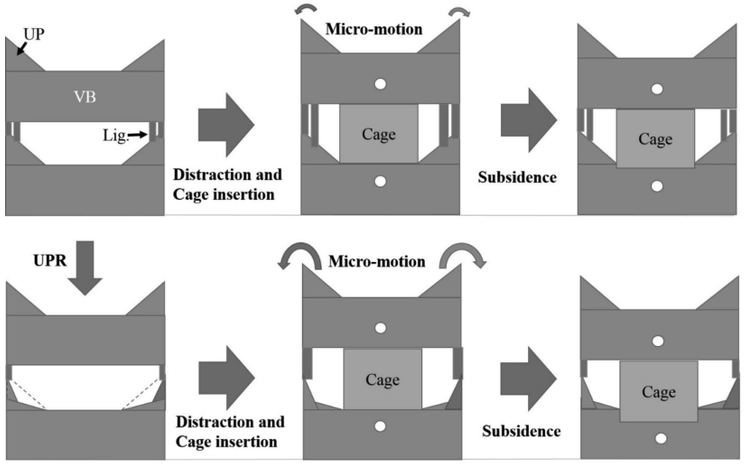

Fig. 1 Scheme illustrating the proposed relationship between uncinated process resection (UPR) and subsidence during anterior cervical discectomy and fusion (ACDF).

The upper line demonstrates ACDF without UPR. Because of the intact uncovertebral joint, the segment achieves rigid stability. The lower line demonstrates ACDF with UPR. Through the disruption of bony structures and ligaments, UPR causes more micro-motion, which leads to the increase of subsidence. UP: uncinated process; VB: vertebral body; Lig: ligaments surrounding uncovertebral joints

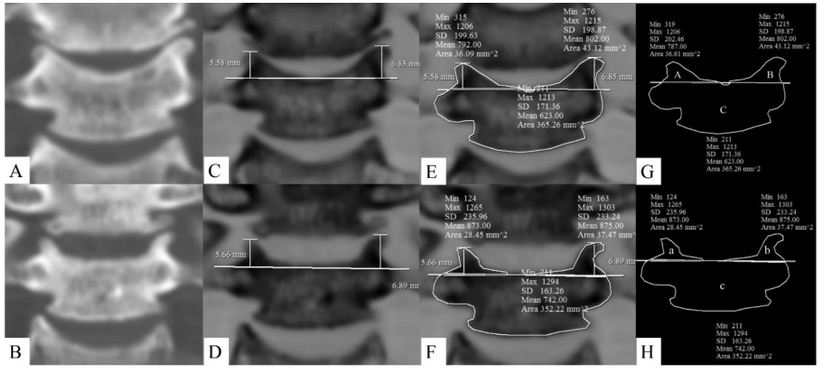

Fig. 2 Area measurements (uncinate process and vertebral body) a: Pre-operative (op), b: post-op coronal reformatted CT image at C5/6. c, d: The images are inverted. The base of the post-op UP was defined as a line connecting two points at the pre-op UP height. e, f: Measurements of bilateral UPs and VB. g, h: Schema of the UP and VB. A = Pre-op right (Rt) UP, B = pre-op left (Lt) UP, C = pre-op VB; a = post-op Rt UP, b = post-op Rt UP, c = post-op VB. Rt pUPR = 1-a/A, the difference in VB = C-c. UP: uncinate process; VB: vertebral body; pUPR: proportion of UPR to pre-UP

Preoperative Mental Health May Not Be Predictive of Improvements in Patient Reported Outcomes Following an Anterior Cervical Discectomy and Fusion

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Introduction: Prior studies have correlated preoperative depression and poor mental health with inferior patient-reported outcomes following lumbar spinal procedures. However, literature regarding the effect of mental health on outcomes following cervical surgery is limited. As such, the purpose of this study is to test for association of preoperative Short Form-12 (SF-12) Mental Health Composite Score (MCS) with improvements in Neck Disability Index (NDI) and neck and arm pain following an anterior cervical discectomy and fusion (ACDF).

Materials / Methods: A prospectively maintained surgical database of patients who underwent a primary, one- to two-level ACDF during 2014–2015 was reviewed. Patients were excluded if they did not have complete patient-reported outcome data for the preoperative or 6-week, 12-week, or 6-month postoperative visits. At baseline, preoperative SF-12 MCS was tested for association with preoperative NDI, neck Visual Analog Scale (VAS), and arm VAS. Preoperative MCS was then tested for association with change in NDI, change in neck VAS, and change in arm VAS from the preoperative visit to postoperative visits. These tests were conducted using multivariate regression controlling for baseline characteristics as well as for the preoperative score for the patient-reported outcome being assessed.

Results: A total of 40 patients were included in the analysis. At baseline, higher preoperative MCS was negatively associated with lower preoperative NDI (Coefficient: -0.73, p=0.001), but not preoperative neck VAS (-0.03, p=0.325), or preoperative arm VAS (-0.05, p=0.138). Additionally, there was no association between preoperative MCS and improvement in NDI, neck VAS, or arm VAS at any of the postoperative time points (6-week, 12-week, 6-month, p>0.05 for each, Table 1). The percent of patients achieving a minimum clinically important difference at 6 months did not differ between the bottom and top MCS halves (p>0.05 for each; Table 2).

Conclusions: The results of this study suggest that better preoperative mental health is associated with lower perceived preoperative disability, but is not associated with severity of preoperative neck or arm pain. In contrast to other studies, the present study was unable to demonstrate that preoperative mental health is predictive of improvement in patient reported outcomes at any postoperative time point following an ACDF.

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Table 1. Preoperative Mental Health Score association with patient reported outcome measures

ACDF Mental Health	Mean±SD	Change±SD	Coefficient±SE	95% CI	†p-value*
NDI					
Preoperative	45.7±18.3	--	--	--	--
6-week	36.8±19.4	-8.9±18.2	0.00±0.25	-0.51-0.51	0.988
12-week	31.2±22.6	-14.5±19.6	-0.06±0.27	-0.63-0.48	0.786
6-month	27.5±24.1	-18.2±22.3	-0.09±0.30	-0.70-0.52	0.772
VAS Neck					
Preoperative	6.1±2.8	--	--	--	--
6-week	3.4±2.6	-2.7±2.6	-0.04±0.03	-0.10-0.03	0.232
12-week	3.6±2.9	-2.5±3.0	-0.02±0.03	-0.05-0.10	0.533
6-month	3.2±3.0	-3.0±3.4	0.04±0.04	-0.03-0.11	0.285
VAS Arm					
Preoperative	6.1±2.6	--	--	--	--
6-week	2.5±2.2	-3.6±2.8	-0.05±0.03	-0.10-0.01	0.075
12-week	2.6±2.7	-3.5±3.1	-0.02±0.03	-0.08-0.03	0.401
6-month	2.7±2.5	-3.4±3.3	0.00±0.03	-0.06-0.07	0.919

SD=Standard Deviation; VAS=Visual Analog Scale; NDI=Neck Disability Index
*__Boldface__ indicates statistical significance
†p-values calculated using multivariate regression controlling for age, gender, smoking status, BMI category, CCI, number of levels, and preoperative outcome value

Table 2. Percent of patients who achieved minimum clinically important difference by MCS quartile

	Bottom Half (N=20)	Top Half (N=20)	†p-value
NDI (n)	55.0% (11)	55.0% (11)	1.000
VAS Neck (n)	55.0% (11)	50.0% (10)	0.752
VAS Arm (n)	35.0% (7)	45.0% (9)	0.519

MCS=Mental Component Score; VAS=Visual Analog Scale; NDI=Neck Disability Index
†p-values calculated using multivariate regression controlling for age, gender, smoking status, BMI category, CCI, and preoperative outcome value

Effects of Crooked Anterior Cervical Plates on Clinical Outcomes

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Introduction: Anterior cervical plates are used in anterior cervical discectomy and fusion (ACDF) for symptomatic cervical disc pathologies. Angulation and lateral displacement of plates (crooked plates) from the midline have been noticed in postoperative x-rays; however, the clinical relevance of these crooked plates is unknown. The purpose of the study was to determine the effects of angulated and/or laterally displaced anterior cervical plates on clinical outcomes after anterior cervical discectomy and fusion (ACDF).

