44TH

FORTY-FOURTH ANNUAL MEETING

OF THE

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

December 1 – 3, 2016

Westin Harbour Castle Hotel
Toronto, Ontario, Canada

Robert F. Heary, MD, *President*
Alpesh A. Patel, MD, *Scientific Program Chair*

www.csrs.org

FUTURE INSTRUCTIONAL COURSES

Nov 29, 2017	The Diplomat, Hollywood, Florida
Dec 5, 2018	The Phoenician, Scottsdale, Arizona

FUTURE ANNUAL MEETINGS

Nov 30 – Dec 2, 2017	The Diplomat, Hollywood, Florida
Dec 6 – 8, 2018	The Phoenician, Scottsdale, Arizona

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

CONTINUING EDUCATION CREDIT

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

The American Academy of Orthopaedic Surgeons designates this live activity for a maximum of 18 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

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

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

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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Carol Swift, Society Coordinator
Lisa DuShane, Society Assistant

CSRS 2016

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

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CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

Cervical Spine Research Society

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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

2016 Officers

President	Robert F Heary, MD
Immediate Past President	Alan S. Hilibrand, MD
Past President	Bruce V. Darden II, MD
President Elect	Darrel S. Brodke, MD
Vice President	Jeffrey C. Wang, MD
Secretary	Alexander R. Vaccaro III, MD, PhD
Treasurer	Christopher I. Shaffrey, MD

2016 Committees

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Wellington K. Hsu, MD	2018
Sukvinder Kalsi-Ryan, MSc, PhD	2018
Michael P. Kelley, MD	2017
Brandon D. Lawrence, MD	2017
Kristen E. Radcliff, MD	2017
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Eric B. Laxer, MD	2016
Jeffrey A. Rihn, MD	2018
W. Ryan Spiker, MD	2018
Jim A. Youssef, MD	2018

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Jacob M. Buchowski, MD	2018
Louis G. Jenis, MD	2018
R. Alden Milam, IV, MD	2016
Brian W. Su, MD	2018

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Stanford E. Emery, MD, MBA	2018
K. Daniel Riew, MD	2016
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Alpesh A. Patel, MD, Co-Chair	2016

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Douglas G. Orndorff, MD	2017

Finance Committee

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Robert F. Heary, MD	2018
Alan S. Hilibrand, MD	2017
Christopher I. Shaffrey, MD	2017
Jeffrey C. Wang, MD	2018

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Praveen V. Mummaneni, MD	2018
Robert F. Heary, MD (ex officio)	2016

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Clifford B. Tribus, MD	2018

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Jacob M. Buchowski, MD	2018
Alexander C. Ching, MD	2017
Scott D. Daffner, MD	2018
Darren R. Lebl, MD	2016
Steven C. Ludwig, MD	2018
Mark L. Prasarn, MD	2018
Themistocles S. Protopsaltis, MD	2017
Kern Singh, MD	2018

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Neil M. Wright, MD	2016
Jim A. Youssef, MD	2016

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James S. Harrop, MD, Neuro Chair	2018
Peter G. Whang, MD	2017
Seth Zeidman, MD	2017

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Alpesh A. Patel, MD	2016
Christopher I. Shaffrey, MD	2016

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Timothy A. Moore, MD	2016
Ahmad Nassr, MD	2017

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D. Greg Anderson, MD	2016
Nitin N. Bhatia, MD	2017
Erics F. Bisson, MD	2018
Hans-Ulrich Bueff, MD	2018
Ezequiel Cassinelli, MD	2017
Clinton J. Devin, MD	2017
Mitchell B. Harris, MD	2017
Serena S. Hu, MD	2017
Brian K. Kwon, MD, PhD	2017
Joon Yung Lee, MD	2017
Praveen Mummaneni, MD	2016
Ahmad Nassr, MD	2016
Sheeraz A. Qureshi, MD, MBA	2017
Kristen E. Radcliff, MD	2016
Lee H. Riley III, MD	2018
P. Bradley Segebarth, MD	2018
Justin S. Smith, MD, PhD	2018
Leo R. Spector, MD	2017
Brian W. Su, MD	2018

Program Committee (cont.)

Robert F. Heary, MD (ex officio)	2016
Louis G. Jenis, MD (ex officio)	2017
Clifford B. Tribus, MD	2018
Jean-Paul Wolinsky, MD	2018

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John M. Rhee, MD, Chair	2016
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Avinash Patwardhan, PhD	2018
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Ivan Cheng, MD	2018
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Justin S. Smith, MD, PhD	2016

Traveling Fellowship Committee

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Michael G. Fehlings, MD, PhD	2018
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Please visit our Exhibitors in the Metropolitan Ballroom

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Thank you

*as of Oct. 25, 2016

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December 1 – 3, 2016

Westin Harbour Castle
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President:	Robert F. Heary, MD
Program Chair:	Alpesh A. Patel, MD
Local Arrangements:	Michael G. Fehlings, MD, PhD

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.

Individual Disclosures can be found on pages 39–89.

7:00 – 7:10 am	**Welcome and Announcements** Alpesh A. Patel, MD
7:11 – 7:59 am	**Session I: SURGERY TECHNIQUES I** Moderators: Erica F. Bisson, MD and Clinton J. Devin, MD
7:11 – 7:17 am Presentation #1 (pg. 92)	**Is Cervical Bracing Necessary after Single- and Multi-Level Anterior Cervical Discectomy and Fusion? A Prospective Randomized Study** **Samuel C. Overley, MD**; Robert K. Merrill, BS; Evan Baird, MD; Samuel K.W. Cho, MD; Andrew C. Hecht, MD; Sheeraz Qureshi, MD, MBA
7:18 – 7:24 am Presentation #2 (pg. 94)	**The Effect of Local vs. Intravenous Steroids on Dysphagia and Dysphonia following Anterior Cervical Discectomy and Fusion (ACDF): A Single-Blinded, Prospective, Randomized Control Trial** **Tyler J. Jenkins, MD**; Rueben Nair, MD; Brett D. Rosenthal, MD; Marco Mendoza, MD; Wellington K. Hsu, MD; Alpesh A. Patel, MD; Jason W. Savage, MD
7:25 – 7:31 am Presentation #3 (pg. 97)	**The Impact of Local Steroid Application on Dysphagia following an Anterior Cervical Discectomy and Fusion: Preliminary Results of a Prospectively, Randomized, Single Blind Trial** **Kern Singh, MD**; Dustin H. Massel, BS; Benjamin C. Mayo, BA; Junyoung Ahn, BS; Daniel D. Bohl, MD, MPH; Krishna Modi; William W. Long Jr., BA
7:32 – 7:38 am Presentation #4 (pg. 101)	**A Prospective Comparative Study in Skin Antiseptic Solutions for Posterior Spine Surgeries: Chlorhexidine-Gluconate Ethanol vs. Povidone-Iodine** **Toshitaka Yoshii, MD, PhD**; Takashi Hirai, MD, PhD; Kenichiro Sakai, MD, PhD; Atsushi Okawa; Kenichi Shinomiya, MD, PhD
7:39 – 7:45 am Presentation #5 (pg. 103)	**Prospective Study of Deep Vein Thrombosis in Patients Associated with Degenerative Cervical Spine Surgery** **Katsuhisa Yamada, MD**; Kota Suda, MD; Satoko M. Harmon, MD; Miki Komatsu, MD, PhD; Chikara Ushiku, MD; Masahiko Takahata, MD
7:46 – 7:59 am	**Discussion**
8:00 – 8:48 am	**Session II: MOTION PRESERVATION I** Moderators: Sheeraz Qureshi, MD, MBA and D. Greg Anderson, MD
8:00 – 8:06 am Presentation #6 (pg. 104)	**Long-Term Clinical Outcomes of Cervical Disc Arthroplasty: A Prospective, Randomized, Controlled Trial** **Joseph D. Smucker, MD**; Willa R. Sasso; Rick C. Sasso, MD; Maria P. Sasso
8:07 – 8:13 am Presentation #7 (pg. 105)	• **Similar Outcomes of Hybrid TDR/ACDF and Multi-Level ACDF at 5-Year Follow-up** **Glenn R. Buttermann, MD** • Synthes Prodisc, LDR Mobi-C

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8:14 – 8:20 am Presentation #8 (pg. 106)	**Prestige Cervical Disc Arthroplasty vs. Cervical Discectomy/Fusion: 84 Month IDE Outcomes of Two Level, Prospective, Randomized Clinical Trial** **Scott D. Hodges, DO**; Matthew F. Gornet, MD; Todd H. Lanman, MD; J. Kenneth Burkus, MD; Randall F. Dryer, MD; Jeffrey Ross McConnell, MD
8:21 – 8:27 am Presentation #9 (pg. 108)	**Elevated Risk for Repeated Surgery after ADR Compared to ACDF in a Cohort of 715 Patients – A Retrospective Study with Minimum Five-Year Follow-up** **Martin Skeppholm, MD, PhD**
8:28 – 8:34 am Presentation #10 (pg. 109)	**Artificial Disc Replacements Do Not Prevent Adjacent Segment Degeneration in the Cervical Spine** **Anna MacDowall, MD**; Nuno Maria Canto-Moreira, MD, PhD; Martin Skeppholm, MD, PhD; Catarina Marques, MD; Yohan Robinson, MD; Claes Olerud, MD
8:35 – 8:48 am	**Discussion**
8:49 – 9:37 am	**Session III: CERVICAL MYELOPATHY I** Moderators: Themistocles S. Protopsaltis, MD and Masatoshi Sumi, MD, PhD
8:49 – 8:55 am Presentation #11 (pg. 110)	**Tobacco Smoking and Outcomes of Decompressive Surgery in Patients with Symptomatic Degenerative Cervical Myelopathy** **Paul M. Arnold, MD**; Branko Kopjar, MD; Lindsay A. Tetreault, PhD; Hiroaki Nakashima, MD; Michael G. Fehlings, MD, PhD
8:56 – 9:02 am Presentation #12 (pg. 111)	**Comparative Effectiveness between Laminectomy with Fusion and Laminoplasty for the Treatment of Multilevel Cervical Spondylotic Myelopathy** **Colin Haines, MD**; Heath Gould, BS; Emily Hu, BA; Jacob A. Miller, BS; Roy Xiao, BA; Thomas E. Mroz, MD; Don K. Moore, MD
9:03 – 9:09 am Presentation #13 (pg. 114)	**Comparisons of Anterior and Posterior Surgery for Cervical Spondylotic Myelopathy – A Propensity Score Matched Analysis Using AOSpine CSM North America and International Database** **So Kato, MD**; Aria Nouri, MD, MSc; Dongjin Wu; Satoshi Nori, MD, PhD; Lindsay A. Tetreault, PhD; Michael G. Fehlings, MD, PhD
9:10 – 9:16 am Presentation #14 (pg. 116)	**Postoperative Walking Ability of Non-Ambulatory Cervical Myelopathy Patients** **Yoshiki Takeoka, MD**; Shuichi Kaneyama, MD, PhD; Masatoshi Sumi, MD, PhD; Koichi Kasahara, MD, PhD; Aritetsu Kanemura, MD, PhD; Masato Takabatake; Akihiro Koh, MD; Hiroaki Hirata, MD, PhD; Masanori Tsubosaka

Individual Disclosures can be found on pages 39 – 89.

9:17–9:23 am Presentation #15 (pg. 118)	**Impact of Preoperative Cervical Sagittal Balance on Surgical Treatment for Cervical Spondylotic Myelopathy Caused by Ossification of the Posterior Longitudinal Ligament** **Kenichiro Sakai, MD, PhD**; Toshitaka Yoshii, MD, PhD; Takashi Hirai, MD, PhD; Yoshiyasu Arai; Yu Matsukura, MD, PhD; Atsushi Okawa, MD, PhD
9:24–9:37 am	**Discussion**
9:38–10:03 am	**Break** Metropolitan Ballroom
10:04–10:52 am	**Session IV: HEALTHCARE ECONOMICS/VALUE I** Moderators: Serena S. Hu, MD and Mark L. Prasarn, MD
10:04–10:10 am Presentation #16 (pg. 120)	**A Health Economic and Patient-Centered Analysis on the Value of Surgery for Degenerative Cervical Myelopathy: Strong Support for Surgical Intervention** **Christopher D. Witiw, MD**; Lindsay A. Tetreault, PhD; Fabrice Smieliauskas; Branko Kopjar, MD; Eric Massicotte, MD; Michael G. Fehlings, MD, PhD
10:11–10:17 am Presentation #17 (pg. 123)	**Resource Utilization for Anterior Compared to Posterior Surgical Approaches for Cervical Spondylotic Myelopathy: An Analysis of Private Payer and Medicare Databases** **Sohrab Virk, MD**; Frank M. Phillips, MD; Safdar N. Khan, MD
10:18–10:24 am Presentation #18 (pg. 125)	**Trends in Resource Utilization and Rate of Cervical Disc Arthroplasty and Anterior Cervical Discectomy and Fusion throughout the United States from 2006 to 2013** **Comron Saifi, MD**; Arielle W. Fein, BA; Alejandro Cazzulino, BA; Alex Ha, MD; Ronald A. Lehman, MD; K. Daniel Riew, MD
10:25–10:31 am Presentation #19 (pg. 127)	**Impact of Type of Graft on Patient Reported Outcomes and Costs following Anterior Cervical Discectomy and Fusion** Silky Chotai, MD; Scott L. Parker, MD; Elliott J. Kim, MD; Ahilan Sivaganesan, MD; Matthew J. McGirt, MD; Clinton J. Devin, MD; **J. Alex Sielatycki, MD**
10:32–10:38 am Presentation #20 (pg. 128)	**Factors Associated with Financial Relationships between Spine Surgeons and Industry: An Analysis of the Open Payments Database** Joseph A. Weiner, BS; Ralph Cook, BS; Sohaib Z. Hashmi, MD; Michael S. Schallmo, BS; Danielle Chun, BA; Kathryn A. Barth, BA; Sameer K. Singh, BA; Alpesh A. Patel, MD; **Wellington K. Hsu, MD**
10:39–10:52 am	**Discussion**
10:53–11:13 am	**History of CSRS** Edward J. Dunn, MD

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11:14–11:20 am	**Introduction of CSRS President** Darrel S. Brodke, MD
11:21 am–12:00 pm	**PRESIDENTIAL ADDRESS** Robert F. Heary, MD
12:00 pm	**Adjourn**

COMPLIMENTARY WORKSHOPS

REGISTRATION REQUIRED ~ LUNCH INCLUDED

Optional Workshops – No CME Credits

12:00–3:30 pm	**Workshop 1**	**DePuy Synthes** **Biologics and Biomaterials in Cervical Spine Surgery**
	Workshop 2	**LDR, Zimmer Biomet** **Cervical Disc Arthroplasty I & Cervical Myelopathy I**
	Workshop 3	**Medtronic** **Cervical Disc Arthroplasty II**
	Workshop 4	**NuVasive** **Cervical Spinal Deformity and Complex Osteotomies**
	Workshop 5	**Globus Medical** **Cervical Myelopathy II**

4:30–6:30 pm	**Welcome Reception** Metropolitan Ballroom

Individual Disclosures can be found on pages 39–89.

7:00–7:10 am	**Welcome and Announcements** Alpesh A. Patel, MD
7:11–7:59 am	**Session V: CERVICAL DEFORMITY** Moderators: Clifford B. Tribus, MD and Jean-Paul Wolinsky, MD
7:11–7:17 am Presentation #21 (pg. 131)	**Cervical Sagittal Imbalance is Associated with a Higher Rate of Reoperation for Adjacent Segment Disease following Anterior Cervical Discectomy and Fusion** **Matthew Colman, MD**; Dustin H. Massel, BS; Benjamin C. Mayo, BA; William W. Long Jr., BA; Krishna Modi; Kern Singh, MD
7:18–7:24 am Presentation #22 (pg. 134)	**A Novel Score Predicting Spine Sagittal Imbalance Based on a Lateral Cervical Plain Radiograph** **Ezequiel Goldschmidt, MD, PhD**; Federico Angriman Sr.; Bruno Ferreyro; Nitin Agarwal, MD; Zachary J. Tempel, MD; Peter Gerszten, MD; Adam Kanter, MD; David Okonkwo, MD, PhD; Peter G. Passias, MD; Justin K. Scheer, BS; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Robert Shay Bess, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; D. Kojo Hamilton
7:25–7:31 am Presentation #23 (pg. 137)	**Relationship between T1 Slope and Cervical Alignment following Multi-Level Posterior Cervical Fusion Surgery: Impact of T1 Slope Minus Cervical Lordosis** **Seung-Jae Hyun, MD, PhD**; Kim Ki-Jeong
7:32–7:38 am Presentation #24 (pg. 138)	**Outcomes of Operative Treatment for Adult Cervical Deformity: A Prospective Multicenter Assessment with 1-Year Follow-up** **Justin S. Smith, MD, PhD**; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Gregory M. Mundis, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Brian J. Neuman, MD; Alan H. Daniels, MD; Tamir Ailon, MD, MPH; Justin K. Scheer, BS; Khaled M. Kebaish, MD; Robert A. Hart, MD; Michael F. O'Brien, MD; Douglas C. Burton, MD; Vedat Deviren, MD; Todd J. Albert, MD; K. Daniel Riew, MD; Robert Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group
7:39–7:45 am Presentation #25 (pg. 140)	**Postoperative Cervical Sagittal Realignment after Debridement and Reconstruction in Cervical Spinal Tuberculotic Kyphosis** **Kai Cao, MD, PhD**; Jiaquan Luo; Zhimin Pan, MD; Junlong Zhong; Yiwei Chen; Pingguo Duan; Li Zhiyun, MD
7:46–7:59 am	**Discussion**
8:00–8:43 am	**Session VI: TRAUMA I** Moderators: Jeffrey C. Wang, MD and Michael P. Kelly, MD

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8:00–8:06 am Presentation #26 (pg. 142)	**Management of Hangman Variant Fractures of the Axis** **Thomas E. Niemeier, MD**; Sakthivel Rajan Manoharan, MD; Steven M. Theiss, MD
8:07–8:13 am Presentation #27 (pg. 143)	**Risk Factors for Failure of Non-Operative Treatment of Unilateral Cervical Facet Fractures** **Amir Michael Abtahi, MD**; Carola F. Van Eck, MD; Mitchell Fourman, MD; Louis Alarcon, MD; William F. Donaldson III, MD; Amir Abtahi, MD; Joon Yung Lee, MD
8:14–8:20 am Presentation #28 (pg. 146)	**An Economic Case for the Surgical Treatment of Type II Odontoid Fractures in the Elderly: A Markov Cost-Utility Analysis Based on the Prospective AOSpine Geriatric Odontoid Fracture Study** **Jefferson R. Wilson, MD, PhD**; James S. Harrop, MD; Gregory D. Schroeder, MD; Alexander Vaccaro, MD, PhD; Jens R. Chapman, MD; Srinivas K. Prasad, MD; Justin S. Smith, MD, PhD; Christopher Kepler, MD; Paul M. Arnold, MD; Michael G. Fehlings, MD, PhD
8:21–8:27 am Presentation #29 (pg. 150)	**Minimally Clinical Important Difference (MCID) of a Clinical Impairment Measure Specific for Traumatic Tetraplegia: A Multi-Centre Assessment of the Grassp Version 1.0** **Sukhvinder Kalsi-Ryan, PhD**; Michael G. Fehlings, MD, PhD
8:28–8:43 am	**Discussion**
8:44–8:49 am	**Preview CSRS 2017 Annual Meeting in Hollywood, Florida** **Frank J. Eismont, MD**
8:50–8:55 am	**Preview CSRS Asia Pacific Section 2017 Annual Meeting in Kobe, Japan** **Masatoshi Sumi, MD, PhD**
8:56–9:01 am	**Preview CSRS European Section 2017 Annual Meeting in Salzburg, Austria** **Ronald HMA Bartels, MD, PhD**
9:02–9:32 am	**Break** Metropolitan Ballroom
9:33–10:35 am	**Session VII: HIGHLIGHT POSTER PRESENTATIONS** Moderators: Todd J. Albert, MD and Alexander R. Vaccaro, MD, PhD, MBA
	DIAGNOSTICS/IMAGING
9:34–9:36 am Presentation #30 (pg. 152)	**Principal Radiographic Characteristics for Cervical Spinal Deformity: A Health-Related Quality of Life Analysis** **Virginie Lafage, PhD**; Hongda Bao, MD, PhD; Jeffrey J. Varghese, BS; Renaud Lafage; Barthelemy Liabaud, MD; Bassel Diebo, MD; Subaraman Ramchandran, MBBS, MS; Louis Day; Cyrus Jalai, BA; Dana Cruz, MD; Thomas J. Errico, MD; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Aaron Buckland; Frank J. Schwab, MD

Individual Disclosures can be found on pages 39–89.

9:37 – 9:39 am Presentation #31 (pg. 154)	**Diffusion Tensor Imaging can Predict Surgical Outcomes of Patients with Cervical Compression Myelopathy** **Mitsuhiro Kitamura**; Satoshi Maki, MD; Takeo Furuya, MD, PhD; Yasushi Iijima; Junya Saito; Masashi Yamazaki, MD, PhD; Masao Koda, MD, PhD
9:40 – 9:42 am Presentation #32 (pg. 155)	**Posterior Cervical Spinal Cord Shift following Posterior Decompression and Prediction of Persistent Anterior Spinal Cord Compression using K-Plane: A Three Dimensional Modification of K-Line on MRI** **Sang-Hun Lee, MD, PhD**; Ki-Tack Kim, MD; Jung-Hee Lee, MD, PhD; Kyung-Chung Kang, MD
9:43 – 9:45 am Presentation #33 (pg. 158)	**Modular Organization of Whole-Brain Resting-State Functional Connectivity in Spinal Cord Injury: A Comparative Study** **Mayank Kaushal**; Akinwunmi Oni-Orisan, MD; Gang Chen, PhD; Wenjun Li, PhD; John Leschke; Benjamin T. Kalinosky, PhD; Matthew Budde; Brian Schmit, PhD; Vaishnavi Muqeet, MD; Shekar N. Kurpad, MD, PhD
9:46 – 9:48 am Presentation #34 (pg. 161)	**Prospective Clinical and Radiographic Assessment of the Cervical Spine in Professional Rodeo Riders after Exposure to Greater than 10G Linear Acceleration** **Jeremie Larouche, MD**; Robert Trigg McClellan, MD; Alexander Theologis, MD; Jeremy Dewitt Shaw, MD, MS; Jeffrey Mulvihill, MD; Musa Zaid, MD; Safa Herfat, PhD; Christopher Hess; Jared Narvid, MD; Alisa Gean
9:48 – 9:53 am	**Discussion**
	SURGICAL TECHNIQUES/ACD
9:54 – 9:56 am Presentation #35 (pg. 163)	**Anterior Cervical Discectomy and Fusion with Stand-Alone Peek Cages with Integrated Screws Compared to an Allograft and Plate Construct** **Grant Daniel Shifflett, MD**; Jahanzeb Kaikaus; Melissa G. Goczalk; Bryce A. Basques, MD; Philip Louie, MD; Frank M. Phillips, MD
9:57 – 9:59 am Presentation #36 (pg. 166)	**Anterior Cervical Decompression and Fusion (ACDF)–Why Do Patients Proceed to Surgery? Does it Matter? Is it Neck Pain, Arm Pain or Neurological Change that Motivates the Patient?** **Eduardo C. Beauchamp, MD**; Timothy A. Garvey, MD
Presentation #37	Withdrawn

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10:03 – 10:05 am Presentation #38 (pg. 168)	**Longitudinal Effects of Intraoperative Neurophysiological Monitoring on Costs and Clinical Outcomes for Single Level Cervical Spine Surgery** **John P. Ney, MD, MPH**; Daniel P. Kessler, PhD
10:06 – 10:08 am Presentation #39 (pg. 169)	**Surgical and Functional Outcomes after Multi-Level Cervical Fusion for Degenerative Disc Disease Compared to Fusion for Radiculopathy: A Study of Workers' Compensation Population** **Nicholas Ahn, MD**; Mhamad Faour, MD; Joshua T. Anderson, BS
10:08 – 10:13 am	**Discussion**
	HEALTHCARE ECONOMICS/VALUE
10:14 – 10:16 am Presentation #40 (pg. 171)	**An Analysis of Conflicts of Interest in Cervical Spine Surgery: The Effects of Industry Payments on Practice Patterns and Complication Rates** **Wellington K. Hsu, MD**; Ralph Cook, BS; Joseph A. Weiner, BS; Michael S. Schallmo, BS; Danielle Chun, BA; Sameer K. Singh, BA; Kathryn Barth, BA; Alpesh A. Patel, MD
10:17 – 10:19 am Presentation #41 (pg. 174)	**The Effect of Surgeon Volume on Complications, Length of Stay, and Costs following Anterior Cervical Fusion** **Bryce A. Basques, MD**; Philip Louie, MD; Grant Shifflett, MD; Dustin H. Massel, BS; Benjamin C. Mayo, BA; Daniel D. Bohl, MD, MPH; Kern Singh, MD
10:20 – 10:22 am Presentation #42 (pg. 176)	**Defining Health Utility following One- or Two-Level ACDF or CDR at Five Years** **Steve McAnany, MD**; Samuel Overley, MD; Jun Sup Kim, MD; Robert Brochin, MD; Sheeraz Qureshi, MD, MBA
10:23 – 10:25 am Presentation #43 (pg. 179)	**Patient Reported Outcomes and Costs in Revision Cervical Surgery** **Elliott J. Kim, MD;** Silky Chotai, MD; Joseph Bradley Wick, BA; David Stonko, BS, MS; Ahilan Sivaganesan, MD; Clinton J. Devin, MD
10:26 – 10:28 am Presentation #44 (pg. 184)	**Anterior Cervical Discectomy (ACDF): A More Exact, Non-Traditional Activity and Resource Cost Accounting at a University Center Shows $16,500 Cost Differential** **Barton L. Sachs, MD, MBA**; John A. Glaser, MD; Thomas S. Brehmer
10:29 – 10:34 am	**Discussion**
10:35 – 10:43 am	**Special Projects Committee Report,** Robert F. Heary, MD
10:45 – 11:50 am	**Introduction of Presidential Guest Speaker** Robert F. Heary, MD **Henry H. Bohlman Presidential Guest Lecture** Paul Deegan
11:51 am – 12:01 pm	**Discussion**

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12:02–1:05 pm	**Non-Member Lunch** Metropolitan Ballroom
12:02–1:05 pm	**Member Lunch** Queens Quay & Bay
1:06–1:44 pm	**Session VIII: BASIC SCIENCE** Moderators: Addisu Mesfin, MD and Louis G. Jenis, MD
1:07–1:13 pm Presentation #45 (pg. 185)	**Directly Reprogrammed Human Neural Precursor Cells – A Novel and Translationally Relevant Source for Cell Replacement Therapy in Spinal Cord Injury** **Narihito Nagoshi, MD, PhD**; Jan-Eric Ahlfors, BS, MBA, MSc; Mohamad Khazaei, PhD; Morio Matsumoto, MD; Masaya Nakamura, MD; Cindi Morshead; Michael G. Fehlings, MD, PhD
1:14–1:21 pm Presentation #46 (pg. 188)	**Therapeutic Impact of Human Induced Pluripotent Stem Cell Derived Neural Progenitor Cells for the Treatment of Cervical Spinal Cord Injury** **Hiroaki Nakashima, MD**; Mohammed Khazaei; Anna Badner; Jonathon Chio; James Hong, BS, PhD; Narihito Nagoshi, MD, PhD; Kajana Satkundrarajah, PhD; Christopher Ahuja, MD; Andras Nagy; Michael G. Fehlings, MD, PhD
1:22–1:28 pm Presentation #47 (pg. 190)	**Delayed Surgical Decompression for Degenerative Cervical Myelopathy Correlates with Reperfusion and Excessive Activation of the Immune System** **Pia M. Vidal, PhD**; Spyridon Karadimas, MD, PhD; Antigona Ulndreaj; Alex M. Laliberte, MSc; Lindsay A. Tetreault, PhD; Jian Wang; Michael G. Fehlings, MD, PhD
1:29–1:35 pm Presentation #48 (pg. 192)	**Time-Dependent Vascular Remodeling and Inflammation following Decompression in Cervical Myelopathy** **Wenru Yu, MD**; Anna Badner; Michael G. Fehlings, MD, PhD
1:36–1:44 pm	**Discussion**
1:45–2:30 pm	**Session IX: PATIENT REPORTED OUTCOMES** Moderators: Darrel S. Brodke, MD and Justin S. Smith MD, PhD
1:46–1:51 pm Presentation #49 (pg. 193)	**Are Patient Reported Outcomes Predictive of Patient Satisfaction Five Years after Anterior Cervical Spine Surgery?** **Gregory Schroeder, MD**; Han Jo Kim, MD; Todd J. Albert, MD; Kristen E. Radcliff, MD

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1:52–1:58 pm Presentation #50 (pg. 196)	**Diminished Mental Health Prior to Cervical Fusion Can Have a Profound Effect on Patient Derived Outcomes Depending on Presenting Diagnosis: Results of a Prospective Surgeon Driven Cervical Database at 2 Years** **Peter G. Passias, MD**; Cyrus Jalai, BA; Bassel Diebo, MD; Michael C. Gerling, MD, PhD; Gregory W. Poorman, BA; Kristen E. Radcliff, MD; Paul M. Arnold, MD, FACS; Jeffrey A. Rihn, MD; Eli M. Baron, MD; Robert E. Isaacs, MD; Paul A. Anderson, MD; Alexander Vaccaro, MD, PhD
1:59–2:05 pm Presentation #51 (pg. 198)	**Which Domains of the NDI Improve Most after Surgery for Cervical Myelopathy?** **Paul W. Millhouse, MD, MBA**; Kristen Nicholson, PhD; Emily Pflug, BS; Barrett Ivory Woods, MD; Gregory D. Schroeder, MD; D. Greg Anderson, MD; Christopher Kepler, MD; Mark F. Kurd, MD; Jeffrey A Rihn, MD; Alexander Vaccaro, MD, PhD; Alan S. Hilibrand, MD; Kristen E. Radcliff, MD
2:06–2:12 pm Presentation #52 (pg. 200)	**Concurrent Validity and Responsiveness of PROMIS Health Related Quality of Life Assessment in Patients with Cervical Spine Disease** **Richard L. Skolasky Jr., ScD**; Shalini Selvarajah MD, MPH; Brian J. Neuman, MD
2:13–2:19 pm Presentation #53 (pg. 202)	**A Comparison of Patient Centered Outcome Measures to Evaluate Dysphagia and Dysphonia after Anterior Cervical Discectomy and Fusion (ACDF)** **Alpesh A. Patel, MD**; Surabhi A. Bhatt, BS; Junyoung Ahn, BS; Jason W. Savage, MD; Wellington K. Hsu, MD; Kern Singh, MD
2:19–2:30 pm	**Discussion**
2:31–3:18 pm	**Session X: RESEARCH SESSION** John M. Rhee, MD
2:31–2:47 pm	**Announcement–2016 Research Grant Winners** Medtronic CSRS Research Grant 21st Century Research and Education Grants Seed Starter Research and Education Grants Resident Fellow Grants
2:48–2:49 pm	**Introduction – Research Grant Updates**
2:50–2:55 pm	**21st Century Research and Education Grant** **Therapeutic Approaches to Protect against Ischemia/Reperfusion Injury following Surgical Decompression for Cervical Spondylotic Myelopathy(CSM): A Potential Solution to Attenuate Perioperative Neurological Complications following Decompressive Surgery** **Michael G. Fehlings, MD, PhD**; Pia M. Vidal, BS, PhD; Spyridon K. Karadimas, MD, PhD

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2:56–3:01 pm	**PLA2-Responsive Multifunctional Micelles for the Targeted Treatment of Painful Radiculopathy** **Beth A. Winkelstein, PhD**; Zhilang Cheng; Andrew Tsourkas, PhD
3:02–3:07 pm	Seed Starter Grants **Elucidating Metabolite Changes in the Spinal Cord of Cervical Spondylotic Myelopathy (CSM) Patients using Magnetic Resonance Spectroscopy** Izabela Aleksanderek; Michael G. Fehlings, MD; PhD, **Allan R. Martin, MD**
3:08–3:13 pm	**A Randomized Trial of Early Home Exercise vs. Usual Care after Anterior Decompression and Fusion for Degenerative Cervical Spine Conditions** **Rogelio A. Coronado, PT, PhD**; Kristin R. Archer, DPT, PhD; Clinton J. Devin, MD; Joseph S. Cheng, MD, MS; Oran S. Aaronson, MD
3:13–3:18 pm	**Discussion**
3:19–3:49 pm	**Break** Frontenac Ballroom Foyer
3:50–4:30 pm	**Session XI: MOTION PRESERVATION** Moderator: Douglas G. Orndorff, MD and Andrew C. Hecht, MD
3:51–3:57 pm Presentation #54 (pg. 203)	**The Seven Year Cost-Effectiveness of Anterior Cervical Discectomy and Fusion vs. Cervical Disc Arthroplasty** **Steven J. McAnany**; Samuel Overley, MD; Jun Sup Kim, MD; Robert Brochin, MD; Sheeraz Qureshi, MD, MBA
3:58–4:04 pm Presentation #55 (pg. 206)	**Progressive Bone Formation after Cervical Disc Replacement: Minimum of 5-Year Follow-up** **Feifei Zhou, MD**; Kevin L. Ju, MD; John G. Heller, MD; Yu Sun, MD
4:05–4:11 pm Presentation #56 (pg. 207)	**Unintended Fusion in Cervical Artificial Disc Replacement: A Prospective Study on Heterotopic Ossification with 5 Years Follow-up** **Catarina Marques, MD**; Anna Marianne MacDowall, MD; Martin Skeppholm, MD, PhD; Nuno Maria Canto-Moreira, MD, PhD; Claes Olerud, MD
4:12–4:18 pm Presentation #57 (pg. 208)	**Clinical Implications of Heterotopic Ossification after Cervical Disc Arthroplasty at 7 Years** **Pierce D. Nunley, MD**; Eubulus J. Kerr, MD; David A. Cavanaugh, MD; Andrew Utter, MD; Kelly Frank, MS; Marcus Stone, PhD
4:19–4:30 pm	**Discussion**
4:31–5:17 pm	**Session XII: COMPLICATIONS** Moderator: Ahmad Nassr, MD and Jason W. Savage, MD