Materials/Methods: Prospectively collected ACDFs between 2014 and 2016 as part of a multicenter IDE trial. Study sample n=69. In immediate postoperative anteroposterior (AP) radiographs: an angle formed between the vertical line drawn between caudal and cephalad cervical spinous processes and another parallel line drawn to angulated plate axis was determined as plate angulation. A straight horizontal line was drawn from mid-point of the plate to the vertical spinous processes line to determine the lateral displacement (right or left) of plate. The percentage of displacement to the width of the vertebrae was calculated as (plate lateral displacement distance/width of the vertebrae) × 100. Clinical outcomes at 6-month follow-up were measured using Neck Disability Index (NDI) scores, and neck, left and right visual analog scales (VAS). Patients with angulation ≥8 degrees were placed in one group and<8 degrees in another. Patients with≥10% lateral displacement in one group and<10% in placed in another group. Clinical outcomes were compared in the groups using ANOVA test; $p<0.05$ was considered statistically significant.

Results: In the study, patients (n=69) with a mean age of 48 years were included. All plates were medial to the uncus.The mean angulation of the plates was 3.9 degrees (0–13 degrees) and the mean lateral displacement from the midline was 12.3% (0–58%). No statistical difference was noticed between angulation groups (<8 vs. ≥8) for clinical outcomes (NDI=22 v.s 26; Neck=2.3 vs. 1.3, respectively); the preop and 6- month postoperative difference was NDI=Δ 25 vs. Δ 27 and Neck VAS=Δ 4.2 vs. Δ 4.1, respectively. For plate displacement groups, no statistical significant difference was noticed (<10% vs. ≥10%) for clinical outcomes (NDI=18 vs. 27; Neck=1.8 vs. 2.9) and differences were NDI=Δ 27 vs. Δ 35 and Neck VAS=Δ 4.4 vs. Δ 6.4, respectively.

See Disclosure Index pages 41–95.

Conclusions: All ACDF patients had positive clinical outcomes irrespective of plate angulation and lateral displacement. Our displacement mean values were small; therefore, it is possible that the study may have been unable to determine the cutoff values for plate angulation and displacement for negative clinical outcomes. Further studies are needed to determine if these results are valid for more extreme angulations and displacements of anterior cervical plates.

The Effect of Age on Baseline SWAL-QOL Scores

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Introduction: The SWAL-QOL survey is a widely used, 13-section instrument to assess dysphagia and quality of life. In spine surgery, the SWAL-QOL is frequently used to assess changes in swallowing function following anterior cervical procedures. However, baseline SWAL-QOL variations by age have not been previously described. The purpose of this study is to assess variations in SWAL-QOL scores across age groups.

Materials / Methods: Retrospective cohort analysis of a prospectively maintained surgical database of patients undergoing cervical spine surgery between 2014–2016. Patients were stratified by age in to one of four cohorts: <40 years, 40–49 years, 50–59 years, and ≥60 years. A scaled SWAL-QOL score was calculated by adding the total number of points scored for each section, and dividing by the total possible points for that section, as well as for the test as a whole. A secondary analysis was completed omitting question 9 and 13, as both assess general health not related to swallowing function.

Results: A total of 79 patients who completed a SWAL-QOL survey prior to undergoing cervical spine surgery were included in this analysis, of which 11 (13.92%) were <40 years old, 25 (31.65%) were 40-49, 31 (39.24%) were 50-59, and 12 (15.19%) were ≥60. The average scaled score for all patients was 92.2±6.0, with a minimum score of 62.3 and a maximum of 100. Two patients (2.53%) achieved scores of 100, while 27 (34.18%) achieved scores over 95. No significant difference in total scaled SWAL-QOL score, or the scaled score for any individual section, was demonstrated across age cohorts (Table 1). The secondary analysis demonstrated a mean score of 96.8±5.3, with a minimum score of 68 and a maximum of 100. Twenty-four (34.18%) patients achieved scores of 100, while 63 (78.48%) achieved scores over 95. No significant difference in scores between age groups was demonstrated in the secondary analysis.

Conclusions: The results of this study suggest baseline dysphagia levels as assessed by SWAL-QOL in patients undergoing cervical spine surgery are not affected by patient age. As such, a preoperative scaled score of 92.2 may be considered normal for patients of all ages. Additionally, the total scaled score is significantly affected by questions 9 and 13 that assess general health and not swallowing. Thus, the SWAL-QOL may be adjusted to remove those questions in order to better assess pure swallowing ability and its effect on quality of life, with a scaled average of 96.8 across all age cohorts.

See Disclosure Index pages 41–95.

Table 1. Mean swallowing score by age group

	Age <40 (n=11)	Age 40-49 (n=25)	Age 50-59 (n=31)	Age ≥60 (n=12)	†p-value*
Total score (Mean±SD)	91.6±4.9	93.1±5.0	91.1±7.6	93.7±4.0	0.484
Section 1	94.5±12.1	98.4±6.2	96.1±9.5	98.3±3.9	0.524
Section 2	94.5±11.2	94.7±10.9	93.9±11.5	97.0±3.5	0.862
Section 3	95.6±6.6	94.5±8.4	91.9±10.5	91.0±9.7	0.479
Section 4	97.3±9.0	96.0±8.7	92.9±12.2	96.7±7.8	0.491
Section 5	100.0±0.0	98.4±3.7	94.8±12.3	100.0±0.0	0.128
Section 6	98.6±4.5	98.8±3.6	96.9±7.0	97.9±3.3	0.587
Section 7	97.5±7.2	97.9±6.0	97.8±9.6	100.0±0.0	0.648
Section 8	99.6±1.2	98.7±5.6	96.3±12.3	99.0±3.5	0.570
Section 9	61.5±19.2	69.4±24.1	68.6±23.1	74.3±21.8	0.601
Section 11	94.5±9.3	98.4±8.0	98.1±7.9	100.0±0.0	0.368
Section 12	100.0±0.0	96.8±11.1	98.7±5.0	98.3±5.8	0.653
Section 13	65.5±18.0	70.4±18.4	67.7±17.6	71.7±19.9	0.812

***Boldface** indicates statistical significance
†p-value calculated using ANOVA

Timing of Complications Following Posterior Cervical Fusion

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Background: Understanding the expected timing of postoperative complications facilitates early diagnosis of potential adverse events and is important for optimizing postoperative care. Though studies have examined the incidence of complications after posterior cervical fusion, no study has characterized the timing of these complications.

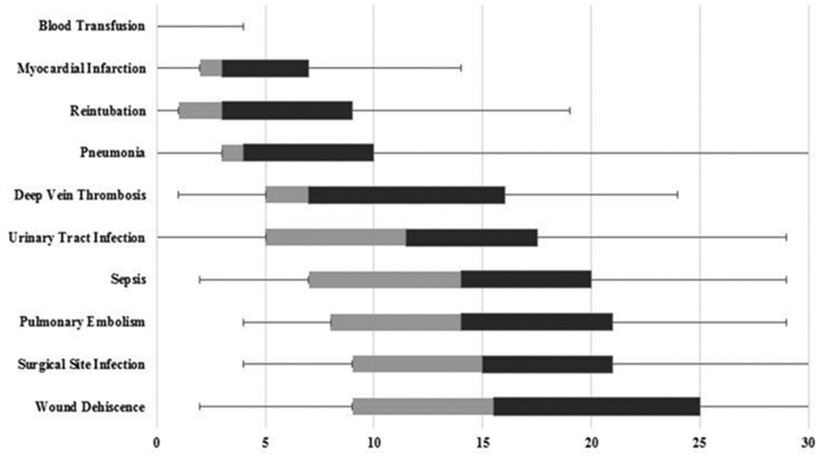
Methods: Patient data in the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) dataset with a primary CPT code 22600, corresponding to posterior cervical fusion, was analyzed for demographics, comorbidities, and ten specific complications. Complication timing was assessed, and univariate analysis was performed to investigate the relationship of patient demographic and clinical variables on the development of postoperative complications.

Results: A total of 2,517 patients with a mean age of 59.3±12.5 met inclusion criteria. The overall complication rate was 12.4%. The median day of diagnosis and interquartile range for each complication was: blood transfusion (0.0, 0–0), myocardial infarction (3, 2–7), reintubation (3, 1–9), pneumonia (4, 3–10), deep venous thrombosis (7, 5–16), urinary tract infection (11.5, 5–17.5), sepsis (14, 7–20), pulmonary embolism (14, 8–21), surgical site infection (15, 9–21), and wound dehiscence (15.5, 9–25) (Figure 1). Less than 50% deep venous thromboses were diagnosed before discharge, and less than 30% of pulmonary emboli were diagnosed before discharge (Figure 2). On univariate analysis, increased age, decreased functional status, fusing more than one level, current smoker status, diabetes, and CHF were associated with increased complications.

Conclusions: This timing data is useful to the practicing spine surgeon as it provides a guide for when to expect and investigate for specific complications after posterior cervical procedures. It may aid in the early diagnosis of complications and may also assist in healthcare reimbursement negotiations by providing data regarding the rate and timing of complications following posterior cervical fusion.

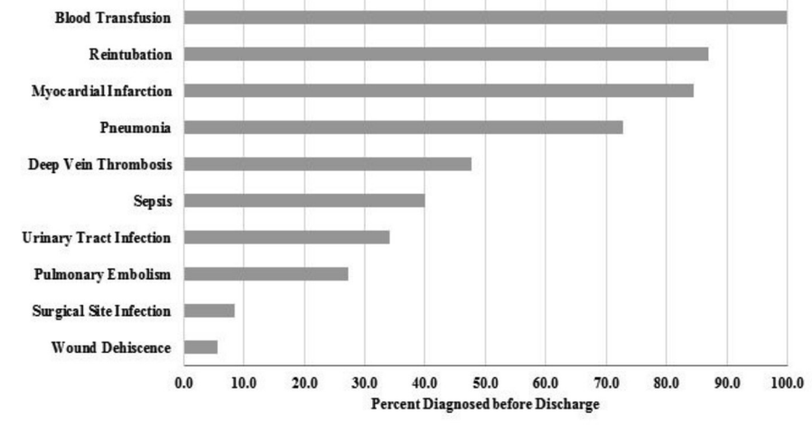
See Disclosure Index pages 41–95.

Figure 1. Complication Timing within 30 days of PCF



The light boxes represent the second quartile, the dark boxes represent the third quartile, and the line separating them represents the median number of days to diagnosis of the complication. The error bars represent the range.

Figure 2. Complications Diagnosed before Discharge



Cervical Spinal Cord Impairment Associated with Neck Flexion in Posterior Cervical Decompression

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Introduction: Many hospitals perform intraoperative monitoring of the spinal cord using transcranial electrical motor evoked potentials (TCE-MEP) and have reported their utility. Then the intraoperative monitoring (IOM) can prevent intraoperative neural damage. However, some unexplained postoperative paralyses have been reported in the cervical spine surgery. We experienced several cases of intraoperative monitoring warnings because of neck flexion in posterior cervical procedure. In this study, we investigated to evaluate preoperative factors in patients with spinal cord disorder due to flexion of the neck during posterior cervical spine surgery by changes in waveforms in IOM.

Materials / Methods: A retrospective analysis of prospectively collected data of 179 consecutive patients who underwent IOM using TCE-MEP and transcranial electrical stimulated spinal cord evoked potential (TCE-SCEP) during posterior cervical spine surgery for compression myelopathy such as cervical spondylotic myelopathy CSM and OPLL. When warning alarms were set off by amplitude changes in the period between skin incision and exposure of the lamina, the neck position was changed from flexion to neutral, and patients whose electrical potentials were recovered by a change in cervical position were placed in the flexion-induced potential reduction group. We analyzed to extract risk factors for flexion-induced reduction in potentials.

Results: After excluding some patients, 156 patients were analyzed in this study. A warning alarm went off in 7 patients (4.5%) at the time of posterior cervical spine exposure. However, by changing their neck position from flexion to neutral, the electrical potentials recovered in all patients, with no postoperative adverse events such as paralysis (flexion-induced potential reduction group) and the remaining 148 patients were used as controls. Under the most compressed level, the occupancy of the anterior element, kyphotic angle in flexion, and the range of motion from the neutral to flexion position were significantly associated with flexion-induced reduction in TCE-MEP.

Furthermore, logistic regression analysis was performed to identify the risk factors affecting the reduction of TCE-MEP. The two factors that were significantly associated with the risk of reduction of TCE-MEP were the occupying rate of anterior compression component at the most compressed level and Kyphotic angle in the flexion position of anterior compression component at the most compressed level.

Conclusions: In posterior cervical decompression, 7 (4.5%) patients had changes in monitored electrical potentials apparently because of overflexion of the cervical spine. Our findings suggest a large anterior compression element and large kyphotic angle in neck flexion under the most compressed level would be risk factors for intraoperative spinal cord impairment. Intraoperative neurophysiological monitoring with appropriate neck position can make surgery safer by preventing spinal cord dysfunction associated with the position of the cervical spine.

See Disclosure Index pages 41–95.

Comparison of Outcomes of Open Door Laminoplasty and Muscle Preserving Selective Laminectomy for Cervical Spondylotic Myelopathy in Young Adults

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Introduction: Efficacy of laminoplasty in elderly patients with cervical spondylotic myelopathy (CSM) has been widely reported. However, very few studies have shown outcomes of posterior decompression for CSM in young adults. The purpose of this study was to compare surgical outcomes in young adults between open door laminoplasty and muscle-preserving selective laminectomy using operating microscope.

Methods: This is a retrospective study. Total 1,227 patients who received posterior decompression for CSM from 2012 to 2014 in 17 affiliated hospitals were reviewed. After applying inclusion criteria (CSM, age at surgery <45 years and with minimum of 2 years follow-up), 18 patients (17 males and 1 female) were included in open door laminoplasty group (O group) and 16 patients (10 males and 6 females) in muscle-preserving selective laminectomy group (S group). Age at surgery, numbers of decompressed levels, operating time, blood loss, Japanese Orthopedic Association (JOA) score, imaging parameters in plain radiographs and perioperative complications were evaluated. A comparison of each independent variable between O and S groups was performed using Mann-Whitney U-test and a comparison of preoperative and postoperative imaging parameters in each group was performed using a paired t-test. Differences were considered significant at $p<0.05$.

Results: Age at surgery was 38.8 and 38.8, number of decompressed levels was 3.5 and 3.2, JOA score (preop./final follow up/change/recovery rate) was 12.0/14.7/2.8/57.3% and 12.5/15.4/3.0/61.8% in O and S group respectively. There were no significant differences in these parameters between the two groups. In S group, operating time was longer without significant difference (115 mins vs. 128 mins; P=0.09) but blood loss was significantly smaller (103ml vs. 15ml; P=0.01). Although there were no significant intergroup differences or significant postoperative changes in imaging parameters (preop./final follow up/change) including C2-7 SVA (21.4/21.5/+0.2 vs. 19.8/18.1/-1.6), C2-7 lordotic angle (4.4/4.8/+0.5 vs. 2.5/5.4/2.8) and C2-7 ROM (44.6/37.5/-6.8(90.8%) vs. 36.0/39.1/+3.2(123.0%)), C2-7 lordotic angle and C2-7 ROM increased postoperatively in S group. C5 palsy was not observed in both groups and extradural hematoma was observed in one case in O group.