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4:32–4:38 pm Presentation #59 (pg. 209)	**Cervical Deformity Surgery Does Not Result In Post-Operative Dysphagia: A Prospective Cohort Study** **Sravisht Iyer, MD**; Hongda Bao, MD, PhD; Han Jo Kim, MD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Munish C. Gupta, MD; Todd J. Albert, MD; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Peter G. Passias, MD; Brian J. Neuman, MD; Eric O. Klineberg, MD; Virginie Lafage, PhD; Christopher P. Ames, MD
4:39–4:45 pm Presentation #60 (pg. 211)	**Pseudarthrosis in Patients Undergoing Multilevel Posterior Cervical or Cervical-Thoracic Fusions: Multi-Center Analysis** **Eeric Truumees, MD**; Devender Singh, PhD; Matthew J. Geck, MD; John K. Stokes, MD
4:46–4:52 pm Presentation #61 (pg. 212)	**Not All Patients with Diabetes Have the Same Risk: The Association of Perioperative Glycemic Control with Deep Postoperative Infection following ACDF in Patients with Diabetes** **Jourdan M. Cancienne, MD**; Brian C. Werner, MD; Anuj Singla, MD; Hamid Hassanzadeh, MD; Francis H. Shen, MD; James Andrew Browne, MD; Adam L. Shimer, MD
4:53–4:59 pm Presentation #62 (pg. 214)	**Laminoplasty and Wide Decompression were Risk Factors of C5 Palsy: Analysis of 303 Surgical Cases with Cervical Compression Myelopathy** **Satoshi Nori, MD, PhD**; Ryoma Aoyama, MD, PhD; Ken Ninomiya, MD; Junichi Yamane, MD, PhD; Kazuya Kitamura, MD, PhD; Tateru Shiraishi, MD, PhD
5:00–5:06 pm Presentation #63 (pg. 217)	**Reoperation Rates following Open Door Cervical Laminoplasty** John Rodriguez-Feo, MD; Daniel Leas, MD; Susan Marie Odum, PhD; Mark F. Kurd, MD; Bruce V. Darden II, MD; **R. Alden Milam IV, MD**
5:07–5:17 pm	**Discussion**

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7:00 – 7:05 am	**Welcome and Announcements** Alpesh A. Patel, MD
7:06 – 7:54 am	**Session XIII: HEALTHCARE ECONOMICS/VALUE II** Moderators: Alpesh A. Patel, MD and Ezequiel Cassinelli, MD
7:06 – 7:12 am Presentation #64 (pg. 219)	**Impact of Body Mass Index on Surgical Outcomes, Narcotic Consumption, Costs and Reimbursements following Anterior Cervical Discectomy and Fusion** **Kern Singh, MD;** Benjamin C. Mayo, BA; Dustin H. Massel, BS; Krishna Modi; William W. Long Jr., BA; Jonathan S. Markowitz, BS; Jacob V. Dibattista, BS
7:13 – 7:19 am Presentation #65 (pg. 222)	**Effect of Surgical Setting (Tertiary vs. Community Hospitals) on Hospital Reported Outcomes for Anterior Cervical Spine Procedures** **Eugene Koh, MD, PhD**; Ehsan Jazini, MD; Neil Sardesai, MD; Tristan Buchannan Weir, BS; Kelley E. Banagan, MD; Daniel E. Gelb, MD; Steven C. Ludwig, MD
7:20 – 7:26 am Presentation #66 (pg. 226)	**Predictive Models for Patient-Centered Efficacy and Discharge Destination after Elective Cervical Spine Surgery** **Ahilan Sivaganesan, MD**; Silky Chotai, MD; Elliott J. Kim, MD; David Stonko, BS, MS; Joseph Bradley Wick, BA; Matthew McGirt, MD; Clinton J. Devin, MD
7:27 – 7:33 am Presentation #67 (pg. 229)	**Reimbursement and Charges Related to A 90-Day Episode of Care for a One- or Two-Level Anterior Cervical Discectomy and Fusion** **Sohrab Virk, MD**; Frank M. Phillips, MD; Safdar N. Khan, MD
7:34 – 7:40 am Presentation #68 (pg. 231)	**Is There Value in Retrospective, 90 Day Bundled Payment Models for Cervical Spine Procedures?** **Susan M. Odum, PhD**; Bryce A. Van Doren, MA, MPH; Leo R. Spector, MD
7:41 – 7:54 am	**Discussion**
7:55 – 8:55 am	**Symposium: COMPLICATIONS** Moderators: Wellington K. Hsu, MD and Andrew T. Dailey, MD
7:55 – 8:02 am	**Dysphagia – Risk Factors and Prevention** Michael D. Daubs, MD
8:03 – 8:10 am	**Latrogenic Esophageal Injury – Prevention and Treatment** James S. Harrop, MD
8:11 – 8:18 am 8:19 – 8:25 am	**Prophylactic Foraminotomy for C5 Nerve Root Palsy – To Be or Not to Be?** K. Daniel Riew, MD Thomas E. Mroz, MD
8:25 – 8:32 am 8:33 – 8:40 am	**If I Could Do It All Over Again – Case-based Lessons** Rick C. Sasso, MD Paul A. Anderson, MD
8:41 – 8:55 am	**Discussion**

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8:56 – 9:43 am	**Session XIV: CERVICAL MYELOPATHY II** Moderators: Michael C. Gerling, MD and Christopher I. Shaffrey, MD
8:56 – 9:02 am Presentation #69 (pg. 232)	**The Use of a Novel iPad Application to Quantify Dysfunction on Cervical Myelopathy Patients** **Tyler J. Jenkins, MD**; Brett D. Rosenthal, MD; Arjun Ranade; Surabhi A. Bhatt, BS; Wellington K. Hsu, MD; Alpesh A. Patel, MD
9:03 – 9:09 am Presentation #70 (pg. 234)	**Association between Paraspinal Muscle Morphology, Clinical Symptoms and Functional Status in Patients with Degenerative Cervical Myelopathy** Octavian Dobrescu; Matthew Courtemanche; Carolyn J. Sparrey, PhD; Michael G. Fehlings, MD, PhD; Michael H. Weber, MD; **Carlo Santaguida, MD**
9:10 – 9:16 am Presentation #71 (pg. 236)	**MRI Analysis of the Combined AOSpine North America and International Studies: The Prevalence and Spectrum of Pathologies in a Global Cohort of Patients with Degenerative Cervical Myelopathy** **Aria Nouri, MD**; Allan Martin, MD; Lindsay A. Tetreault, PhD; So Kato, MD; Hiroaki Nakashima, MD; Narihito Nagoshi, MD, PhD; Hamed Reihani-Kermani, MD; Michael G. Fehlings, MD, PhD
9:17 – 9:23 am Presentation #72 (pg. 238)	**High-Resolution Magnetization Transfer (MT) MRI in Patients with Cervical Spondylotic Myelopathy** **Brett D. Rosenthal, MD**; Linda Suleiman, MD; Kenneth Weber, DC; Jason W. Savage, MD; Wellington K. Hsu, MD; Todd B. Parrish, PhD; Alpesh A. Patel, MD
9:24 – 9:30 am Presentation #73 (pg. 240)	**The K-Line Tilt – A Novel Radiographic Parameter of Cervical Sagittal Balance is a Predictor of Postoperative Kyphotic Deformity after Laminoplasty for Cervical Myelopathy Caused by Ossification of the Posterior Longitudinal Ligament** **Kenichiro Sakai, MD, PhD**; Toshitaka Yoshii, MD, PhD; Takashi Hirai, MD, PhD; Yoshiyasu Arai; Yu Matsukura, MD, PhD; Atsushi Okawa, MD, PhD
9:31 – 9:44 am	**Discussion**
9:45 – 9:49 am	**Poster Award Winners Announcement** D. Greg Anderson, MD
9:50 – 9:55 am	**Presentation of CSRS Medallion to Darrel S. Brodke, MD**
9:56 – 10:11 am	**Break** Frontenac Ballroom Foyer
10:12 – 11:00 am	**Session XV: SURGICAL TECHNIQUES II** Moderators: R. Alden Milam IV, MD and Bruce V. Darden II, MD
10:12 – 10:18 am Presentation #74 (pg. 242)	**The Difference in Clinical Outcomes between ACDF, Total Disc Arthroplasty and Posterior Foraminotomy in Professional Athletes** **Harry T. Mai, BS**; Andrew Schneider, BA; Sean M. Mitchell, BS; Jason W. Savage, MD; Alpesh A. Patel, MD; Andrew C. Hecht, MD; Wellington K. Hsu, MD

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10:19–10:25 am Presentation #75 (pg. 244)	**The Accuracy and Safety of Subaxial Cervical Pedicle Screw Insertion using Vertebral Lateral Notch-Referred Technique** **Kai Cao, MD, PhD**; Chunyang Wu, MD; Qingxiu Leng, MD; Zhimin Pan, MD, MSc; Jiaquan Luo; Pingguo Duan
10:26–10:32 am Presentation #76 (pg. 245)	**Degenerative Cervical Spondylolisthesis: Does Adjacent Level Surgical Stabilization Result in Progressive Listhesis?** **Grant D. Shifflett, MD**; Jake Emerson; Hollis Johanson; Bryce A. Basques, MD; Jacob Birlingmair, BS; Dennis P. McKinney; Po-Hsin Chou, MD; Philip Louie, MD; Howard S. An, MD
10:33–10:39 am Presentation #77 (pg. 247)	**Should Long Segment Cervical Fusions be Routinely Carried into the Thoracic Spine? Multi-Center Analysis** **Eeric Truumees, MD**; Devender Singh, PhD; Matthew J. Geck, MD; John K. Stokes, MD
10:40–10:46 am Presentation #78 (pg. 248)	**Should Asymptomatic Levels with MRI Abnormalities be Included in an ACDF Construct? A Long-Term MRI Analysis** **Marcus D. Mazur, MD**; Andrew Dailey, MD; Lubdha M. Shah, MD; Joel D. MacDonald, MD
10:47–11:00 am	**Discussion**
11:01–12:15 pm	**Session XVI: HIGHLIGHT POSTERS II** Moderators: Michael G. Fehlings, MD, PhD and Michael D. Daubs, MD
	DEFORMITY
11:01–11:03 am Presentation #79 (pg. 250)	**Thoraco-Lumbar Reciprocal Changes following Cervical Reconstruction Surgery for Cervical Kyphosis** **Jun Mizutani, MD**; Strom Russell; Kenji Endo; Kuniyoshi Abumi, MD; Ken Ishii, MD; Mitsuru Yagi, MD, PhD; Bobby Tay, MD; Vedat Deviren, MD; Christopher P. Ames, MD
11:04–11:06 am Presentation #80 (pg. 252)	**Preoperative Global Sagittal Imbalance is a Predictor of Postoperative Neck Pain following Laminoplasty in Patients with Cervical Spondylotic Myelopathy: Based on the Prospective Analysis of 165 Patients** **Jun Ouchida, MD**; Hiroaki Nakashima, MD; Naoki Segi, MD
11:07–11:09 am Presentation #81 (pg. 253)	**Adult Spinal Deformity Patients with Proximal Junctional Kyphosis Adjust with Cervical Malalignment at Similar Rates but Distinct Characteristics Relative to Those Unaffected** **Peter G. Passias, MD**; Cyrus Jalai, BA; Han Jo Kim, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; D. Kojo Hamilton; Robert K. Eastlack, MD; Douglas C. Burton, MD; Munish C. Gupta, MD; Robert Shay Bess, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; International Spine Study Group

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11:10–11:12 am Presentation #82 (pg. 254)	**The Difference of Spinal Sagittal Alignment and Health-Related QoL between Males and Females with Cervical Deformity** **Shin Oe, MD**; Daisuke Togawa, MD; Tomohiko Hasegawa, MD; Yu Yamato, MD, PhD; Sho Kobayashi, MD; Tomohiro Banno, MD; Yuuki Mihara, MD; Kenta Kurosu; Yukihiro Matsuyama, MD, PhD
11:13–11:15 am Presentation #83 (pg. 256)	**Analysis of Successful vs. Failed Radiographic Outcomes following Cervical Deformity Surgery** **Themistocles S. Protopsaltis, MD**; Subaraman Ramchandran, MBBS, MS; D. Kojo Hamilton; Daniel Sciubba, MD; Peter G. Passias, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Robert A. Hart, MD; Douglas C. Burton, MD; Robert Shay Bess, MD; Munish C. Gupta, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group
11:16–11:21 am	**Discussion**
	MYELOPATHY
11:22–11:24 am Presentation #84 (pg. 258)	**Laminoplasty Decreases Postoperative Axial Neck Pain Scores in Myelopathic Patients: A Comparison with Laminectomy and Fusion** John M. Rhee, MD; **Thomas M. Neustein, BA;** Salvador R. Arceo V
11:25–11:27 am Presentation #85 (pg. 259)	**The Pa-mJOA: A Patient-Derived, Self Reported Outcome Instrument for Measuring Myelopathy - Comparison with the mJOA** **John M. Rhee, MD**; Weilong Jeffrey Shi, MD; Jin Young Kim, MD; Feifei Zhou, MD; Anuj Patel, MD
11:28–11:30 am Presentation #86 (pg. 261)	**Accuracy of Post-Operative Recall of Baseline Neurological Function by Patients Undergoing Surgical Decompression for Cervical Spondylotic Myelopathy** Nanfang Xu; **Shaobo Wang, MD**
11:31–11:33am Presentation #87 (pg. 262)	**What are the Research Priorities for Patients with Degenerative Cervical Myelopathy?** **Mark R. Kotter, MD, PhD;** Davies M. Benjamin, MBChB, MRCSEd
11:34–11:36 am Presentation #88 (pg. 263)	**The Impact of Cervical Sagittal Alignment on Axial Neck Pain and Health-Related QoL after Laminoplasty - A Prospective Comparative Study between Cervical OPLL and CSM** **Hiroyasu Fujiwara, MD**; Takenori Oda, MD; Takahiro Makino, MD, MSc; Yu Moriguchi, MD, PhD; Kazuo Yonenobu, MD; Takashi Kaito, MD, PhD
11:37–11:42 am	**Discussion**
	COMPLICATIONS
11:43–11:45 am	**Complications and Readmission after Cervical Spine Surgery in**

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Presentation #89 (pg. 265)	**Elderly Patients: An Analysis of 1586 Patients** Ahmed Saleh; Caroline Thirukumaran; Robert W. Molinari, MD; **Addisu Mesfin, MD**
11:46–11:48 am Presentation #90 (pg. 267)	**Opioid Use Trends Following Cervical Spine Surgery** **Andrew J. Pugely, MD;** Nicholas Bedard, MD; Jamal Shillingford, MD; Comron Saifi, MD; Joseph Laratta, MD; K. Daniel Riew, MD; Ronald A. Lehman, MD
11:49–11:51 am Presentation #91 (pg. 269)	**Adjacent-Level Degeneration after Bryan Cervical Disc Arthroplasty Compared with Anterior Discectomy and Fusion** **Justin W. Miller, MD**; Rick C. Sasso, MD; Paul A. Anderson, MD; K. Daniel Riew, MD
11:52–11:54 am Presentation #92 (pg. 270)	**Incidence, Epidemiology, and Treatment Trends for Spinal Epidural Abscesses Involving the Cervical Spine** **Zachary Denham**; Antonino Bucca; James Darnley; Kari Stammen, ATC; Ryan Rauck, MD; Sohrab Virk, MD; Safdar N. Khan, MD
11:55–11:57 am Presentation #93 (pg. 271)	**The Posterior Use of BMP-2 in Cervical Deformity Surgery Does not Result in Increased Peri-Operative Complications: A Prospective Multicenter Study** **Han Jo Kim, MD**; Sravisht Iyer, MD; Hongda Bao, MD, PhD; Justin S. Smith, MD, PhD; Munish C. Gupta, MD; Todd J. Albert, MD; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Peter G. Passias, MD; Brian J. Neuman, MD; Eric O. Klineberg, MD; Virginie Lafage, PhD; Christopher P. Ames, MD; International Spine Study Group
11:58 am–12:04 pm	**Discussion**
12:15–12:16 pm	**Closing Remarks** Darrel S. Brodke, MD
12:17 pm	**Adjourning Notices** Alpesh A. Patel, MD

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Aaronson, Oran S [rs]	No Conflicts to Disclose; Submitted on 05/01/2016		
Abtahi, Amir	No Conflicts to Disclose; Submitted on 04/28/2016	27	
Abumi, Kuniyoshi	Submitted on: 04/30/2016 Asia-Pacific Spine Society: Board or committee member CSRS 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	79	30
Agarwal, Nitin	No Conflicts to Disclose; Submitted on 03/30/2016	22	
Ahlfors, Jan-Eric	Submitted on: 05/02/2016 New World Laboratories: Employee; Stock or stock Options	45	
Ahn, Junyoung	No Conflicts to Disclose; Submitted on 05/14/2016	3	
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Aleksanderek, Izabela [rs]	No Conflicts to Disclose; Submitted on 10/18/2016		
Alentado, Vincent	No Conflicts to Disclose; Submitted on 04/20/2016		42
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Ames, Christopher P	Submitted on: 04/29/2016 Biomet Spine: IP royalties DePuy: Paid consultant Fish & Richardson, P.C.: Other financial or material support Medtronic: Paid consultant Stryker: IP royalties; Paid consultant	22, 24, 59, 79, 81, 83, 93,	10, 16, 24, 25, 26, 27, 28, 30