Conclusions: Operative procedure under operating microscope in selective laminectomy could take longer operating time but reduce blood loss. JOA recovery rate, alignment and ROM of cervical spine were well maintained in both groups at minimum of 2 years postoperatively and these techniques would be therefore safe and reliable treatment for CSM in young adults. QOL and VAS for numbness and neck pain, which should have significant impact on returning to jobs in young adults, were not assessed in this study and a larger number of patients and longer follow-up are required to evaluate the result that C2-7 lordotic angle and C 2-7 ROM increased postoperatively in S group.

See Disclosure Index pages 41–95.

Inpatient Pain Among Worker's and Non-Worker's Compensation Patients Following Anterior Cervical Discectomy and Fusion

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Introduction: Current literature demonstrates varying clinical outcomes between worker's compensation (WC) and non-worker's compensation (NWC) populations following anterior cervical discectomy and fusion (ACDF). The purpose of this study is to identify the differences in inpatient pain scores between WC and NWC populations following an ACDF.

Materials / Methods: A retrospective cohort analysis of a prospectively maintained surgical database was conducted of patients who underwent a primary, one or two-level, ACDF for degenerative spinal pathology between 2010 and 2015 by a single surgeon. Patients were stratified by insurance payer status and assessed with regards to demographics and preoperative characteristics using a chi-squared test and Student's t-test for categorical and continuous variables, respectively. Peri- and postoperative outcomes were compared using Poisson regression with robust error variance or linear regression adjusted for patient demographics and preoperative characteristics.

Results: A total of 250 patients were included in this analysis, of which 165 (66.0%) possessed NWC payer status and 85 (34.0%) possessed WC payer status. The WC cohort was younger (46.3 vs. 51.1, p<0.001), and had a greater percentage of male (67.1% vs. 50.9%, p=0.015) smokers (29.4% vs. 17.0%, p=0.023) (Table 1). The WC cohort reported greater average hourly inpatient pain on POD 0 (5.8 vs. 4.9, p=0.002) and pain at 6- and 12-weeks (6-weeks: 4.1 vs. 3.4, p=0.015; 12-weeks: 3.7 vs. 2.5, p=0.003) compared to the NWC cohort (Table 2). Additionally, the WC cohort experienced less improvement in pain at the 6- and 12-week postoperative visits (6-weeks: -2.3 vs. -3.1, p=0.015; 12-weeks: -2.7 vs. -3.9, p=0.003) (Table 2). The remainder perioperative outcomes including hourly narcotic consumption were no different between cohorts.

Conclusions: The results of this study suggest that WC patients report greater pain in the immediate postoperative period and at follow-up following an ACDF. These findings are consistent with current literature demonstrating worse outcomes in WC patients. Further studies are required to determine the reason for the increased reported pain in the WC population and whether these findings are demonstrated long-term.

Table 1. Baseline characteristics.*

	Non-Worker's Compensation (N=165)	Worker's Compensation (N=85)	p-value
Age (Mean±SD, years)	**51.1±10.0**	**46.3±8.5**	**<0.001**
Sex (n)			**0.015**
Female	**49.1% (81)**	**32.9% (28)**	
Male	**50.9% (84)**	**67.1% (57)**	
Smoking status (n)			**0.023**
Non-smoker	**83.0% (137)**	**70.6% (60)**	
Smoker	**17.0% (28)**	**29.4% (25)**	
Operative Level (n)			0.885
1-level	53.7% (87)	51.8% (44)	
2-level	47.3% (78)	48.2% (41)	
Comorbidity burden (CCI)	3.0±1.7	2.7±1.4	0.088
Preoperative VAS (Mean±SD)	6.5±2.1	6.4±1.9	0.698

SD=Standard Deviation; CCI=Charlson Comorbidity Index; VAS=Visual Analog Scale
*__Boldface__ indicates statistical significance

See Disclosure Index pages 41–95.

Table 2. Outcomes.*

	Non-Worker's Compensation (N=165)	Worker's Compensation (N=85)	†p-value
Operative Time (min)	53.6±16.3	58.3±19.3	0.164
Estimated Blood Loss (mL)	43.4±19.9	47.1±27.7	0.676
Length of Hospital Stay (hours)	31.7±19.3	35.4±15.8	0.252
Discharge Day (n)			0.613
POD 0	74.6% (123)	70.6% (60)	
POD 1	25.5% (42)	29.4% (25)	
Inpatient VAS Pain Scores (Mean±SD)			
POD 0	**4.9±1.7**	**5.8±1.6**	**0.002**
POD 1	4.2±1.7	4.8±1.7	0.119
Hourly OME Consumption (Mean±SD)			
POD 0	3.3±2.4	3.8±2.7	0.169
POD 1	1.8±1.4	2.2±1.4	0.581
Visual Analogue Scale (Mean±SD)			
6-week VAS	**3.4±3.1**	**4.1±2.3**	**0.015**
12-week VAS	**2.5±2.6**	**3.7±2.7**	**0.003**
6-month VAS	2.4±2.7	2.8±2.8	0.438
Change in VAS (Mean±SD) Δ			
ΔVAS at 6-weeks	**-3.1±3.2**	**-2.3±2.6**	**0.015**
ΔVAS at 12-weeks	**-3.9±2.9**	**-2.7±3.0**	**0.003**
ΔVAS at 6-months	-4.0±3.1	-3.6±2.9	0.438

*__Boldface__ indicates statistical significance
† P-values calculated using Poisson regression with robust error variance adjusted for age, gender, smoking status, number of levels, BMI category, CCI, preoperative VAS, operative time, EBL, and operative level
Δ Change in VAS=Postoperative VAS (6 weeks, 12 weeks or 6 months) – Preoperative VAS

Cervical Disc Arthroplasty: Do Conflicts of Interest Influence the Outcome of Clinical Studies?

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Introduction: Cervical disc arthroplasty (CDA) is an emerging technique for the treatment of cervical degenerative disease. Multiple studies have investigated the outcomes of CDA, particularly in comparison to cervical arthrodesis techniques such as anterior cervical discectomy and fusion (ACDF). As many entities have financial interests in CDA implants, it is imperative to consider the influence of conflicts of interest on the results of studies investigating the efficacy of CDA. Therefore, the purpose of this study was to determine if there is an association between the presence of conflicts of interest amongst study authors and the reported outcome of studies involving CDA.

Methods: PUBMED and MEDLINE databases were searched for articles presenting clinical, radiographic, and cost outcomes of CDA. Data extracted from each article included: title, authors, publication year, level of evidence, prosthesis type, number of operative levels, presence of conflicts of interest, and outcome. Conflicts of interest were determined by the presence of any conflicts for any author within manuscript disclosure sections or through open payments reporting. Outcomes of each study were graded as either favorable, unfavorable, or equivocal. The presence of conflicts of interest was tested for an association with the level of evidence and study outcome using Pearson's chi-square analysis, Fisher's exact test, or logistic regression for categorical variables.

Results: 98 articles were included in this analysis. In total, 44.9% (44) of articles had the presence of a conflict of interest, while 55.1% (54) of articles did not (Table 1). Conflicted studies were more likely to present level I evidence and less likely to present level IV evidence than non-conflicted studies ($p<0.001$). Furthermore, conflicted studies were more likely to report favorable outcomes after CDA than non-conflicted studies (Table 2, 90.9% vs. 74.1%, $p=0.040$).

Conclusions: The results of this study suggest that the majority of conflicted and non-conflicted studies report favorable results in patients undergoing CDA. However, conflicted studies were also more likely to report favorable outcomes compared to non-conflicted studies. Individual clinicians must critically review published studies for potential conflicts of interest before incorporating CDA into their practice.

See Disclosure Index pages 41–95.

Table 1. Summary of Conflicts of Interest

	(N=98)
Conflicted by Disclosures (n)	
Not Conflicted	55.1% (54)
Conflicted	44.9% (44)
Conflicted by Open Payment Reporting (n)*	
Not Conflicted	66.3% (65)
Conflicted	33.7% (33)
Conflict of Interest Status (n)	
Not Conflicted	55.1% (54)
Conflicted	44.9% (44)
Conflict of Interest Directly Related to the Study (n)	43.9% (43)
License or Royalties	23.5% (23)
Consultant Fees	33.7% (33)
Research Funding	37.8% (37)
Stock Ownership	15.3% (15)

*Open payments determined using data from the Centers for Medicare and Medicaid Services

Table 2. Association between study outcome and study characteristics

	Favorable (n=80)	Equivocal/Unfavorable (n=18)	Odds Ratio (95% CI)	†p-value
Conflict of Interest Status (n)				**0.040**
Not Conflicted	**74.1% (40)**	**25.9% (14)**	**Ref**	
Conflicted	**90.9% (40)**	**9.1% (4)**	**3.5 (1.06–11.56)**	
Level of Evidence (n)				**0.035**
I–II	**90.0% (45)**	**10.0% (5)**	**2.0 (0.70–5.52)**	
III–IV	**72.9% (35)**	**27.1% (13)**	**Ref**	
Number of Levels (n)				0.201
Single-Level	85.5% (53)	14.5% (9)	Ref	
Multi-Level	75.0% (27)	25.0% (9)	0.5 (0.18–1.43)	

*Level of evidence based on *Sackett et al*
†p-value calculated using logistic regression to determine odds ratio and 95% confidence intervals

See Disclosure Index pages 41–95.

Does Stopping at C7 in Long Posterior Cervical Fusion Accelerate the Symptomatic Breakdown of Cervicothoracic Junction?

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Introduction: Long posterior cervical fusion surgery (PCF) is often performed for multi-level radiculopathy, myelopathy, or severe kyphotic deformity. Since the cervicothoracic junction (CTJ) represents a unique region that shifts from the mobile lordotic cervical spine to the rigid kyphotic thoracic spine, stopping long fusion at C7 may accelerate adjacent segmental disease (ASD), thus requiring revision surgeries at the C7-T1 segment. While surgeons commonly recommend extending cervical fusion into the thoracic spine to protect the adjacent levels, we did not find any direct evidence to support this procedure. Therefore, the purpose of this study is to compare the clinical and radiological outcomes between patients with long PCF in which fusion stopped at C7 versus patients in which fusion crossed the CTJ.

Methods: We reviewed the clinical records and radiographic data of 54 consecutive PCF alone cases performed by a single surgeon. Among them, we included 38 patients with minimum 3-level PCF and at least a 2 year follow-up period. The patients were divided into 2 groups on the basis of the lowermost instrumented vertebra (LIV). C7 group patients (n=21) underwent a long fusion stopping at C7. In upper thoracic (UT) group (n=17), LIVs were T1 (n=11), T2 (n=5), or T3 (n=1). To compare the clinical outcomes, we analyzed the visual analogue scale of arm / neck pain, Japanese Orthopedic Association (JOA) score, and neck disability index (NDI). To evaluate fusion status and sagittal alignment, we also measured the following parameters: (1) pseudomotion of fused segments; (2) segmental instability or breakdown of C7-T1; (3) C2–C7 sagittal vertical axis; (4) T1 slope; and (5) C2–C7 lordosis.

Results: There were no significant differences in age, gender, or follow-up period between the two groups. Although UT patients had longer fusion levels, the fusion rates were not significantly different between the C7 and UT groups (95.2% vs. 88.2%; p=0.577) (Table 1). Arm and neck pain were similar in both groups pre- and postoperatively. Mean JOA score was significantly worse in UT group preoperatively (6.8±2.0 vs. 12.0±1.5, p<0.001), but it improved to a similar degree as the C7 group after surgery (15.4±2.1 vs. 15.2±1.4, p=0.294). Interestingly, mean postoperative NDI score in the UT group was significant worse when compared with the C7 group (9.7±4.6 vs. 14.2±3.7, p=0.006). No patient in either group had any obvious instability or disc breakdown requiring revision surgeries at caudal adjacent segments. Additionally, the radiographic parameters indicating sagittal alignment including C2–C7 sagittal vertical axis, C2–C7 lordosis and T1 slope did not show any significant differences between the groups at final follow-up (Table 2).

Conclusions: Our study demonstrates that multi-level PCF stopping at C7 does not negatively affect C7-T1 segment failure, fusion rate, neck pain, neurologic outcomes, and global sagittal alignment of the cervical spine. On the contrary, unnecessary long fusion across the CTJ is likely to deteriorate postoperative neck function (worse NDI scores). These results suggest that it is unnecessary to extend the long PCF levels caudally across the healthy CTJ for fear of development of ASD at the C7-T1 segment.

Table 1. Comparisons of demographics and union rate between the C7 and UT groups.

	C7 group (n=21)	UT group (n=17)	P-value
Age (years)	60.95±10.91	65.29±9.87	0.181
Sex (M:F)	13:8	10:7	1.000
Follow-up periods (months)	38.14±15.22	38.88±22.67	0.426
Operation levels	5.38±0.59	7.29±1.72	<0.001
Lowermost instrumented vertebra (LIV)			
C7	21		
T1		11	
T2		5	
T3		1	
Union rate (final follow-up)	95.24 % (20/21)	88.24 % (15/17)	0.577

UT, Upper thoracic; M, Male; F, Female

See Disclosure Index pages 41–95.

Table 2. Clinical and radiological outcomes between preoperative periods and final follow-up in both groups.

	C7 group (n=21)	UT group (n=17)	P-value
Neck VAS			
Preoperative	6.24±1.45	6.18±1.78	0.794
Final follow-up	1.38±1.32	2.06±1.48	0.220
Arm VAS			
Preoperative	6.48±1.44	6.65±1.32	0.816
Final follow-up	0.95±1.20	1.53±1.23	0.170
JOA score			
Preoperative	6.76±2.02	12.00±1.50	<0.001
Final follow-up	15.43±2.06	15.18±1.43	0.294
NDI			
Preoperative	22.19±5.79	22.88±3.18	0.367
Final follow-up	9.8±4.55	14.24±3.70	0.006
C2-C7 Lordosis (degree)			
Preoperative	12.95±6.11	14.82±7.06	0.601
Final follow-up	7.05±6.42	6.12±5.33	0.772
C2-C7 SVA (mm)			
Preoperative	22.95±11.14	21.04±13.57	0.399
Final follow-up	28.98±10.59	33.07±11.91	0.281
T1 Slope (degree)			
Preoperative	27.86±7.74	24.18±6.35	0.033
Final follow-up	22.71±9.08	23.59±10.36	0.885

UT, Upper thoracic; VAS, Visual analogue scale; JOA, Japanese orthopedic association; retNDI, Neck disability index; SVA, Sagittal vertical axis

Rigid Cervical Plate Fixation is Associated with Greater Restoration and Maintenance of Cervical Lordosis Compared to Semi-Rigid Plate Fixation in Anterior Cervical Discectomy and Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) is one of the most common procedures in spine surgery. Both rigid and semi-rigid plates have been used to stabilize the anterior cervical spine after intervertebral graft application. No studies have compared the radiographic outcomes between rigid and semi-rigid cervical plate fixation over multiple level ACDF procedures. The goal of this study was to compare the long-term radiographic outcomes of patients treated with either rigid or semi-rigid plating modalities.