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Anderson, D Greg [a,p,m]	Submitted on: 06/13/2016 CSRS, 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	51	53
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Archer, Kristin [rs]	Submitted on: 04/29/2016 American Physical Therapy Association: Board or committee member Physical Therapy: Editorial or governing board		17, 35

Name	Disclosure Information	Presentation	E-Poster
Arnold, Paul M	Submitted on: 04/22/2016 AANS/CNS Joint Section on Neurotrauma & Critical Care: Board or committee member AOSpine 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 FzioMed: Paid consultant IAMI, Asubio Pharmaceuticals, Spineology, AOSpine International, Acorda Therapeutics, AOSpine International: Research support 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 Stryker: Paid consultant Z-plasty: Stock or stock Options	11, 28, 50	52
Asher, Anthony	Submitted on: 04/24/2016 Hyperbranch: Stock or stock Options		17, 35
Badner, Anna	No Conflicts to Disclose; Submitted on 04/28/2016	46, 48	
Baird, Evan	No Conflicts to Disclose; Submitted on 04/29/2016	1	
Banagan, Kelley E	Submitted on: 04/06/2016 Johnson & Johnson: Employee Orthofix: Other financial or material support	65	
Banno, Tomohiro	No Conflicts to Disclose; Submitted on 04/28/2016	82	
Bao, Hongda	No Conflicts to Disclose; Submitted on 05/02/2016	30, 59, 93	

a = Awards Committee • c = CSRS Staff • df = Dinner Symposium • lf = Lunch Symposium • m = Moderator • p = Program Committee • rc = Research Committee • rs = Research Session • s = Symposium Presenter • sp = Special Presenter

Name	Disclosure Information	Presentation	E-Poster
Baron, Eli M	Submitted on: 04/29/2016 Elsevier: Publishing royalties, financial or material support McGraw Hill: Publishing royalties, financial or material support	50	
Bartels, Ronald HMA [sp]	Submitted on: 09/16/2016 CSRS: Board or committee member European Spine Journal: Editorial or governing board		
Barth, Kathryn A	No Conflicts to Disclose; Submitted on 04/26/2016	20, 40	18
Basques, Bryce A	No Conflicts to Disclose; Submitted on 05/18/2016	35, 41 46	
Beauchamp, Eduardo C	No Conflicts to Disclose; Submitted on 08/30/2016	36	
Bedard, Nicholas	No Conflicts to Disclose; Submitted on 05/05/2016	90	
Benjamin, Davies M	No Conflicts to Disclose; Submitted on 05/02/2016	87	
Benzel, Edward	Submitted on: 04/19/2016 AxioMed: IP royalties; Paid consultant; Publishing royalties, financial or material support; Stock or stock Options CSRS Secretary: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties none: Unpaid consultant Spine, The Spine Journal, Journal of Spinal Disorders, Neurosurgery and World Spine Journal: Editorial or governing board World Neurosurgery: Editorial or governing board		42
Bess, Robert Shay	Submitted on: 05/14/2016 allosource: Paid consultant DePuy, A Johnson & Johnson Company: Research support Innovasis: Research support K2 Medical: IP royalties; Paid consultant; Paid presenter or speaker; Research support Medtronic Sofamor Danek: Research support NASS: Board or committee member NuVasive: Paid consultant; Paid presenter or speaker Pioneer Spine: IP royalties Scoliosis Research Society: Board or committee member Stryker: Research support	22, 24, 81, 83	10, 16, 24, 25, 26, 28

Name	Disclosure Information	Presentation	E-Poster
Bhatia, Nitin N [p]	Submitted on: 04/11/2016 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 NASS: 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		
Bhatt, Surabhi A	No Conflicts to Disclose; Submitted on 04/25/2016	53, 69	
Birlingmair, Jacob	No Conflicts to Disclose; Submitted on 05/02/2016	76	
Bisson, Erica F [p,m]	Submitted on: 04/15/2016 AANS Ethics, AANS/CNS Spine SPC: Board or committee member AANS Neurosurgeon: Editorial or governing board nView: Paid consultant; Stock or stock Options		
Bohl, Daniel D	No Conflicts to Disclose; Submitted on 08/25/2016	3, 41	31, 33, 36, 58
Bovonratwet, Patawut	No Conflicts to Disclose; Submitted on 08/23/2016 –		58
Brehmer, Thomas S	No Conflicts to Disclose; Submitted on 05/03/2016	44	
Brochin, Robert	No Conflicts to Disclose; Submitted on 05/02/2016	42, 54	
Brodke, Daniel S [m]	Submitted on: 04/13/2016 Amedica: IP royalties AOSpine: Board or committee member CSRS: Board or committee member Clinical Orthopaedics and Related Research: Editorial or governing board DePuy Synthes: IP royalties Lumbar Spine Research Society: Board or committee member Medtronic: IP royalties Vallum: Paid consultant		

a = Awards Committee • c = CSRS Staff • df = Dinner Symposium • lf = Lunch Symposium • m = Moderator • p = Program Committee • rc = Research Committee • rs = Research Session • s = Symposium Presenter • sp = Special Presenter

Name	Disclosure Information	Presentation	E-Poster
Browne, James A	Submitted on: 08/06/2016 American Journal of Orthopedics: Editorial or governing board Biocomposites Ltd: Paid consultant DJ Orthopaedics: IP royalties; Paid consultant Journal of Arthroplasty: Editorial or governing board Radlink: Stock or stock Options Radlink/DePuy: Paid consultant Saunders/Mosby-Elsevier: Publishing royalties, financial or material support Southern Orthopaedic Association: Board or committee member	61	
Bucca, Antonino	No Conflicts to Disclose; Submitted on 04/25/2016	92	
Buckland, Aaron	No Conflicts to Disclose; Submitted on 05/08/2016	30	
Budde, Matthew	No Conflicts to Disclose; Submitted on 04/30/2016	33	
Bueff, Hans-Ulrich [p]	Submitted on: 05/23/2016 CSRS: Board or committee member		
Burkus, J Kenneth	Submitted on: 04/22/2016 American Journal of Orthopedics: Editorial or governing board Biomet: IP royalties; Paid consultant; Paid presenter or speaker; Research support Clinical Orthopaedics and Related Research: Editorial or governing board Journal of Spinal Disorders and Technique: Editorial or governing board Medtronic Sofamor Danek: Research support Medtronic Sofamor Danek Biomet: Paid consultant; Paid presenter or speaker	8	
Burton, Douglas C	Submitted on: 04/25/2016 DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Research support	24, 81, 83	16, 24
Buttermann, Glenn R	Submitted on: 05/17/2016 Solco: Other financial or material support	7	
Bydon, Mohamad	No Conflicts to Disclose; Submitted on 04/12/2016		17, 35
Cancienne, Jourdan Michael	No Conflicts to Disclose; Submitted on 08/10/2016	61	
Canto-Moreira, Nuno Maria	No Conflicts to Disclose; Submitted on 04/29/2016	10, 56	
Cao, Kai	No Conflicts to Disclose; Submitted on 05/31/2016	25, 75	14
Cassinelli, Ezequiel [p,c]	Submitted on: 09/16/2016 CSRS: Board or committee member Irrisept: Stock or stock Options Stryker: Paid consultant; Paid presenter or speaker		
Cavanaugh, David A	No Conflicts to Disclose; Submitted on 05/01/2016	57	22
Cazzulino, Alejandro	No Conflicts to Disclose; Submitted on 05/02/2016	18	

Name	Disclosure Information	Presentation	E-Poster
Chang, Han	No Conflicts to Disclose; Submitted on 05/04/2016		6, 8
Chapman, Jens R	Submitted on: 04/29/2016 AO North America Board of Directors: Board or committee member Evidence Based Spine Journal, Spine, 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	28	3
Chen, Yiwei	No Conflicts to Disclose; Submitted on 05/31/2016	25	14
Chen, Gang	No Conflicts to Disclose; Submitted on 05/01/2016	33	
Cheng, Joseph S [rs]	Submitted on: 05/30/2016 AANS: Board or committee member NASS: Board or committee member		
Cheng, Zilang [rs]	Submitted on: 10/13/2016 Johnson & Johnson: Employee		
Chikuda, Hirotaka	No Conflicts to Disclose; Submitted on 04/29/2016		9, 45
Chio, Jonathon	No Conflicts to Disclose; Submitted on 04/29/2016	46	
Cho, Samuel KW	Submitted on: 04/29/2016 AOSpine North America: Board or committee member CSRS: Board or committee member DePuy, A Johnson & Johnson Company: Paid consultant Medtronic: Paid consultant NASS: Board or committee member Scoliosis Research Society: Board or committee member Stryker: Paid consultant Zimmer: Paid consultant; Research support	1	
Cho, Jae Hwan	No Conflicts to Disclose; Submitted on 04/29/2016		44
Choi, Sung Hoon	No Conflicts to Disclose; Submitted on 05/01/2016		44
Chotai, Silky	No Conflicts to Disclose; Submitted on 05/02/2016	19, 43, 66	17, 35, 56
Chou, Po-Hsin	No Conflicts to Disclose; Submitted on 05/03/2016	76	
Chun, Danielle	No Conflicts to Disclose; Submitted on 04/26/2016	20, 40	4, 18
Chung, Andrew S	No Conflicts to Disclose; Submitted on 04/30/2016		47

Name	Disclosure Information	Presentation	E-Poster
Chutkan, Norman B	Submitted on: 04/04/2016 AAOS: Board or committee member AOA: Board or committee member AOSpine North America: Board or committee member Globus Medical: IP royalties NASS: Board or committee member Orthopedics: Editorial or governing board SLACK: Editorial or governing board		47
Colman, Matthew	Submitted on: 03/21/2016 Globus Medical: Paid presenter or speaker Medicrea: Paid consultant	21	32
Cook, Ralph	No Conflicts to Disclose; Submitted on 04/27/2016	20, 40	4, 18
Coronado, Rogelio A [rs]	No Conflicts to Disclose; Submitted on 05/02/2016		
Courtemanche, Matthew	No Conflicts to Disclose; Submitted on 04/28/2016	70	
Craven, Cathy	Submitted on: 05/01/2016 Rick Hansen Institute Care Committee: Board or committee member		21
Cruz, Dana	No Conflicts to Disclose; Submitted on 05/01/2016	30	
Cruz, Dana	No Conflicts to Disclose; Submitted on 05/01/2016		16
Cui, Jonathan	Submitted on: 08/23/2016 Merck: Employee; Stock or stock Options		58
Dailey, Andrew [m]	Submitted on: 05/01/2016 Biomet: IP royalties CSRS: Board or committee member K2M: Paid consultant; Research support Medtronic Sofamor Danek: Paid consultant Orthofix: Paid consultant	78	
Daniels, Alan H	Submitted on: 05/23/2016 DePuy, A Johnson & Johnson Company: Paid consultant Globus Medical: Paid consultant Orthofix: Paid consultant; Research support Osseus: Unpaid consultant Stryker: Paid consultant	24	11, 24, 27

Name	Disclosure Information	Presentation	E-Poster
Darden, Bruce V [m,s]	Submitted on: 05/20/2016 4Web: Paid consultant; Stock or stock Options BioMedFlex: Stock or stock Options CSRS, 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 Spineguard: Paid consultant Stryker: IP royalties; Paid consultant; Paid presenter or speaker Synthes: Paid presenter or speaker; Research support	63	
Darnley, James	No Conflicts to Disclose; Submitted on 04/27/2016	92	
Daubs, Michael D [m,s]	Submitted on: 04/28/2016 AOSpine North America Board Member: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties		
Deegan, Paul [sp]	No Conflicts to Disclose; Submitted on 10/12/2016		
Day, Louis	No Conflicts to Disclose; Submitted on 04/30/2016	30	16
Denham, Zachary R	No Conflicts to Disclose; Submitted on 08/07/2016	92	
Depasse, John M	Submitted on: 05/02/2016 Stryker: Other financial or material support		11
Devin, Clinton J [m]	Submitted on: 06/01/2016 CSRS: Board or committee member DePuy, A Johnson & Johnson Company: Paid consultant; Research support Exparel: Paid consultant NASS: Board or committee member Stryker: Research support	19, 43, 66	17, 35, 56
Deviren, Vedat	Submitted on: 05/25/2016 AOSpine: Research support Globus Medical: Research support NuVasive: IP royalties; Paid consultant; Research support	24, 79	24, 25, 30
Dibattista, Jacob V	No Conflicts to Disclose; Submitted on 04/29/2016	64	33, 36
Diebo, Bassel	No Conflicts to Disclose; Submitted on 04/21/2016	30, 50	
Dietrich, W Dalton	No Conflicts to Disclose; Submitted on 05/02/2016		57
Dobrescu, Octavian	No Conflicts to Disclose; Submitted on 04/30/2016	70	
Dodwad, Shah-Nawaz	No Conflicts to Disclose; Submitted on 05/02/2016		54
Donaldson, William F	Submitted on: 04/01/2016 AAOS: Board or committee member IEP: Paid presenter or speaker	27	

a = Awards Committee • c = CSRS Staff • df = Dinner Symposium • lf = Lunch Symposium • m = Moderator • p = Program Committee • rc = Research Committee • rs = Research Session • s = Symposium Presenter • sp = Special Presenter

Name	Disclosure Information	Presentation	E-Poster
Douleh, Diana G	No Conflicts to Disclose; Submitted on 04/30/2016		56
Dryer, Randall F	Submitted on: 05/04/2016 Globus: Paid presenter or speaker; Stock or stock Options Globus Medical, Medtronic, NuVasive, Paradym: IP royalties Globus, Medtronic: Paid consultant Paradym: Stock or stock Options	8	
Duan, Pingguo	(This individual reported nothing to disclose); Submitted on: 05/31/2016	25, 75	14
Dunn, Edward J [sp]	Submitted on: 09/20/2016 AbbVie: Stock or stock Options Abbott Laboratories: Stock or stock Options Amgen: Stock or stock Options Baxter International: Stock or stock Options Bristol-Myers Squibb: Stock or stock Options CVS Health Corp: Stock or stock Options Express Scripts Holding Co: Stock or stock Options Gilead Sciences: Stock or stock Options Johnson & Johnson: Stock or stock Options Medtronic: Stock or stock Options Merck & Co: Stock or stock Options Novartis AG: Stock or stock Options Sanofi SA: Stock or stock Options GlaxoSmithKline PLC: Stock or stock Options		
DuShane, Lisa A [c]	No Conflicts to Disclose; Submitted on 10/10/2016		
Dvorak, Marcel F	Submitted on: 04/30/2016 AOSpine: Other financial or material support AOSpine International: Research support Arcus: Research support DePuy, A Johnson & Johnson Company: Other financial or material support; Research support Medtronic: IP royalties Medtronic Sofamor Danek: IP royalties; Other financial or material support; Paid consultant; Paid presenter or speaker; Research support Synthes: Other financial or material support; Paid presenter or speaker; Research support Thieme: Publishing royalties, financial or material support Vancouver General Hospital Foundation: Board or committee member		3

Name	Disclosure Information	Presentation	E-Poster
Eastlack, Robert K	Submitted on: 05/16/2016 Aesculap/B.Braun: Paid consultant Alphatec Spine: Paid consultant; Stock or stock Options Carevature: Stock or stock Options DePuy, A Johnson & Johnson Company: Paid consultant DiFusion: Paid consultant; Stock or stock Options DJ Orthopaedics: Paid consultant Eli Lilly: Paid presenter or speaker Globus Medical: IP royalties Invuity: Paid consultant; 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	81	
Egawa, Satoru	No Conflicts to Disclose; Submitted on 05/02/2016		34
Eismont, Frank J [sp]	Submitted on: 10/06/2016 Alphatec Spine: IP royalties; Paid consultant; Stock or stock Options Saunders/Mosby-Elsevier: Publishing royalties, financial or material support		
Eltorai, Adam E M	No Conflicts to Disclose; Submitted on 05/01/2016		11
Emerson, Jacob T	No Conflicts to Disclose; Submitted on 05/03/2016	76	
Endo, Kenji	No Conflicts to Disclose; Submitted on 05/05/2016	79	30
Errico, Thomas J	Submitted on: 05/12/2016 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 OMEGA: Research support Pfizer: Research support	30	16
Eyberg, Blake	No Conflicts to Disclose; Submitted on 05/01/2016		47
Faour, Mhamad	No Conflicts to Disclose; Submitted on 05/01/2016	39	
Fehlings, Michael G [rs,m]	Submitted on: 04/27/2016 None: Board or committee member; Editorial or governing board	11, 13, 16, 28, 29, 45, 46, 47, 48, 70, 71	1, 2, 7, 21, 52, 57

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Fein, Arielle W	Submitted on: 05/01/2016 American Thyroid Association: Board or committee member	18	
Ferreyro, Bruno	No Conflicts to Disclose; Submitted on 03/30/2016	22	
Fessler, Richard G	Submitted on: 10/14/2016 DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant Medtronic Sofamor Danek: IP royalties Stryker: IP royalties		20
Fourman, Mitchell	No Conflicts to Disclose; Submitted on 04/27/2016	27	
Frank, Kelly	No Conflicts to Disclose; Submitted on 04/27/2016	57	22
Freeman, Thomas	Submitted on: 04/30/2016 Abbott: Stock or stock Options		56
Freshman, Ryan D	No Conflicts to Disclose; Submitted on 04/27/2016		4
Fujiwara, Hiroyasu	No Conflicts to Disclose; Submitted on 04/30/2016	88	
Funaba, Masahiro	No Conflicts to Disclose; Submitted on 04/18/2016		40
Furlan, Julio C	No Conflicts to Disclose; Submitted on 05/02/2016		21, 57
Furuya, Takeo	No Conflicts to Disclose; Submitted on 05/01/2016	31	41, 50
Garvey, Timothy A	Submitted on: 05/02/2016 Medtronic: Paid presenter or speaker Medtronic Sofamor Danek: IP royalties	36	
Gary, Joshua L	Submitted on: 05/20/2016 Journal of Bone and Joint Surgery - American: Editorial or governing board Orthopaedic Trauma Association: Board or committee member Smith & Nephew: Paid presenter or speaker Summitt Medventures: Stock or stock Options Wolters Kluwer Health - Lippincott Williams & Wilkins: Editorial or governing board		54
Gean, Alisa	No Conflicts to Disclose; Submitted on 05/01/2016	34	
Geck, Matthew J	Submitted on: 04/18/2016 Diffusion: Stock or stock Options	60, 77	37, 38
Geddes, Benjamin J	No Conflicts to Disclose; Submitted on 06/01/2016		58
Gelb, Daniel E	Submitted on: 05/31/2016 Advanced Spinal Intellectual Property: Stock or stock Options Depuy-Synthes Spine: IP royalties; Paid presenter or speaker Globus Medical: IP royalties	65	

Name	Disclosure Information	Presentation	E-Poster
Gerling, Michael C [m]	Submitted on: 04/11/2016 AAOS: Board or committee member Brooklyn Orthopedic Society: Board or committee member CSRS: Board or committee member	50	
Gerszten, Peter	Submitted on: 03/30/2016 Medtronic: Paid consultant Zimmer: Paid consultant	22	
Glaser, John A	Submitted on: 05/02/2016 AOA: Board or committee member NASS: Board or committee member Spine: Editorial or governing board The Spine Journal: Editorial or governing board	44	
Goczalk, Melissa	No Conflicts to Disclose; Submitted on 05/02/2016	35	
Goldschmidt, Ezequiel	No Conflicts to Disclose; Submitted on 03/30/2016	22	
Gornet, Matthew F	Submitted on: 04/18/2016 Bonovo: Stock or stock Options International Spine & Orthopedic Institute, LLC: Stock or stock Options K2M: Paid consultant Medtronic: IP royalties; Paid consultant; Research support Nocimed: Stock or stock Options OuroBorus: Stock or stock Options Paradigm Spine: Stock or stock Options	8	
Gould, Heath	No Conflicts to Disclose; Submitted on 04/27/2016	12	
Grad, Sibylle	No Conflicts to Disclose; Submitted on 04/29/2016		3
Grauer, Jonathan N	Submitted on: 08/23/2016 AAOS: Board or committee member American Journal of Orthopedics: Editorial or governing board Bioventus: Paid consultant CSRS: Board or committee member Contemporary Spine Surgery: Editorial or governing board ISTO Technologies: Paid consultant Lumbar Spine Research Society: Board or committee member Medtronic: Paid consultant NASS: Board or committee member Novella clinical: Paid consultant Stryker: Paid consultant The Spine Journal: Editorial or governing board		58

Name	Disclosure Information	Presentation	E-Poster
Gum, Jeffrey	Submitted on: 04/11/2016 Acuity: Paid consultant Alphatec Spine: Paid consultant American Journal of Orthopedics: Editorial or governing board DePuy, A Johnson & Johnson Company: Paid consultant Fischer Owen Fund - Travel Fund: Other financial or material support LifeSpine: Paid consultant Medtronic: Paid consultant MiMedx: Paid presenter or speaker Pacira Pharmaceuticals: Paid presenter or speaker PAKmed: Paid consultant Stryker: Paid consultant The Spine Journal - Reviewer: Editorial or governing board		24
Gupta, Munish C	Submitted on: 04/05/2016 DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant Johnson & Johnson: Stock or stock Options Medtronic: Paid consultant Orthofix: Paid consultant Pfizer: Stock or stock Options Procter & Gamble: Stock or stock Options	24, 59, 81, 83, 93	10, 24, 26
Ha, Alex	No Conflicts to Disclose; Submitted on 05/02/2016	18	
Ha, Jung-Ki	No Conflicts to Disclose; Submitted on 05/01/2016		44
Haines, Colin	No Conflicts to Disclose; Submitted on 05/02/2016	12	
Hamilton, D Kojo	Submitted on: 05/28/2016 European Spine Journal: Editorial or governing board	22, 81, 83	28
Harmon, Satoko M	No Conflicts to Disclose; Submitted on 05/03/2016	5	
Harrell, Frank E	Submitted on: 05/03/2016 American Heart Journal: Editorial or governing board Bayer: Paid consultant Journal of Clinical Epidemiology: Editorial or governing board Medtronic Sofamor Danek: Paid consultant; Research support Norvartis: Paid presenter or speaker Science Translational Medicine: Editorial or governing board Statistics in Medicine: Editorial or governing board		17, 35
Harris, Mitchell B [p]	Submitted on: 10/05/2016 NASS: Board or committee member		

Name	Disclosure Information	Presentation	E-Poster
Harrop, James S [s]	Submitted on: 04/28/2016 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 Tejin: Other financial or material support	28	
Hart, Robert A	Submitted on: 05/23/2016 AAOS: Board or committee member AAOS ICL Volume 62, Assistant Editor: Editorial or governing board AOA: Board or committee member CSRS: Board or committee member DePuy: Paid consultant; Paid presenter or speaker; Research support DePuy, A Johnson & Johnson Company: IP royalties Globus Medical: Paid consultant; Paid presenter or speaker International Spine Study Group: Board or committee member Lumbar Spine Research Society: Board or committee member NASS: Board or committee member Oregon Association of Orthopaedics: Board or committee member Scoliosis Research Society: Board or committee member SeaSpine: IP royalties	24, 83	10, 24, 25, 26, 27
Hasegawa, Tomohiko	No Conflicts to Disclose; Submitted on 05/01/2016	82	
Hashimoto, Kunihiko	No Conflicts to Disclose; Submitted on 04/29/2016		5
Hashmi, Sohaib Zafar	No Conflicts to Disclose; Submitted on 04/28/2016	20	
Hassanzadeh, Hamid	Submitted on: 05/13/2016 Orthofix: Research support Pfizer: Research support	61	12
Hayashi, Kazunori	No Conflicts to Disclose; Submitted on 04/26/2016		43

Alphabetical Participant Disclosure List

Name	Disclosure Information	Presentation	E-Poster
Heary, Robert F [p,m,sp]	Submitted on: 05/03/2016 AANS: Board or committee member CSRS: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties Lumbar Spine Research Society: Board or committee member Thieme Medical Publishers: Publishing royalties, financial or material support Zimmer: IP royalties		52
Hecht, Andrew C [m]	Submitted on: 04/09/2016 AAOS, Musculoskeletal Transplant Foundation: Board or committee member American Journal of Orthopedics: Editorial or governing board Global Spine Journal: Editorial or governing board Johnson & Johnson: Stock or stock Options journal of spinal disorders and techniques: Editorial or governing board Medtronic Sofamor Danek: Paid consultant Orthopaedic Knowledge Online Journal: Editorial or governing board Orthopedics Today: Editorial or governing board Stryker Spine, Zimmer Spine: Paid consultant Zimmer: IP royalties; Paid consultant	1, 74	
Heller, John G	Submitted on: 05/11/2016 CSRS: Board or committee member Medtronic: IP royalties; Paid consultant; Stock or stock Options	55	
Herfat, Safa	No Conflicts to Disclose; Submitted on 05/01/2016	34	
Hess, Christopher	Submitted on: 05/01/2016 American Journal of Neuroradiology: Editorial or governing board American Society of Neuroradiology: Board or committee member Cererbrotech: Research support General Electric: Research support International Society for Magnetic Resonance in Medicine: Board or committee member Quest Diagnostics: Research support Radiological Society of North America: Board or committee member Siemens: Paid presenter or speaker	34	

Name	Disclosure Information	Presentation	E-Poster
Hilibrand, Alan S	Submitted on: 04/17/2016 AAOS: Board or committee member Aesculap/B.Braun: IP royalties Amedica: IP royalties; Stock or stock Options Benvenue Medical: Stock or stock Options Biomet: IP royalties CSRS: Board or committee member Lifespine: Stock or stock Options Nexgen: Stock or stock Options NASS: 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	51	53
Hirai, Takashi	No Conflicts to Disclose; Submitted on 04/27/2016	4, 15, 73	34
Hirata, Hiroaki	No Conflicts to Disclose; Submitted on 04/30/2016	14	
Hodges, Scott D	Submitted on: 04/26/2016 Biomet: IP royalties Globus Medical: Research support	8	
Hong, James	No Conflicts to Disclose; Submitted on 04/28/2016	46	
Hoshino, Masatoshi	No Conflicts to Disclose; Submitted on 04/29/2016		43
Hosogane, Naobumi	No Conflicts to Disclose; Submitted on 04/29/2016		30
Hsu, Erin L.	Submitted on: 06/01/2016 AAOS: Board or committee member Bacterin: Paid consultant Bioventus: Paid consultant CeramTec: Paid consultant CSRS: Board or committee member Globus Medical: Paid consultant Graftys: Paid consultant Journal of Spinal Disorders and Techniques: Editorial or governing board Lifenet: Paid consultant LSRS: Board or committee member Medtronic: Research support 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: Paid consultant Terumo: Paid consultant Zimmer: Paid consultant		4

Name	Disclosure Information	Presentation	E-Poster
Hsu, Wellington K	Submitted on: 05/18/2016 AAOS: Board or committee member AONA: Paid consultant; Paid presenter or speaker Bacterin: Paid consultant Bioventus: Paid consultant CeramTec: Paid consultant CSRS: Board or committee member Globus: Paid consultant Graftys: Paid consultant Journal of Spinal Disorders and Techniques: Editorial or governing board Lifenet: Paid consultant Lumbar Spine Research Society: Board or committee member Medtronic: Research support Medtronic Sofamor Danek: Paid consultant NASS: Board or committee member Relievant: Paid consultant Rti: Paid consultant SI Bone: Paid consultant Stryker: IP royalties; Paid consultant	2, 20, 40, 53, 69, 72, 74	4, 18
Hu, Emily	No Conflicts to Disclose; Submitted on 04/27/2016	12	
Hu, Serena S [p,m]	Submitted on: 05/02/2016 AOA: Board or committee member Johnson & Johnson: Paid presenter or speaker NuVasive: IP royalties; Paid consultant; Stock or stock Options Stryker: Paid presenter or speaker		
Hustedt, Joshua	No Conflicts to Disclose; Submitted on 05/01/2016		47
Hwang, Chang Ju	No Conflicts to Disclose; Submitted on 05/02/2016		44
Hwang, Sang-Phil	No Conflicts to Disclose; Submitted on 05/02/2016		48
Hyun, Seung-Jae	Submitted on: 04/30/2016 AEGIS SPINE: Paid consultant Medtronic: Unpaid consultant	23	
Iijima, Yasushi	No Conflicts to Disclose; Submitted on 05/02/2016	31	41, 50
Inage, Kazuhide	No Conflicts to Disclose; Submitted on 05/01/2016		50
International Spine Study Group	Submitted on: 04/06/2016 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 Stryker: Research support	24, 59, 81, 83, 93	10, 24, 25, 26, 27

Name	Disclosure Information	Presentation	E-Poster
Isaacs, Robert E	Submitted on: 05/02/2016 NuVasive: IP royalties; Paid consultant; Research support Providence: Stock or stock Options Saferay Spine, LLC: Stock or stock Options Safewire: Stock or stock Options Vertera: Stock or stock Options Vilaspine: Stock or stock Options	50	
Ishiguro, Hiroyuki	No Conflicts to Disclose; Submitted on 04/25/2016		5
Ishii, Ken	No Conflicts to Disclose; Submitted on 04/29/2016	79	30
Iyer, Sravisht	No Conflicts to Disclose; Submitted on 05/18/2016	59, 93	
Jain, Amit	No Conflicts to Disclose; Submitted on 05/01/2016		12
Jalai, Cyrus	No Conflicts to Disclose; Submitted on 04/21/2016	30, 50, 81	
Jang, Soo-Jin	No Conflicts to Disclose; Submitted on 05/02/2016		48
Janssen, Michael E	Submitted on: 04/28/2016 Cerapedics: Paid presenter or speaker; Stock or stock Options DePuy, A Johnson & Johnson Company: Paid presenter or speaker Global Spine Journal: Editorial or governing board Synthes, Cerapedics: Research support		52
Jazini, Ehsan	No Conflicts to Disclose; Submitted on 05/02/2016	65	
Jenis, Louis G [p,m]	Submitted on: 10/03/2016 CSRS: Board or committee member Intrinsic Therapeutics: Paid consultant 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 J	No Conflicts to Disclose; Submitted on 05/18/2016	2, 69	
Johanson, Hollis	No Conflicts to Disclose; Submitted on 05/02/2016	76	
Ju, Kevin L	No Conflicts to Disclose; Submitted on 01/11/2016	55	
Kaikaus, Jahanzeb	No Conflicts to Disclose; Submitted on 05/02/2016	35	
Kaito, Takashi	No Conflicts to Disclose; Submitted on 06/19/2016	88	5
Kalinosky, Benjamin T	No Conflicts to Disclose; Submitted on 05/02/2016	33	
Kalsi-Ryan, Sukhvinder [a]	Submitted on: 05/02/2016 Asterias: Paid consultant Daichii Sankyo: Paid consultant Stem Cells: Paid consultant Vertex: Paid consultant	29	

Alphabetical Participant Disclosure List

Name	Disclosure Information	Presentation	E-Poster
Kanayama, Sadaaki	No Conflicts to Disclose; Submitted on 04/28/2016		5
Kanchiku, Tsukasa	No Conflicts to Disclose; Submitted on 04/09/2016		50
Kandziora, Frank	Submitted on: 04/29/2016 DePuy, A Johnson & Johnson Company: Paid consultant; Paid presenter or speaker; Research support Siemens: Paid presenter or speaker		3
Kanemura, Aritetsu	No Conflicts to Disclose; Submitted on 05/02/2016	14	
Kaneyama, Shuichi	No Conflicts to Disclose; Submitted on 04/27/2016	14	
Kang, Kyung-Chung	No Conflicts to Disclose; Submitted on 05/01/2016	32	48
Kanter, Adam	Submitted on: 05/16/2016 NuVasive: IP royalties; Research support Physician and Sports Medicine: Editorial or governing board Zimmer: IP royalties	22	
Karadimas, Spyridon [rs]	No Conflicts to Disclose; Submitted on 05/02/2016	47	1, 2
Kasahara, Koichi	No Conflicts to Disclose; Submitted on 05/02/2016	14	
Kato, So	No Conflicts to Disclose; Submitted on 04/24/2016	13, 71	
Kaushal, Mayank	No Conflicts to Disclose; Submitted on 04/30/2016	33	
Kazuma, Kitaguchi	No Conflicts to Disclose; Submitted on 05/09/2016		5
Kebaish, Khaled M	Submitted on: 04/29/2016 DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Paid presenter or speaker; Research support Orthofix: Paid consultant Orthofix, K2 medical: Paid presenter or speaker Scoliosis Research Society: Board or committee member	24	28
Kelly, Michael P [a,m]	Submitted on: 04/05/2016 AOSpine: Research support Barnes Jewish Hospital Foundation: Research support CSRS: Research support Fox Family Foundation: Research support OREF: Research support UCSF Spine Course: Paid presenter or speaker	59	24
Kepler, Christopher	Submitted on: 06/01/2016 Biomet: Research support Clinical spine surgery: Editorial or governing board Medtronic: Research support Pfizer: Research support	28, 51	3, 58
Kerr, Eubulus J	No Conflicts to Disclose; Submitted on 05/01/2016	57	22
Kessler, Daniel P	Submitted on: 05/03/2016 SpecialtyCare: Paid consultant	38	