Materials / Methods: We performed a retrospective cohort analysis of patients who underwent a single-level or multi-level ACDF for cervical radiculopathy or myelopathy. All of the cases were performed by one of two senior spine surgeons in the department. Patients were excluded from analysis if they were under 18 years of age at the time of surgery, had postoperative follow up less than 1 year or had an ACDF for cervical spine fracture or infection. Radiographic assessments included: C2-C7 lordosis, T1 angle, levels fused, sagittal vertical axis (SVA), fusion mass lordosis, proximal and distal adjacent segment lordosis, adjacent segment degeneration (ASD), and fusion. Appropriate statistical tests were performed to calculate relationships between the variables and the radiographic outcomes.

Results: There were a total of 404 patients who met our inclusion and exclusion criteria. 257 patients underwent semi-rigid plating and 147 patients underwent rigid plating. Regarding demographic variables, there were statistically significantly higher proportions of smokers (24.1% vs. 10.9%; p=0.001) in the semi-rigid plating group relative to the rigid group. Both plating systems successfully restore cervical lordosis with an ACDF, without significant changes in the SVA. On multivariate analysis, rigid plate fixation was associated with greater change in pre-operative to post-operative overall lordosis compared to semi-rigid plating (4.5±8.6 degrees vs. 2.5±7.6 degrees; p=0.046) (Table 1). Similarly, rigid plating was associated with greater change in pre-operative to post-operative fusion segment lordosis compared to semi-rigid plate fixation (8.2±7.2 degrees vs. 5.4±5.8 degrees; p=0.002). Rigid plate fixation also maintained fusion segment lordosis from the immediate post-operative period to final follow-up better than semirigid plating (7.2±7.4 degrees vs. 5.0±6.2; p=0.014). There were no significant differences in radiographic ASD (rigid 23.1% vs. semi-rigid 26.9%; p=0.525) or reoperation rates (rigid 6.8% vs. semi-rigid 3.5%; p=0.134) (Table 2).

See Disclosure Index pages 41–95.

Conclusions: Rigid and semi-rigid plating are appropriate treatment options for patients undergoing ACDF for degenerative cervical pathology. Rigid plate fixation provides greater restoration and maintenance of cervical lordosis and fusion segment lordosis compared semi-rigid plating. Radiographic evidence of ASD is present in approximately a quarter of both groups, however re-operation rates are low.

Table 1. Change in parameters at different time points

				Bivariate		Multivariate	
	Semi-rigid	**Rigid**	**All patients**	Beta	p-value	Beta	p-value
Change Preoperative to Postoperative							
Lordosis (deg)	2.5±7.6	4.5±8.6	3.1±8.1	**2.3**	**0.009**	**1.8**	**0.046**
SVA (mm)	2.2±7.1	2.8±8.8	2.4±7.8	0.6	0.472	0.8	0.353
Fusion segment lordosis (deg)	5.4±5.8	8.2±7.2	6.4±6.5	**2.7**	**<0.001**	**2.1**	**0.002**
T1 slope (deg)	1.8±5.0	2.7±6.1	2.2±5.5	0.9	0.264	0.3	0.698
Proximal lordosis (deg)	-0.2±4.1	-0.8±3.6	-0.4±4.0	-0.6	0.171	-0.50	0.239
Distal lordosis (deg)	-1.0±4.3	-1.7±4.2	-1.2±1.8	-0.8	0.19	-0.60	0.326
Change Postoperative to Final							
Lordosis (deg)	2.1±5.7	0.6±5.3	1.5±5.6	-1.5	0.011	-1.20	0.037
SVA (mm)	-3.0±7.3	-2.5±7.3	-2.8±7.3	0.4	0.566	0.00	0.974
Fusion segment lordosis (deg)	-0.4±3.7	-0.8±3.6	-0.6±3.7	-0.4	0.268	-0.30	0.491
T1 slope (deg)	-0.4±6.5	0.3±4.6	-0.1±5.7	0.7	0.406	0.9	0.314
Proximal lordosis (deg)	1.0±3.8	0.9±3.6	1.0±3.8	-0.1	0.732	-0.20	0.599
Distal lordosis (deg)	0.9±3.9	1.3±4.0	1.0±3.9	0.4	0.459	0.4	0.470
Change Preoperative to Final							
Lordosis (deg)	4.5±7.8	5.1±7.8	4.7±7.8	0.6	0.485	0.2	0.740
SVA (mm)	-0.6±7.2	0.3±9.2	-0.3±8.0	0.9	0.327	0.7	0.457
Fusion segment lordosis (deg)	5.0±6.2	7.2±7.4	5.8±6.7	**2.2**	**0.002**	**1.7**	**0.014**
T1±slope (deg)	2.1±7.5	2.4±5.6	2.2±6.8	0.3	0.755	0.3	0.791
Proximal lordosis (deg)	0.9±4.7	0.1±4.3	0.6±4.6	-0.7	0.13	-0.8	0.101
Distal lordosis (deg)	-0.1+4.4	-0.7±4.4	-0.3±4.4	-0.7	0.276	0.37	0.541

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

Table 2. Comparison of ASD and reoperation rat es (Semi-rigid used as reference)

				Bivariate		Multivariate	
	Semirigid	**Rigid**	**All patients**	OR	p-value	OR	p-value
Overall ASD	26.9%	23.1%	25.5%	0.8	0.41	0.9	0.525
Proximal	14.8%	16.3%	15.4%	1.1	0.679	1.2	0.611
Distal	9.0%	11.6%	9.9%	1.3	0.398	1.4	0.301
Reoperations	3.5%	6.8%	4.7%	2.0	0.138	2.1	0.134

See Disclosure Index pages 41–95.

Post-Operative Functional Prognosis and Life Expectancy of Severe Myelopathy Patients (Ranawat IIIB) by RA Cervical Spine

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Introduction: The functional outcomes of surgery in the non-ambulant severe myelopathy patients due to RA cervical spine (Ranawat IIIB) have been reported to be poor. However, without any surgical backup those severely damaged RA patients won't survive with further progress of disabilities in ADL. Therefore, we need to clarify the surgical prognosis and postoperative life expectancy of severe myelopathy patients caused by RA cervical spine.

Methods: A total of 55 patients (51 females, 4 males; mean age 66.8 years), who underwent surgery for cervical lesion of RA and followed more than 3 years or until their deceases (average 6.1 years, range 0.8–9.0 years), were included. We assessed their neurological status with Ranawat classification and judged their mobilization capacities, whether bedridden or not. Age at the surgery, duration of RA, existence of vertical subluxation, history of biological agents use and perioperative complication were also assessed to determine the prognostic factors of surgical treatment for RA cervical myelopathy. Postoperative prognosis was investigated by Kaplan-Meier analysis. Log-rank tests and logistic regression analysis were performed for prognostic factor analysis.

Results: The study population consisted of 33 patients with Ranawat II-IIIA and 22 with IIIB, and included 16 bedridden patients preoperatively. Thirteen patients (two with Ranawat II-IIIA and eleven with IIIB) died during the follow-up. The average age of death was 77.8 years old and the average duration of postoperative survival was 3.8 years. The survival rate (SR) at 5 years after surgery and median life expectancy (LE) of preoperative IIIB patients was 57.4% and 9.0 years, which were significantly lower and shorter than preoperative II-IIIA patients (97.0% and over 10 years) ($p<0.01$). No significant improvement was seen in Ranawat classification during follow-up; the number of IIIB patients decreased from 22 to 13 and II-IIIA increased from 33 to 42 ($p=0.26$). However, the number of bedridden patients was significantly decreased after surgery; eleven of 16 preoperative bedridden patients (68.8%) improved their mobilization ability to non-bedridden, while 5 patients (31.2%) remained bedridden ($p<0.05$). In 22 preoperative IIIB patients, non-bedridden patients increased from six to seventeen postoperatively. These 17 improved patients to non-bedridden status resulted in significantly higher 5 years SR (75.1%) and longer median LE (8.9 years) after the surgical treatments than bedridden patients (5 years SR: 0.0% and median LE: 2.4 years) ($p<0.01$). Logistic regression analysis revealed that postoperative bedridden was a significant risk factor for poor prognosis ($p<0.05$, odds ratio: 70.5).