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Khan, Safdar N	No Conflicts to Disclose; Submitted on 04/28/2016	17, 67, 92	
Khazaei, Mohamad	No Conflicts to Disclose; Submitted on 05/02/2016	45, 46	
Ki-Jeong, Kim	No Conflicts to Disclose; Submitted on 05/01/2016	23	
Kim, Han Jo	Submitted on: 04/21/2016 HSS Journal, Asian Spine Journal: Editorial or governing board K2M: Paid consultant Scoliosis Research Society: Board or committee member Zimmer Biomet: Paid consultant	24, 49, 59, 81, 93	10, 24, 25, 26, 27
Kim, Ki-Tack	No Conflicts to Disclose; Submitted on 05/02/2016	32	
Kim, Jun S	No Conflicts to Disclose; Submitted on 05/02/2016	42, 54	
Kim, Elliott J	No Conflicts to Disclose; Submitted on 04/28/2016	19, 43, 66	56
Kim, Jin Young	No Conflicts to Disclose; Submitted on 05/02/2016	85	
Kim, Ki-Tack	No Conflicts to Disclose; Submitted on 05/02/2016		48
Kitamura, Mitsuhiro	No Conflicts to Disclose; Submitted on 05/01/2016	31	41, 50
Kitamura, Kazuya	No Conflicts to Disclose; Submitted on 04/27/2016	62	51
Klineberg, Eric O	Submitted on: 04/04/2016 AOSpine: 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 Stryker: Paid consultant	24, 59, 93	24, 25, 26, 27, 28
Kobayashi, Sho	No Conflicts to Disclose; Submitted on 04/28/2016	82	
Koda, Masao	No Conflicts to Disclose; Submitted on 05/01/2016	31	41, 50
Koerner, John	Submitted on: 04/28/2016 Clinical Spine Surgery: Editorial or governing board Jaypee Publishing: Publishing royalties, financial or material support Medtronic: Research support Novartis: Employee		3
Koh, Akihiro	No Conflicts to Disclose; Submitted on 04/30/2016	14	
Koh, Eugene Y	Submitted on: 04/25/2016 Biomet: Paid consultant DePuy, A Johnson & Johnson Company: Paid presenter or speaker	65	
Komatsu, Miki	No Conflicts to Disclose; Submitted on 05/03/2016	5	

Name	Disclosure Information	Presentation	E-Poster
Kopjar, Branko	Submitted on: 04/28/2016 Amendia: Paid consultant Cerapedics: Paid consultant CSRS: Board or committee member Hip Innovation Technology: Paid consultant Innovative Surgical Designs: Paid consultant NASS: Board or committee member PorOsteon: Paid consultant Smith & Nephew: Paid consultant	11, 16	52
Kotter, Mark	No Conflicts to Disclose; Submitted on 05/02/2016	87	
Kurd, Mark F	Submitted on: 04/27/2016 Journal of Spinal Disorders and Techniques: Editorial or governing board Stryker: Paid consultant	51, 63	53
Kurosu, Kenta	No Conflicts to Disclose; Submitted on 05/01/2016	82	
Kurpad, Shekar N	Submitted on: 04/28/2016 Congress of Neurological Surgeons: Board or committee member Neurosurgery: Editorial or governing board Spine: Editorial or governing board	33	
Kwon, Brian K [p]	Submitted on: 08/12/2016 Acorda Therapeutics: Paid consultant		
Lafage, Virginie	Submitted on: 05/02/2016 DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Research support Medicrea: Paid presenter or speaker Nemaris: Board or committee member; Stock or stock Options NuVasive: Paid presenter or speaker	22, 24, 30, 59, 81, 83, 93	10, 16, 24, 25, 26, 27, 28
Lafage, Renaud	No Conflicts to Disclose; Submitted on 05/31/2016	24, 30, 83	24, 25
Laliberte, Alex	No Conflicts to Disclose; Submitted on 05/03/2016	47	
Lanman, Todd H	Submitted on: 04/17/2016 Medtronic: Paid consultant Medtronic Sofamor Danek (prestige LP study): Research support Medtronic Sofamor Danek - Peek Rod: IP royalties Stryker: IP royalties	8	
Laratta, Joseph	No Conflicts to Disclose; Submitted on 04/22/2016	90	
Larouche, Jeremie	No Conflicts to Disclose; Submitted on 05/01/2016	34	
Lawrence, Brandon D [a]	Submitted on: 05/31/2016 AOSpine Fellowship Committee: Board or committee member AOSpine North America: Paid presenter or speaker CSRS: Board or committee member		
Leas, Daniel	No Conflicts to Disclose; Submitted on 04/04/2016	63	

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Lee, Joon Y [p]	No Conflicts to Disclose; Submitted on 04/04/2016	27	
Lee, Sang-Hun	Submitted on: 04/29/2016 Medtronic: Paid consultant; Paid presenter or speaker	32	48
Lee, Jung-Hee	No Conflicts to Disclose; Submitted on 05/02/2016	32	48
Lee, Choon Sung	No Conflicts to Disclose; Submitted on 04/29/2016		44
Lee, Dong-Ho	No Conflicts to Disclose; Submitted on 04/17/2016		44
Lehman, Ronald A	Submitted on: 04/18/2016 AOSpine: Board or committee member Associate Editor - Spine Deformity: Editorial or governing board CSRS: 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 NASS: 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	18, 90	
Leng, Qingxiu	No Conflicts to Disclose; Submitted on 03/02/2016	75	
Leschke, John	No Conflicts to Disclose; Submitted on 04/30/2016	33	
Li, Wenjun	No Conflicts to Disclose; Submitted on 05/01/2016	33	
Liabaud, Barthelemy	No Conflicts to Disclose; Submitted on 06/01/2016	30	
Line, Breton G	Submitted on: 04/25/2016 ISSGF: Paid consultant		24
Lipiz, John	Submitted on: 05/02/2016 Pfizer: Stock or stock Options		42
Liu, Yang	No Conflicts to Disclose; Submitted on 10/08/2016		57
Liu, Zhongjun	No Conflicts to Disclose; Submitted on 04/27/2016		23
Long, William W	No Conflicts to Disclose; Submitted on 04/12/2016	3, 21, 64	31, 32, 33, 36
Louie, Philip	No Conflicts to Disclose; Submitted on 04/09/2016	35, 41, 76	

Name	Disclosure Information	Presentation	E-Poster
Ludwig, Steven C	Submitted on: 04/25/2016 ABOS: Board or committee member AOA: Board or committee member AOSpine North America Spine Fellowship Support: Research support ASIP, ISD: Stock or stock Options CSRS: 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	65	
Luo, Jiaquan	No Conflicts to Disclose; Submitted on 03/01/2016	25, 75	14
MacDowall, Anna M	No Conflicts to Disclose; Submitted on 04/27/2016	10, 56	
MacDonald, Joel D	No Conflicts to Disclose; Submitted on 04/24/2016	78	
Mai, Harry	No Conflicts to Disclose; Submitted on 04/19/2016	74	
Maki, Satoshi	No Conflicts to Disclose; Submitted on 05/02/2016	31	
Makino, Takahiro	No Conflicts to Disclose; Submitted on 04/30/2016	88	5
Maltenfort, Mitchell	No Conflicts to Disclose; Submitted on 08/16/2016		53
Manoharan, Sakthivel R	No Conflicts to Disclose; Submitted on 05/02/2016	26	
Markova, Dessislava Z	No Conflicts to Disclose; Submitted on 04/29/2016		3
Markowitz, Jonathan S	No Conflicts to Disclose; Submitted on 04/30/2016	64	31, 33
Marques, Catarina	No Conflicts to Disclose; Submitted on 05/01/2016	10, 56	
Martin, Allan [rs]	No Conflicts to Disclose; Submitted on 05/02/2016	71	
Massel, Dustin H	No Conflicts to Disclose; Submitted on 04/12/2016	3, 21, 41, 64	31, 32, 33, 36
Massicotte, Eric	Submitted on: 04/11/2016 AOSpine North America: Paid presenter or speaker Watermark Research Partners: Paid consultant	16	
Matsubayashi, Yoshitaka	No Conflicts to Disclose; Submitted on 04/29/2016		9, 45
Matsukura, Yu	No Conflicts to Disclose; Submitted on 08/21/2016	15, 73	15

Name	Disclosure Information	Presentation	E-Poster
Matsumoto, Morio	Submitted on: 05/20/2016 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	45	
Matsuyama, Yukihiro	No Conflicts to Disclose; Submitted on 04/28/2016	82	
Mayo, Benjamin C	No Conflicts to Disclose; Submitted on 05/14/2016	3, 21, 41, 64	31, 32, 33, 36
Mazur, Marcus D	No Conflicts to Disclose; Submitted on 04/23/2016	78	
McAnany, Steven	No Conflicts to Disclose; Submitted on 05/01/2016	42, 54	
McClellan, Robert T	Submitted on: 05/01/2016 Advanced Biologics, LLC: Unpaid consultant Biologica Technologies, LLC: Unpaid consultant Episode Solutions, LLC: Stock or stock Options Epix Orthopaedics: Stock or stock Options Northern California Orthopaedic Society: Board or committee member PDP Holdings, LLC: Stock or stock Options Shape Memory Orthopedics: Stock or stock Options Skeletal Kinetics, LLC: Unpaid consultant Total Connect Spine, LLC: Stock or stock Options	34	
McConnell, Jeffrey R	Submitted on: 04/20/2016 Globus Medical: IP royalties; Paid consultant; Paid presenter or speaker; Stock or stock Options IMSE: Paid consultant LDR: Paid presenter or speaker Medtronic: Paid consultant Synthes: Paid consultant	8	

Name	Disclosure Information	Presentation	E-Poster
McGirt, Matthew J	Submitted on: 05/02/2016 DePuy, A Johnson & Johnson Company: Paid consultant DJ Orthopaedics: Paid consultant Stryker: Paid consultant	19	66, 17, 35
McKinney, Dennis P	No Conflicts to Disclose; Submitted on 05/02/2016	76	
McLynn, Ryan P	No Conflicts to Disclose; Submitted on 08/23/2016		58
Mendoza, Marco	No Conflicts to Disclose; Submitted on 05/18/2016	2	
Merrill, Robert K	No Conflicts to Disclose; Submitted on 05/02/2016	1	
Mesfin, Addisu [m]	Submitted on: 04/30/2016 AAOS: Board or committee member CSRS: Board or committee member J. Robert Gladden Society: Board or committee member NASS: Board or committee member	89	
Mihara, Yuki	No Conflicts to Disclose; Submitted on 04/28/2016	82	
Milam, R Alden [m]	Submitted on: 04/04/2016 AO Foundation: Other financial or material support CSRS: Board or committee member K2M: Paid consultant RTI: Paid consultant Spinal Kinetics: Research support Spinewave: Paid consultant Stryker: IP royalties; Paid consultant	63	
Miller, Jacob A	No Conflicts to Disclose; Submitted on 04/27/2016	12	
Miller, Justin W	No Conflicts to Disclose; Submitted on 04/28/2016	91	
Miller, Emily K	No Conflicts to Disclose; Submitted on 06/16/2016		28
Millhouse, Paul W	Submitted on: 06/14/2016 Globus Medical: Stock or stock Options	51	
Min, Woo-kie	No Conflicts to Disclose; Submitted on: 04/11/2016		44
Mistry, Akshitkumar	No Conflicts to Disclose; Submitted on 04/30/2016		56
Mitchell, Sean M	No Conflicts to Disclose; Submitted on 04/28/2016	74	
Mizutani, Jun	No Conflicts to Disclose; Submitted on 04/28/2016	79	30
Modi, Krishna	No Conflicts to Disclose; Submitted on 04/12/2016	3, 21, 64	31, 32, 33, 36
Molinari, Robert W	No Conflicts to Disclose; Submitted on 05/01/2016	89	
Moore, Don K	Submitted on: 04/05/2016 NASS: Board or committee member	12	
Moriguchi, Yu	No Conflicts to Disclose; Submitted on 04/30/2016	88	5
Morshead, Cindi	No Conflicts to Disclose; Submitted on 05/01/2016	45	

Name	Disclosure Information	Presentation	E-Poster
Mroz, Thomas E [s]	Submitted on: 04/27/2016 AOSpine: Paid presenter or speaker Ceramtec: Paid consultant Chairman, Research Committee, AOSpine North America, Education Committee, NASS Radiology Section, NASS: Board or committee member PearlDiver: Stock or stock Options SpineLine, Editor, Global Spine Journal, Deputy Editor: Editorial or governing board Stryker: IP royalties; Paid consultant	12	42
Mulvihill, Jeffrey	No Conflicts to Disclose; Submitted on 05/01/2016	34	
Mummaneni, Praveen V [p]	Submitted on: 04/06/2016 AANS/CNS Spine Section and Scoliosis Research Society: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties; Paid presenter or speaker 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 Taylor and Francis: Publishing royalties, financial or material support Thieme: Publishing royalties, financial or material support World Neurosurgery: Editorial or governing board		
Mundis, Gregory M	Submitted on: 04/04/2016 ISSGF: Research support K2M: IP royalties; Paid consultant; Paid presenter or speaker Medicrea: Paid consultant Misonix: Paid consultant NuVasive: IP royalties; Paid consultant; Paid presenter or speaker; Research support	24, 59, 93	24, 25, 26, 27, 28
Muqeet, Vaishnavi	No Conflicts to Disclose; Submitted on 05/02/2016	33	
Nagoshi, Narihito	No Conflicts to Disclose; Submitted on 05/02/2016	45, 46, 71	7
Nagy, Andras	No Conflicts to Disclose; Submitted on 04/29/2016	46	
Nair, Rueben	No Conflicts to Disclose; Submitted on 04/04/2016	2	
Nakamura, Masaya	Submitted on: 04/28/2016 Eli Lilly: Paid presenter or speaker Medtronic Sofamor Danek: Paid presenter or speaker Pfizer: Paid presenter or speaker	45	

Name	Disclosure Information	Presentation	E-Poster
Nakamura, Norimasa	Submitted on: 05/30/2016 International Cartilage Repair Society: Board or committee member Journal of Experimental Orthopaedics (Springer): Editorial or governing board Journal of Orthopaedic Science (Springer): Editorial or governing board Sage (Cartilage): Editorial or governing board		5
Nakamura, Hiroaki	No Conflicts to Disclose; Submitted on 05/08/2016	11, 46, 71, 80	43
Nakashima, Hiroaki	No Conflicts to Disclose; Submitted on 04/28/2016	11, 80	
Narvid, Jared	No Conflicts to Disclose; Submitted on 05/01/2016	34	
Nassr, Ahmad [p,m]	Submitted on: 04/28/2016 AOA: Board or committee member AOSpine: Research support CSRS: 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		
Neuman, Brian J	Submitted on: 04/04/2016 DePuy, A Johnson & Johnson Company: Research support	24, 52, 59, 93	10, 25, 28
Neustein, Thomas M	No Conflicts to Disclose; Submitted on 04/29/2016	84	
Ney, John P	Submitted on: 05/03/2016 American Academy of Neurology: Board or committee member Neurology-Clinical Practice (LWW): Editorial or governing board SpecialtyCare: Paid consultant	38	
Nicholson, Kristen	No Conflicts to Disclose; Submitted on 04/28/2016	51	53
Niemeier, Thomas	No Conflicts to Disclose; Submitted on 04/12/2016	26	
Ninomiya, Ken	No Conflicts to Disclose; Submitted on 05/01/2016	62	51
Nishida, Norihiro	No Conflicts to Disclose; Submitted on 04/11/2016		40
Niu, Chi-Chien	No Conflicts to Disclose; Submitted on 04/26/2016		23
Norenberg, Michael	No Conflicts to Disclose; Submitted on 05/01/2016		57
Nori, Satoshi	No Conflicts to Disclose; Submitted on 05/02/2016	13, 62	51
Nouri, Aria	Submitted on: 05/01/2016 Rexahn Pharmaceuticals: Stock or stock Options	13, 71	

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Nunley, Pierce D	Submitted on: 05/01/2016 ABSS - American Board of Spine Surgery: Board or committee member Amedica: Stock or stock Options AxioMed: Research support Biomet: IP royalties; Paid presenter or speaker K2M: IP royalties; Paid presenter or speaker; Research support LDR Spine: IP royalties; Paid consultant; Research support Medtronic: Research support Nanovis: Paid consultant OKO: Stock or stock Options Orthofix: Research support Osprey: Stock or stock Options Spinal Motion: Paid consultant; Research support Spineology: Stock or stock Options Vertiflex: Paid consultant; Research support	57	22
O'Brien, Michael F	Submitted on: 05/25/2016 DePuy, A Johnson & Johnson Company: IP royalties; Paid consultant; Research support DJ Orthopaedics: Research support K2M: Research support NuVasive: Research support Seeger: Research support	24	
Oda, Takenori	No Conflicts to Disclose; Submitted on 05/01/2016	88	
Odum, Susan M	Submitted on: 04/19/2016 American Association of Hip and Knee Surgeons: Board or committee member Ceramtec: Paid presenter or speaker Journal of Arthroplasty: Editorial or governing board	63, 68	
Oe, Shin	Submitted on: 04/28/2016 Japan Medical Dynamic Marketing: Research support Medtronic Sofamor Danek: Research support Meitoku Medical Institution Jyuzen Memorial Hospital: Research support	82	
Ohnmeiss, Donna D	Submitted on: 04/25/2016 International Journal Spine Surgery (ISASS): Editorial or governing board International Society for Advancement of Spine Surgery: Board or committee member NASS: Board or committee member		23
Ohyama, Shoichiro	No Conflicts to Disclose; Submitted on 04/26/2016		43