Conclusion: Our results demonstrated preoperative IIIB patients had significantly poorer postoperative prognosis than II–IIIA. Therefore, earlier surgical intervention should be strongly recommended. However, 68.8% of bedridden myelopathy patients even with IIIB recovered to non-bedridden status and better postoperative prognosis and life expectancy were observed in these IIIB patients who gained non-bedridden mobilization ability postoperatively. Because of their potentiality to improve their longer LE with non-bedridden higher QOL, surgical treatments should be considered even for Ranawat IIIB patients with bedridden status.

See Disclosure Index pages 41–95.

Cervical Risk Score: Evaluating Risk in Cervical Spine Surgery

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Joseph H. Perra, MD, Minneapolis, MN

Introduction: Cervical spine surgeries are being performed on patients with an uptrend in age and burden of comorbidities. Identifying risk preoperatively is important to make informed treatment decisions and to manage patient expectations. We have developed a Cervical Risk Score (CRS) to assess a patient's overall risk for perioperative complications after elective cervical spine surgery in a retrospective cohort study.

Materials / Methods: This retrospective study is on a series of 508 consecutive patients over 18 years old undergoing elective cervical spine surgery in 2013 or 2014. It was approved by the Institutional Review Board; written informed consent was obtained from all participants. Perioperative complications are events that adversely affect the recovery of the patient requiring specific medical or surgical intervention. Exclusions are made of minor perioperative events that do not require intervention or have little prognostic significance. The CRS is composite score of patient and procedural factors. Patient factors include demographic characteristics, tobacco use, worker compensation status, diagnosis, co-morbidities, immunosuppressant use, narcotic use, prior cervical spine surgery, and if the procedure was a revision surgery. Procedural factors include surgical approach, levels, and osteotomies / corpectomies. Statistical techniques include 2-sample t-tests for continuous variables and Chi-square or Fisher's Exact test as appropriate for categorical variables. Variables with $p<0.2$ were included in a multivariate model to predict complication. The multivariate logistic regression model uses a backwards stepwise approach with exit criteria>0.1. Variables in the final iteration of the multivariate model are then assigned risk points using their odds ratios.

Results: The multivariate analysis finds that 3+ fusion levels, female sex, a preoperative history of dysphagia and co-morbid conditions including hypertension, history of thromboembolic disease, a psychiatric diagnosis and osteoporosis are all statistically significant predictors of a perioperative complication. The CRS is formulated from these predictive variables in the multivariate analysis on a weighted basis (OR<1: 0 points; OR<2: 1 point; OR≥2: 2 points). Risk score points are added for each patient according to the multivariate analysis model. One hundred thirty-nine patients (27.4%) had a CRS of 2 (the most common risk stratification). Seventy-four patients (14.6%) had a CRS of 0, and 5 patients (1.0%) had a CRS of 8, (the lowest and highest risk groups, respectively). The CRS is predictive against the actual complication rate: patients with a CRS of 0 had a complication rate of 2.7% while the patients in the 6+ CRS group had a complication rate of 50%.

Conclusion: The CRS can be used to determine risk for perioperative complications following elective cervical spine surgery. When a patient presents, non-modifiable patient factors can be used to calculate the majority of the patient's individual CRS. The number of fusion levels is the one surgical variable that can be modified to adjust a patient's overall CRS. Specifically the inclusion of 3+ fusion levels had a statistically significant impact on the overall risk profile.

Quantitative and Qualitative Analyses of Spinal Canal Encroachment During Cervical Laminectomy Using the Kerrison Rongeur vs. High-Speed Burr

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Lee A. Tan, MS, New York, NY
Alexander Tuchman, MD, New York, NY
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Jamal N. Shillingford, MD, New York, NY
Hao Zhang, MD, ShenZhen, China
K. Daniel Riew, MD, New York, NY

Introduction: Cervical myelopathy is a common cause of disability that usually presents as gait imbalance, loss of manual dexterity, or less commonly, bowel and bladder dysfunction. Surgical decompression is generally recommended in patients with overt signs of myelopathy. In severe cases, iatrogenic cord injury during decompression is possible. The purpose of this study is to highlight the degree of canal encroachment when using a Kerrison rongeur or a high-speed burr during decompression of the stenotic canal, thereby demonstrating the relative risk of each method for causing iatrogenic spinal cord injury.

Methods: Study participants included three attending spine surgeons and two spine fellows. Each performed laminectomy procedures using C5 Sawbones foam models. The spinal canal was filled with modeling putty to simulate a stenotic spinal cord (Figure 1). Bilateral trough laminotomies were performed using a 1mm Kerrison, a 2mm Kerrison, and a high-speed burr (Figure 2). Piecemeal laminectomies were performed with a 2mm Kerrison. A blinded independent spine surgery fellow performed all quantitative measurements. Three independent researchers qualitatively ranked the perceived amount of "cord damage".

Results: The average canal occupying depth was 0.50mm +/- 0.45 (range, 0–1.34) for the burr, 1.37mm +/- 0.68 (range, 0.54–2.17) for the 1mm Kerrison, and 1.47mm +/- 0.37 (range, 0.92–1.96) for the 2mm Kerrison ($p=0.002$). There was a statistically significant difference between the burr and 1mm Kerrison ($p=0.01$) and between the burr and the 2mm Kerrison ($p=0.001$). There was no statistically significant difference between the 1 mm and 2mm Kerrison ($p=0.78$).

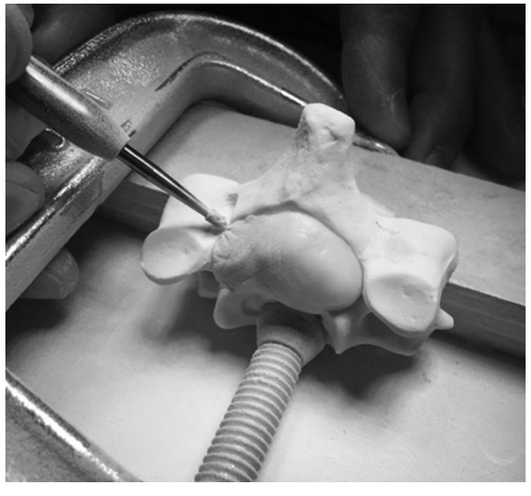
The mean rank of the burr group, the Kerrison group, and the piecemeal group were 1.41, 1.94, and 2.65, respectively, on an ordinal scale of 1 to 3.

Conclusion: When performing a trough laminotomy, the high-speed burr results in less canal encroachment compared to either a 1mm or 2mm Kerrison. In the setting of a severely stenotic spinal canal, spine surgeons should consider exclusively using the drill to perform laminectomy or laminaplasty to minimize risk of iatrogenic neurologic injury.

See Disclosure Index pages 41–95.

Figure 1.

Figure 2.



Changing Patterns in the Prevalence and Mechanisms of Injury for Cervical Spine Fractures in the United States

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Gregory W. Poorman, BA, New York, NY
Samantha R. Horn, BA, New York, NY
Bessel G. Diebo, MD, Brooklyn, NY
Shaleen Vira, MD, New York, NY
Peter Zhou, BA, Douglaston, NY
Jared C. Tishelman, New York, NY
Michael C. Gerling, MD, Brooklyn, NY

Background: Cervical spine fracture is assumed of all trauma patients until proven otherwise due to the conditions' potential for permanent disability. However, actual rates of cervical fractures have not been reported with sufficient power. Our purpose, therefore, was to describe the annual incidence of the diagnosis of cervical fracture, quantify etiology, and describe resulting cord injuries.

Methods: We performed a retrospective review of the Healthcare Cost and Utilization Project's Nationwide Inpatient Sample years 2005-2013. Included were patients diagnosed with traumatic injuries and diagnosed with fracture of any cervical vertebra. Incidence of cervical fracture, cause of injury, and spinal cord damage/neurological complications were measured. Secondary outcomes included simultaneous non-cervical fracture diagnoses and cervical level of fractures. To identify the trauma cases, we searched the NIS databases using HCUP-supplied External Sources of Injury (E-Codes). Yearly incidence of cervical trauma (ICD-9 805* and 806*) was calculated using hospital year and trend weights and by dividing the frequencies of cervical fracture by all selected injuries. Cause of injury (Falls, Motor Vehicle, Assault, etc.) was measured using concurrent E-Codes. Cord injuries, neurological complications, secondary fractures (Femur, clavicle, radius etc.), and level of the fracture were queried using ICD-9 codes and analyzed by t test.

See Disclosure Index pages 41–95.

Results:

Demographics:
463,631 patients (average age: 58.1, 60% male) sustained a traumatic cervical fracture in the NIS database from 2005 to 2013. Total numbers of trauma admission and blunt trauma resulting in cervical fracture increased between years 2005 (38,009 cervical fracture [4.4% incidence]) and 2013 (55,700 cervical fracture [5.8% incidence]), $p<0.001$. C2 (39.0%) and C7 (24.8%) were the most common levels for closed fracture. Open fracture occurred most frequently at C7 (26.0%) and C1 (24.0%). When looking at trends of the causes of cervical fractures from 2005 to 2013 there was an observed steady decline in "Car Crash" from 34% in 2005 to 25.5% in 2013, $p<0.001$. Alternatively, there was an observed increase in "Falls" and "Struck Pedestrian" as the cause for cervical fractures from 2005 to 2013; 19% to 27% and 13.5% to 18%, respectively, both $p<0.001$. In measuring spinal cord injury, incidence was 4.99% upper cervical spine cervical fractures and 6.83% in lower cervical spine fractures. 0.76% of patients were diagnosed with quadriplegia. Other fractures in patients with traumatic cervical fractures were also recorded. The most common were: 19.91% fracture or rib, sternum, larynx, or trachea; 8.89% skull; and 5.38% fracture of radius or ulna.

Conclusions: We observed there has been a steady decline in the number of patients who are suffering cervical fractures from motor vehicle accidents (8.5%). Concurrently, both falling and pedestrian-struck cervical fractures increased over the last ten years, 8% and 5.5% respectively. Further, we observed that almost 20% of patients who had fractured their cervical spine had also presented with the fracture of their rib, sternum, larynx or trachea, 9% their skull, and 5% their arm.

In Memoriam

Deceased CSRS Members

Lewis D. Anderson, MD 1999
Claude Argenson, MD 2002
Robert W. Bailey, MD 1987
Elliott E. Blinderman, MD 2002
Henry H. Bohlman, MD 2010
Mario Boni, MD 1986
Francis R. S. Boumphrey, MD 2012
Craig D. Brigham, MD 2013
José M. Casamitjana, MD 2017
David W. Cahill, MD 2003
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Jerome M. Cotler, MD 2014
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Adolphe Jung, MD 1995
Steven E. Kopits, MD 2003
S. Henry LaRocca, MD ..... date unavailable
Sanford J. Larson, MD, PhD 2012
Leroy S. Lavine, MD 2005
Alan M. Levine, MD 2009
Patrizio Parisini, MD 2009
Wesley W. Parke, PhD 2005
Lourens Penning, MD 2010
Stephen A. Pye Jr., MD 2005
Joseph Ransohoff, MD 2002
Lee H. Riley Jr., MD 2001
Hubert L. Rosomoff, MD 2008
Raymond Roy-Camille, MD 1997
Anthony Sances Jr., MD 2007
Henry H. Sherk, MD 2012
Edward H. Simmons, MD 2009
E. Shannon Stauffer, MD 2002
Henk Verbiest, MD 1997
Jose Maria Vieira, MD 2003
Thomas S. Whitecloud III, MD 2003
Eric T. Yuhl, MD 2005

IN MEMORIAM

Pledge Form

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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 41.

The CSRS does not view the existence of these disclosed interests or commitments as necessarily implying bias or decreasing the value of their participation in this activity.

We apologize for any oversight, deletion or misspelling. Any such occurrences were unintentional.

–CSRS Staff

CERVICAL SPINE RESEARCH SOCIETY

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2017 Instructional Course & Annual Meeting

DAILY SCHEDULE

DAILY SCHEDULE

Tuesday, November 28, 2017

12:00 pm – 7:00 pm	Technical Exhibit Set-up	*Grand Ballroom*
3:00 pm – 7:00 pm	Early Registration	*Grand Registration*

Wednesday, November 29, 2017 – Scheduled Meetings

12:30 pm – 6:00 pm	Board of Director's Meeting	*Room 212/213*

Wednesday, November 29, 2017 – Instructional Course

6:00 am – 7:00 pm	Registration	*Grand Registration*
6:30 am – 4:30 pm	Technical Exhibits	*Grand Ballroom*
7:00 am – 8:00 am	Continental Breakfast	*Grand Ballroom*
7:40 am – 5:00 pm	CSRS 22nd Instructional Course	*Regency Ballroom*
9:30 am – 9:50 am	Break	*Grand Ballroom*
12:00 pm – 1:00 pm	Lunch	*Grand Ballroom*
2:00 pm – 2:15 pm	Break	*Grand Ballroom*
5:00 pm – 6:00 pm	Reception	*Grand Ballroom*

Thursday, November 30, 2017 – Annual Meeting

6:00 am – 5:00 pm	Registration	*Grand Registration*
6:00 am – 6:30 pm	Technical Exhibits	*Grand Ballroom*
6:00 am – 7:30 am	Continental Breakfast	*Grand Ballroom*
6:00 am – 5:00 pm	E-Posters	*Grand Ballroom Foyer*
7:00 am – 4:30 pm	Annual Meeting Scientific Session	*Regency Ballroom*
9:05 am – 9:35 am	Break	*Grand Ballroom*
11:30 am – 1:30 pm	Industry Workshops	*Atlantic Ballrooms I, II, III and Conference Rooms 212, 216, 220*
2:31 pm – 2:51 pm	Break	*Grand Ballroom*
4:30 pm – 6:30 pm	Welcome Reception	*Grand Ballroom*

Friday, December 1, 2017 – Annual Meeting

6:00 am – 3:00 pm	Registration	*Grand Registration*
6:00 am – 1:30 pm	Technical Exhibits	*Grand Ballroom*
6:00 am – 7:30 am	Continental Breakfast	*Grand Ballroom*
6:00 am – 3:00 pm	E-Posters	*Grand Ballroom Foyer*
7:11 am – 3:11 pm	Annual Meeting Scientific Session	*Regency Ballroom*
9:06 am – 9:36 am	Break	*Grand Ballroom*
12:02 pm – 1:05 pm	Non-Member Lunch	*Grand Ballroom*
12:02 pm – 1:05 pm	Members Lunch	*Atlantic Ballroom*

Saturday, December 2, 2017 – Annual Meeting

6:00 am – 12:00 pm	Registration	*Grand Registration*
6:00 am – 3:00 pm	E-Posters	*Grand Ballroom Foyer*
6:00 am – 7:30 am	Continental Breakfast	*Atlantic Ballroom*
7:00 am – 12:11 pm	Annual Meeting Scientific Session	*Regency Ballroom*
9:45 am – 10:00 am	Break	*Grand Ballroom Foyer*
12:14 pm	Annual Meeting Adjourns	

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