Name	Disclosure Information	Presentation	E-Poster
Oichi, Takeshi	No Conflicts to Disclose; Submitted on 04/28/2016		9, 45
Okawa, Atsushi	Submitted on: 04/22/2016 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: Research support Medtronic Sofamor Danek: Research support Pfizer: Research support Stryker: Research support Teijin: Research support	4, 15, 73	34
Okonkwo, David	Submitted on: 05/16/2016 Biomet: IP royalties	22	
Olerud, Claes	Submitted on: 04/27/2016 CSRS European Section: Board or committee member DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Research support Medtronic: Paid presenter or speaker	10	
Olerud, Claes	Submitted on: 04/27/2016 CSRS European Section: Board or committee member DePuy, A Johnson & Johnson Company: Paid presenter or speaker; Research support Medtronic: Paid presenter or speaker	56	
Olmscheid, Neil	No Conflicts to Disclose; Submitted on 05/31/2016		47
Ondeck, Nathaniel T	No Conflicts to Disclose; Submitted on 05/30/2016		58
Oner, FC	Submitted on: 04/28/2016 AOSpine: Board or committee member DePuy, A Johnson & Johnson Company: Research support European Spine Journal: Editorial or governing board Spine: Editorial or governing board		3
Oni-Orisan, Akinwunmi	No Conflicts to Disclose; Submitted on 04/30/2016	33	
Orita, Sumihisa	No Conflicts to Disclose; Submitted on 05/01/2016		50
Orndorff, Douglas G [m]	Submitted on: 10/12/2016 Globus Medical: Research support Integra: IP royalties; Paid consultant; Research support NuVasive: Paid consultant; Research support Stryker: Paid consultant Vertiflex: Research support		
Oshima, Yasushi	No Conflicts to Disclose; Submitted on 05/24/2016		9, 45

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O'Toole, John E	Submitted on: 05/01/2016 Globus Medical: IP royalties Pioneer Surgical: Paid consultant RTI Surgical: IP royalties Theracell: Stock or stock Options		20
Otori, Seiji	Disclosure is not current		50
Ouchida, Jun	No Conflicts to Disclose; Submitted on 05/02/2016	80	
Overley, Samuel	No Conflicts to Disclose; Submitted on 05/01/2016	1, 42, 54	
Ozaki, Tomonori	No Conflicts to Disclose; Submitted on 05/02/2016		43
Palumbo, Mark A	Submitted on: 07/06/2016 AAOS: Board or committee member NASS: Board or committee member Stryker: Paid consultant		11
Pan, Zhimin	No Conflicts to Disclose; Submitted on 05/31/2016	25, 75	14
Park, Jong-Beom	Submitted on: 05/26/2016 AOSpine KF: Board or committee member Asian Spine Journal: Editorial or governing board CSRS Asia Pacific Section: Board or committee member Clinics in Orthopedic Surgery: Editorial or governing board European Spine Journal: Editorial or governing board International Orthopaedics: Editorial or governing board ISSLS: Board or committee member		6, 8
Park, Choon-Keun	Submitted on: 04/26/2016 Johnson & Johnson: Other financial or material support; Research support		23
Parker, Scott L	No Conflicts to Disclose; Submitted on 05/05/2016	19	17, 35
Parrish, Todd B	No Conflicts to Disclose; Submitted on 04/30/2016	72	
Passias, Peter G	Submitted on: 04/11/2016 Medicrea: Paid consultant	22, 24, 30, 50, 59, 81, 83, 93	10, 24, 25, 26, 27

Name	Disclosure Information	Presentation	E-Poster
Patel, Alpesh A [p,m]	Submitted on: 06/07/2016 AAOS: Board or committee member Amedica: IP royalties; Paid consultant; Stock or stock Options AOA: Board or committee member AOSpine North America: Board or committee member Biomet: IP royalties CSRS: Board or committee member Cytonics: Stock or stock Options DePuy, A Johnson & Johnson Company: Paid consultant Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board Nocimed: Stock or stock Options NASS: Board or committee member Pacira: Paid consultant Relievant: Paid consultant Springer: Publishing royalties, financial or material support Surgical Neurology International: Editorial or governing board Ulrich Medical USA: IP royalties Vital5: Stock or stock Options Wolters Kluwer Health - Lippincott Williams & Wilkins: Editorial or governing board Zimmer: Paid consultant	2, 20, 40, 53, 69, 72, 74	18
Patel, Anuj	No Conflicts to Disclose; Submitted on 05/02/2016	85	
Pflug, Emily	No Conflicts to Disclose; Submitted on 05/02/2016	51	
Phillips, Frank M	Submitted on: 04/18/2016 CSRS: Board or committee member DePuy, A Johnson & Johnson Company: IP royalties International 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 PearlDiver: 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	17, 35, 67	
Poorman, Gregory W	No Conflicts to Disclose; Submitted on 04/21/2016	50	
Pourtaheri, Sina	No Conflicts to Disclose; Submitted on 04/23/2016		13

Name	Disclosure Information	Presentation	E-Poster
Prasad, Srinivas K	Submitted on: 04/28/2016 Stryker: IP royalties; Paid consultant; Paid presenter or speaker	28	
Prasarn, Mark L [m]	Submitted on: 05/02/2016 DePuy, A Johnson & Johnson Company: Paid presenter or speaker Eli Lilly: Paid presenter or speaker Stryker: Paid consultant; Paid presenter or speaker		54
Protopsaltis, Themistocles S [m]	Submitted on: 04/28/2016 Globus Medical: Paid presenter or speaker Innovasis: Paid presenter or speaker Medicrea International: Paid consultant; Paid presenter or speaker Zimmer: Research support	22, 24, 30, 59, 83, 93	10, 16, 24, 25, 26, 27
Pugely, Andrew J	Submitted on: 04/05/2016 AAOS: Board or committee member Clinical Orthopaedics and Related Research: Editorial or governing board	90	
Puvanesarajah, Varun	No Conflicts to Disclose; Submitted on 05/02/2016		12
Qureshi, Sheeraz [p,m]	Submitted on: 05/02/2016 AAOS: Board or committee member CSRS: 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: 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	1, 42, 54	

Name	Disclosure Information	Presentation	E-Poster
Radcliff, Kristen E [a,p]	Submitted on: 04/30/2016 4 Web Medical: Stock or stock Options; Unpaid consultant ACSR: Board or committee member Altus Spine: IP royalties; Paid consultant DePuy, A Johnson & Johnson Company: Paid consultant; Research support; Unpaid consultant Globus Medical: IP royalties; Paid consultant; Research support LDR: Unpaid consultant Medtronic: Paid consultant; Research support NEXXT Spine: Other financial or material support NuVasive: Other financial or material support Orthofix: Paid consultant Orthopedic Sciences: IP royalties; Paid consultant Pacira Pharmaceuticals: Research support Paradigm Spine: Research support Stryker: Other financial or material support	49, 50, 51	53, 54
Radwan, Zayde	No Conflicts to Disclose; Submitted on 05/02/2016		54
Rajasekaran, Shanmuganathan	Submitted on: 05/28/2016 AOSpine: Board or committee member CSRS: Board or committee member Journal of Bone and Joint Surgery - British: Editorial or governing board Scoliosis Research Society: Board or committee member SICOT: Board or committee member Spine, European Spine Journal: Editorial or governing board		3
Ramchandran, Subaraman	No Conflicts to Disclose; Submitted on 04/26/2016	30, 83	10, 26, 27
Ranade, Arjun	No Conflicts to Disclose; Submitted on 04/06/2016	69	
Rauck, Ryan	No Conflicts to Disclose; Submitted on 04/25/2016	92	
Rechtine, Glenn R	Submitted on: 03/27/2016 Journal of Spinal Cord Medicine: Editorial or governing board The Spine Journal: Editorial or governing board		54
Reihani-Kermani, Hamed	No Conflicts to Disclose; Submitted on 04/27/2016	71	

Name	Disclosure Information	Presentation	E-Poster
Rhee, John M [m]	Submitted on: 04/18/2016 Alphatec Spine: Stock or stock Options Biomet: IP royalties Biomet Depuy: Paid presenter or speaker Biomet Synthes: Paid consultant CSRS: Board or committee member DePuy, A Johnson & Johnson Company, Kineflex, Medtronic: Research support Phygen: Stock or stock Options Wolters Kluwer Health - Lippincott Williams & Wilkins: Publishing royalties, financial or material support Zimmer: Paid presenter or speaker	84, 85	46
Riew, K Daniels	Submitted on: 04/27/2016 Amedica: Stock or stock Options AOSpine: Board or committee member AOSpine, NASS: Paid presenter or speaker Benvenue: Stock or stock Options Biomet: IP royalties Broadwater: Other financial or material support Cerapedics: Research support Expanding Orthopedics, PSD: Stock or stock Options Global Spine Journal, Spine Journal, Neurosurgery: Editorial or governing board Medtronic: IP royalties Medtronic Sofamor Danek: Research support Nexgen Spine: Stock or stock Options Osprey: Stock or stock Options Paradigm Spine: Stock or stock Options Spinal Kinetics: Stock or stock Options Spineology: Stock or stock Options Vertiflex: Stock or stock Options	18, 24, 90, 91	48
Rihn, Jeffrey A	Submitted on: 05/23/2016 DePuy, A Johnson & Johnson Company: Research support NASS: Board or committee member Pfizer: Paid consultant The Spine Journal: Editorial or governing board	50, 51	53
Riley, Lee H [p]	Submitted on: 06/08/2016 Avitus: Stock or stock Options CSRS: Board or committee member Lifenet Health: Other financial or material support NASS: Board or committee member Spinal Kinetics: Stock or stock Options Spine The Journal of Spinal Disorders: Editorial or governing board		

a = Awards Committee • c = CSRS Staff • df = Dinner Symposium • lf = Lunch Symposium • m = Moderator • p = Program Committee • rc = Research Committee • rs = Research Session • s = Symposium Presenter • sp = Special Presenter

Name	Disclosure Information	Presentation	E-Poster
Robinson, Yohan	Submitted on: 04/27/2016 AOSpine: Board or committee member Asian Spine Journal: Editorial or governing board CSRS: Board or committee member DePuy, A Johnson & Johnson Company: Paid presenter or speaker Medtronic: Paid presenter or speaker Swedish Society of Spinal Surgeons: Board or committee member	10	
Rodriguez-Feo, John	No Conflicts to Disclose; Submitted on 04/27/2016	63	
Rosenthal, Brett D	No Conflicts to Disclose; Submitted on 04/05/2016	2, 69, 72	
Ruttiman, Roy	No Conflicts to Disclose; Submitted on 05/01/2016		11
Sachs, Barton L	Submitted on: 05/02/2016 Globus Medical: IP royalties; Paid consultant; Research support	44	
Saifi, Comron	Submitted on: 05/01/2016 Gilead: Stock or stock Options Novartis: Stock or stock Options	18, 90	
Saito, Junya	No Conflicts to Disclose; Submitted on 04/28/2016	31	41, 50
Sakai, Kenichiro	No Conflicts to Disclose; Submitted on 04/22/2016	4, 15, 73	15
Saleh, Ahmed	No Conflicts to Disclose; Submitted on 05/31/2016	89	
Samuel, Andre M	No Conflicts to Disclose; Submitted on 05/28/2016		58
Santaguida, Carlo	No Conflicts to Disclose; Submitted on 04/27/2016	70	
Sardesai, Neil	Submitted on: 04/25/2016 Medtronic: Stock or stock Options	65	
Sasso, Willa	No Conflicts to Disclose; Submitted on 04/14/2016	6	
Sasso, Rick C [s]	Submitted on: 04/13/2016 Biomet: Stock or stock Options Cerapedics: Research support CSRS: Board or committee member Journal of Spinal Disorders and Technique, Spine, Arthroplasty Society Journal: Editorial or governing board Medtronic: IP royalties; Research support Saunders/Mosby-Elsevier: Publishing royalties, financial or material support Smith & Nephew: Research support SpineCor: Stock or stock Options Stryker: Research support Trans1: Stock or stock Options	6, 91	52
Sasso, Maria	Submitted on: 04/14/2016 Medtronic: IP royalties	6	
Satkunendrarajah, Kajana	No Conflicts to Disclose; Submitted on 05/02/2016	46	1, 2, 7

Name	Disclosure Information	Presentation	E-Poster
Savage, Jason W [m]	Submitted on: 04/04/2016 Journal of Spinal Disorders and Techniques: Editorial or governing board Stryker: Paid consultant	2, 53, 72 74	
Schallmo, Michael S	No Conflicts to Disclose; Submitted on 08/20/2016	20, 40	4, 18
Scheer, Justin K	No Conflicts to Disclose; Submitted on 04/27/2016	22, 24	24, 25, 26, 27, 28
Schmit, Brian	Submitted on: 05/03/2016 Synapse Biomedical: IP royalties	33	
Schnake, Klaus J	Submitted on: 04/28/2016 AOSpine: Board or committee member DePuy, A Johnson & Johnson Company: Paid presenter or speaker Expanding Orthopedics: Paid consultant Medtronic: Paid consultant Otto Bock: Paid consultant Silony: Paid consultant		3
Schneider, Andrew	Submitted on: 04/28/2016 MAZOR Surgical Technologies: Stock or stock Options	74	
Schroeder, Gregory D	Submitted on: 05/15/2016 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	28, 49, 51	3, 53
Schwab, Frank J	Submitted on: 04/06/2016 AO: Research support Biomet: Paid consultant; Paid presenter or speaker DePuy, A Johnson & Johnson Company: Research support K2M: IP royalties; Paid consultant; Paid presenter or speaker Medicrea: Paid consultant; Paid presenter or speaker Medtronic: Paid consultant Medtronic Sofamor Danek: IP royalties; Paid presenter or speaker; Research support 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: Board or committee member	22, 24, 30, 81	10, 16, 24, 25

Name	Disclosure Information	Presentation	E-Poster
Sciubba, Daniel	Submitted on: 04/29/2016 DePuy, A Johnson & Johnson Company: Paid consultant Globus Medical: Paid consultant Medtronic: Paid consultant NuVasive: Paid consultant Stryker: Paid consultant	83	26, 27, 28
Segebarth, Paul B [p]	Submitted on: 05/22/2016 K2M: Paid consultant Medtronic Sofamor Danek: Paid consultant; Research support NuVasive: Paid consultant; Paid presenter or speaker		
Segi, Naoki	No Conflicts to Disclose; Submitted on 04/25/2016	80	
Selvarajah, Shalini	No Conflicts to Disclose; Submitted on 05/03/2016	52	
Shaffrey, Christopher I [m]	Submitted on: 04/06/2016 AANS: Board or committee member ABNS: Board or committee member Biomet: IP royalties; Paid consultant; Paid presenter or speaker CSRS: Board or committee member DePuy, A Johnson & Johnson Company: Research support Globus Medical: Paid presenter or speaker K2M: Paid presenter or speaker Medtronic: IP royalties; Other financial or material support; Paid consultant Medtronic Sofamor Danek: 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	22, 24, 83	10, 16, 24, 25, 26, 27
Shah, Lubdha M	No Conflicts to Disclose; Submitted on 04/23/2016	78	
Shaw, Jeremy D	No Conflicts to Disclose; Submitted on 05/21/2016	34	

Name	Disclosure Information	Presentation	E-Poster
Shen, Francis H	Submitted on: 04/05/2016 CSRS: Board or committee member DePuy, A Johnson & Johnson Company: Other financial or material support; Paid consultant European Spine Journal: Editorial or governing board Globus Medical: IP royalties Medtronic: Research support Medtronic Sofamor Danek: Paid consultant Musculoskeletal Transplant Foudation: Board or committee member Musculoskeletal Transplant Foundation: Research support NASS: Board or committee member Saunders/Mosby-Elsevier: Publishing royalties, financial or material support Spine: Editorial or governing board SpineLine: Editorial or governing board Synthes: Other financial or material support; Paid consultant The Spine Journal: Editorial or governing board	61	12
Shi, Weilong J	Submitted on: 05/02/2016 Cocrystal Pharma: Employee	85	
Shifflett, Grant	No Conflicts to Disclose; Submitted on: 04/04/2016	35, 41, 76	
Shillingford, Jamal	No Conflicts to Disclose; Submitted on 05/01/2016	90	
Shimer, Adam L	Submitted on: 04/07/2016 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	61	12
Shinomiya, Kenichi	No Conflicts to Disclose; Submitted on 04/22/2016	4	34
Shiraishi, Tateru	No Conflicts to Disclose; Submitted on 04/29/2016	62	51
Sielatycki, J A	No Conflicts to Disclose; Submitted on 04/17/2016	19	
Silva, Stephen	No Conflicts to Disclose; Submitted on 04/28/2016		53

Alphabetical Participant Disclosure List

Name	Disclosure Information	Presentation	E-Poster
Singh, Kern	Submitted on: 04/11/2016 AAOS: Board or committee member Avaz Surgical, LLC: Stock or stock Options CSRS: Board or committee member DePuy, A Johnson & Johnson Company: Paid consultant ISASS: Board or committee member Pioneer: IP royalties Scoliosis Research Society: Board or committee member SLACK: 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	3, 21, 41, 53, 64	31, 32, 33, 36
Singh, Sameer K	No Conflicts to Disclose; Submitted on 04/27/2016	20, 40	18
Singh, Devender	No Conflicts to Disclose; Submitted on 04/18/2016	60, 77	37, 38
Singla, Anuj	No Conflicts to Disclose; Submitted on 04/25/2016	61	12
Sivaganesan, Ahilan	No Conflicts to Disclose; Submitted on 05/01/2016	19, 43, 66	
Skeppholm, Martin	Submitted on: 04/16/2016 DePuy, A Johnson & Johnson Company: Research support K2M: Research support	9, 10, 56	
Skolasky, Richard L	Submitted on: 05/02/2016 AT&T Foundation: Research support CSRS: Board or committee member DePuy, A Johnson & Johnson Company: Research support DePuy Spine: Research support NASS: Board or committee member Quality of Life Research: Editorial or governing board	52	
Smieliauskas, Fabrice	No Conflicts to Disclose; Submitted on 04/29/2016	16	20

Name	Disclosure Information	Presentation	E-Poster
Smith, Justin S [p,m]	Submitted on: 04/20/2016 Biomet: IP royalties; Paid consultant Cerapedics: Paid consultant CSRS: Board or committee member DePuy: Research support K2M: Paid consultant Neurosurgery: Editorial or governing board NuVasive: Paid consultant	24, 28, 59, 81, 83, 93	10, 16, 24, 25, 26, 27, 28
Smucker, Joseph D	Submitted on: 04/01/2016 Back Bay Life Science Advisors: Paid consultant Baxter/Apatech: Research support Biostructures, LLC: Research support Medtronic Sofamor Danek: Research support Theorem Clinical Research: Paid consultant Watermark Research Partners: Paid consultant	6	
Sparrey, Carolyn J	Submitted on: 04/28/2016 Medtronic: Research support	70	
Spector, Leo R [p]	Submitted on: 04/04/2016 Stryker: Paid consultant; Paid presenter or speaker	68	
Spiegel, Matthew A	No Conflicts to Disclose; Submitted on 04/30/2016		16
Stammen, Kari	No Conflicts to Disclose; Submitted on 04/25/2016	17, 92	
Steinmetz, Michael P [a]	Submitted on: 04/29/2016 Biomet: IP royalties; Unpaid consultant Biomet Synthese Spine: Paid presenter or speaker Congress of Neurological Surgeons, Council of State Neurosurgical Societies, AANS/CNS Joint Section on Disorders of the Spine: Board or committee member DePuy, A Johnson & Johnson Company: Paid presenter or speaker Globus Medical: Paid presenter or speaker Intellirod: Paid consultant Stryker: Paid presenter or speaker		42
Stephens, Byron F	No Conflicts to Disclose; Submitted on 04/26/2016	84	
Stokes, John K	Submitted on: 04/21/2016 Diffusion: Board or committee member Diffusion: Stock or stock Options Genesys Spine: IP royalties Summit Medventures: Stock or stock Options	60, 77	37, 38
Stone, Marcus	No Conflicts to Disclose; Submitted on 05/02/2016	57	22
Stonko, David	No Conflicts to Disclose; Submitted on 05/01/2016	43, 66	56
Strom, Russell G	No Conflicts to Disclose; Submitted on 05/02/2016	79	

Name	Disclosure Information	Presentation	E-Poster
Su, Brian M [p]	Submitted on: 06/10/2016 CSRS: Board or committee member Gentis: Paid consultant NASS: Board or committee member Orthobullets: Paid consultant Stryker: Paid consultant		
Suda, Kota	No Conflicts to Disclose; Submitted on 05/02/2016	5	
Suleiman, Linda	No Conflicts to Disclose; Submitted on 04/12/2016	72	
Sumi, Masatoshi [m,sp]	No Conflicts to Disclose; Submitted on 04/28/2016	14	
Sun, Yu	No Conflicts to Disclose; Submitted on 04/13/2016	55	46
Suzuki, Hidenori	No Conflicts to Disclose; Submitted on 04/27/2016		7, 40
Suzuki, Akinobu	No Conflicts to Disclose; Submitted on 04/26/2016		43
Suzuki, Satoshi	No Conflicts to Disclose; Submitted on 04/28/2016		51
Swift, Carol [a]	No Conflicts to Disclose; Submitted on 05/19/2016		
Taguchi, Toshihiko	Submitted on: 07/04/2016 Eli Lilly: Paid presenter or speaker Pfizer: Paid presenter or speaker		40
Takabatake, Masato	No Conflicts to Disclose; Submitted on 05/02/2016	14	
Takahashi, Shinji	No Conflicts to Disclose; Submitted on 04/26/2016		43
Takahata, Masahiko	Submitted on: 05/01/2016 Chugai Pharm: Other financial or material support Eli Lilly: Other financial or material support Synthes: Other financial or material support	5	
Takenaka, Shota	No Conflicts to Disclose; Submitted on 04/30/2016		5
Takeoka, Yoshiki	No Conflicts to Disclose; Submitted on 04/28/2016	14	
Takeshita, Katsushi	No Conflicts to Disclose; Submitted on 05/02/2016		9, 45
Tamai, Koji	No Conflicts to Disclose; Submitted on 04/26/2016		43
Tanaka, Sakae	Submitted on: 04/29/2016 Amgen: Paid consultant Bristol-Myers Squibb: Paid consultant Chugai Pharmaceutical: Paid presenter or speaker Chugai Pharmaceutical: Paid consultant Daiichi Sankyo: Paid consultant; Paid presenter or speaker Eli Lilly: Paid presenter or speaker Janssen Pharmaceutical K.K.: Paid consultant Kyocera Medical: Paid consultant MSD K.K.: Paid consultant ONO Pharmaceutical: Paid consultant Teijin: Paid consultant		9, 45
Taniguchi, Yuki	No Conflicts to Disclose; Submitted on 04/29/2016		9, 45

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Tay, Bobby	Submitted on: 04/13/2016 AOSpine North American: Research support Biomet: Paid presenter or speaker Globus Medical: Research support NuVasive: Research support Stryker: Paid presenter or speaker Synthes: Paid presenter or speaker	79	30
Tempel, Zachary J	No Conflicts to Disclose; Submitted on 05/01/2016	22	
Terai, Hidetomi	No Conflicts to Disclose; Submitted on 04/30/2016		43
Tetreault, Lindsay A	No Conflicts to Disclose; Submitted on 04/27/2016	16, 11, 13, 47, 71	
Theiss, Steven M	Submitted on: 05/02/2016 AAOS: Board or committee member AOA: Board or committee member Biomet: IP royalties; Paid consultant Pfizer: Research support Scoliosis Research Society: Board or committee member Synthes: Research support	26	
Theologis, Alexander	Submitted on: 04/27/2016 Synthes: Research support	34	
Thirukumaran, Caroline	No Conflicts to Disclose; Submitted on 05/01/2016	89	
Togawa, Daisuke	Submitted on: 04/28/2016 Japan Medical Dynamic Marketing: Research support Journal of Bone and Joint Surgery - American: Editorial or governing board Medtronic Sofamor Danek: Research support Meitoku Medical Institution Jyuzen Memorial Hospital: Research support	82	
Toyoda, Hiromitsu	No Conflicts to Disclose; Submitted on 04/27/2016		43

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Tribus, Clifford B [p,m]	Submitted on: 06/08/2016 Amedica and Spineology: Stock or stock Options Biomet: IP royalties Clinical Spine Surgery: Editorial or governing board Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board McGraw-Hill: Publishing royalties, financial or material support Medtronic: Research support Scoliosis Research Society, AAOS: Board or committee member Spine: Editorial or governing board Spineology: IP royalties; Paid consultant Stryker: IP royalties; Other financial or material support; Paid consultant; Paid presenter or speaker Zimmer: IP royalties; Paid consultant		
Truumees, Eeric	Submitted on: 04/18/2016 AAOS: Board or committee member AAOS Now: Editorial or governing board Doctor's Research Group: Stock or stock Options Globus Medical: Research support Journal of Bone and Joint Surgery - American: Editorial or governing board Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board NASS: Board or committee member; Publishing royalties, financial or material support Relievant: Research support Spine: Editorial or governing board Stryker: IP royalties The Spine Journal: Editorial or governing board	60, 77	37, 38
Tsourkas, Andrew [rs]	No Conflicts to Disclose; Submitted on 10/13/2016		
Tsubosaka, Masanori	No Conflicts to Disclose; Submitted on 04/30/2016	14	
Ulndreaj, Antigona	No Conflicts to Disclose; Submitted on 05/03/2016	47	
Ushiku, Chikara	No Conflicts to Disclose; Submitted on 05/02/2016	5	
Utter, Andrew	No Conflicts to Disclose; Submitted on 05/01/2016	57	22

Name	Disclosure Information	Presentation	E-Poster
Vaccaro, Alexander [m]	Submitted on: 04/18/2016 Advanced Spinal Intellectual Properties: Stock or stock Options Aesculap/B.Braun: IP royalties AOSpine: Board or committee member Association of Collaborative Spine Research: Board or committee member Avaz Surgical: Stock or stock Options Bonovo Orthopaedics: Stock or stock Options Clinical Spine Surgery: Editorial or governing board Computational Biodynamics: Stock or stock Options Cytonics: Stock or stock Options DePuy, A Johnson & Johnson Company: Paid consultant Dimension Orthotics, LLC: Stock or stock Options Electrocore: Stock or stock Options Ellipse: Paid consultant Elsevier: Publishing royalties, financial or material support Expert Testimony: Paid consultant 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 Guidepoint Global: Paid consultant In Vivo: Stock or stock Options Innovative Surgical Design: Board or committee member; Paid consultant; Stock or stock Options Jaypee: Publishing royalties, financial or material support Location Based Intelligence: Stock or stock Options Medacorp: Paid consultant Medtronic: IP royalties; Paid consultant Orthobullets: Paid consultant Paradigm Spine: Stock or stock Options Prime Surgeons: Board or committee member; Stock or stock Options Progressive Spinal Technologies: Stock or stock Options Replication Medica: Stock or stock Options Rothman Institute and Related Properties: Stock or stock Options Spine Journal: Editorial or governing board Spine Medica: Stock or stock Options Spinology: Stock or stock Options Stout Medical: Paid consultant; Stock or stock Options Stryker: IP royalties; Paid consultant Taylor Francis/Hodder and Stoughton: Publishing royalties, financial or material support Thieme: Publishing royalties, financial or material support Vertiflex: Stock or stock Options	28, 50, 51	3, 52, 53

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Van Doren, Bryce A	No Conflicts to Disclose; Submitted on 05/19/2016	68	
Van Eck, Carola F	No Conflicts to Disclose; Submitted on 04/20/2016	27	
Varghese, Jeffrey J	No Conflicts to Disclose; Submitted on 05/01/2016	30	
Verma, Kushagra	No Conflicts to Disclose; Submitted on 05/25/2016		30
Vidal, Pia M [rs]	No Conflicts to Disclose; Submitted on 04/29/2016	47	
Virk, Sohrab	No Conflicts to Disclose; Submitted on 04/27/2016	17, 67, 92	
Wang, Jeffrey C [m]	Submitted on: 09/26/2016 Aesculap/B.Braun: IP royalties Alphatec Spine: Stock or stock Options 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 CSRS: Board or committee member Corespine: Stock or stock Options Electrocore: Stock or stock Options Evidence Based Spine Journal, The Global Spine Journal, Spine, The Spine Journal, The Journal of Spinal Disorders and Techniques: Editorial or governing board Expanding Ortho: Stock or stock Options Fziomed: Stock or stock Options Nexgen: Stock or stock Options North American Spine Foundation: Board or committee member NASS: 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 Journal of the American Academy of Orthopaedic Surgeons: Editorial or governing board Vertiflex: Stock or stock Options		
Wang, Jian	No Conflicts to Disclose; Submitted on 05/03/2016	47	
Wang, Shaobo	No Conflicts to Disclose; Submitted on 05/03/2016	86	
Weber, Michael	No Conflicts to Disclose; Submitted on 04/28/2016	70	
Weber, Kenneth	No Conflicts to Disclose; Submitted on 04/11/2016	72	
Weiner, Joseph A	No Conflicts to Disclose; Submitted on 04/26/2016	20, 40	4, 18
Weir, Tristan B	No Conflicts to Disclose; Submitted on 05/26/2016	65	
Werner, Brian C	No Conflicts to Disclose; Submitted on 05/08/2016	61	
Wick, Joseph B	No Conflicts to Disclose; Submitted on 04/30/2016	43, 66	56
Wilson, Jefferson R	No Conflicts to Disclose; Submitted on 04/28/2016	28	53

Name	Disclosure Information	Presentation	E-Poster
Winkelstein, Beth A [rs]	Submitted on: 04/01/2016 Spine: Editorial or governing board St Jude Medical: Research support Taylor and Francis: Publishing royalties, financial or material support		
Witiw, Christopher	No Conflicts to Disclose; Submitted on 05/01/2016	16	20
Wlezien, Peggy [c]	No Conflicts to Disclose; Submitted on 10/03/2016		
Wolinsky, Jean-Paul [p,m]	No Conflicts to Disclose; Submitted on 10/16/2016		
Woods, Barrett I	No Conflicts to Disclose; Submitted on 05/02/2016	51	53
Wu, Dongjin	No Conflicts to Disclose; Submitted on 05/01/2016	13	
Wu, Chunyang	No Conflicts to Disclose; Submitted on 03/02/2016	75	
Xiao, Roy	No Conflicts to Disclose; Submitted on 06/13/2016	12	
Xu, Nanfang	No Conflicts to Disclose; Submitted on 04/23/2016	86	
Yagi, Mitsuru	Submitted on: 04/28/2016 K2M: Research support Surgical Spine: Research support	79	30
Yamada, Katsuhisa	No Conflicts to Disclose; Submitted on 04/28/2016	5	
Yamane, Junichi	No Conflicts to Disclose; Submitted on 04/29/2016	62	51
Yamato, Yu	No Conflicts to Disclose; Submitted on 04/28/2016	82	
Yamazaki, Masashi	No Conflicts to Disclose; Submitted on 06/01/2016	31	41, 50
Yonenobu, Kazuo	No Conflicts to Disclose; Submitted on 04/30/2016	88	
Yoshii, Toshitaka	Submitted on: 04/27/2016 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	4, 15, 73	34
Yoshikawa, Hideki	No Conflicts to Disclose; Submitted on 05/01/2016		5
Yu, Wenru	No Conflicts to Disclose; Submitted on 04/22/2016	48	
Yuasa, Masato	No Conflicts to Disclose; Submitted on 05/01/2016		15
Yun, Jonghwa	No Conflicts to Disclose; Submitted on 04/28/2016		4
Zaid, Musa	No Conflicts to Disclose; Submitted on 05/01/2016	34	
Zhang, Yilong	No Conflicts to Disclose; Submitted on 04/30/2016		46
Zhiyun, Li	No Conflicts to Disclose; Submitted on 03/01/2016	25	14
Zhong, Junlong	No Conflicts to Disclose; Submitted on 05/31/2016	25	14
Zhou, Feifei	No Conflicts to Disclose; Submitted on 04/13/2016	55, 85	46

Name	Disclosure Information	Presentation	E-Poster
Zigler, Jack E	Submitted on: 05/02/2016 Aesculap/B.Braun: Paid consultant Coluna: Editorial or governing board DePuy, A Johnson & Johnson Company: Paid consultant Expanding Orthopaedics, Safe Orthopaedics, Spinal Kinetics: Stock or stock Options ISASS: Board or committee member Journal of ISASS: Editorial or governing board K2M: IP royalties Orthofix: Paid consultant Osprey: IP royalties Simplify: Paid consultant Zimmer: IP royalties		23
Zoller, Stephen D	No Conflicts to Disclose; Submitted on 06/27/2016		13

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Podium Presentation Abstracts

Presentation #1

Is Cervical Bracing Necessary after Single and Multi-Level Anterior Cervical Discectomy and Fusion? A Prospective Randomized Study

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Study Design: Prospective randomized controlled trial.

Introduction: ACDF is on of the most common procedures performed on the cervical spine. Graft nonunion and subsidence are complications of the procedure. Rigid cervical collars restrict cervical motion post-operatively in an attempt to prevent such complications, but there is controversy regarding their effectiveness. The purpose of this study is to determine what effect, if any, cervical bracing after ACDF has on rates of subsidence, fusion, and patient reported outcomes.

Methods: The Cervical Spine Research Society Resident Fellow Grant funded this project. Thirty-three consecutive patients undergoing one or two level ACDF surgery were randomized into a group receiving no brace or group receiving a cervical brace for 6 weeks post-operatively. Neck Disability Index (NDI) scores were recorded preoperatively and at 24 months follow-up as a clinical outcome measure. Computed Tomography scans were read 1 year post-operatively to determine fusion rates, and subsidence was measured on follow up lateral cervical radiographs.

Results: Twenty-two patients were in the no-brace group and 22 patients in the brace group, with an average age of 49 and 54, respectively. The no-brace group had a total of 31operative levels, while the brace group had 33 operative levels. There was no statistically significant difference in post-op NDI scores between brace (11.56 ± 8.62) and no-brace (7.28 ± 7.54) group ($p = 0.1969$), as shown in Figure 1. There was no difference in subsidence of all operative levels between the brace ($1.62mm \pm 0.62$) and no-brace ($1.44mm \pm 0.88$) group ($p = 0.5739$), shown in figure 2. Additionally, there was no difference in the fusion rates between the brace (87%) and no-brace (95%) group ($p = 0.5768$).

Conclusions: Our results suggest no advantage in wearing a cervical brace following one or two level ACDF surgery. There is a trend towards improved NDI scores, less subsidence, and increased fusion rates in patients who did not wear a cervical brace during the post-operative period, though these results lack statistical significance.

Thursday, December 1, 2016, 7:11–7:17am CSRS–2016

Presentation #1

Figure 1. Histogram comparing average pre and post-operative NDI scores between groups with and without a cervical brace. Histograms demonstrate the mean of each group and error bars indicate the

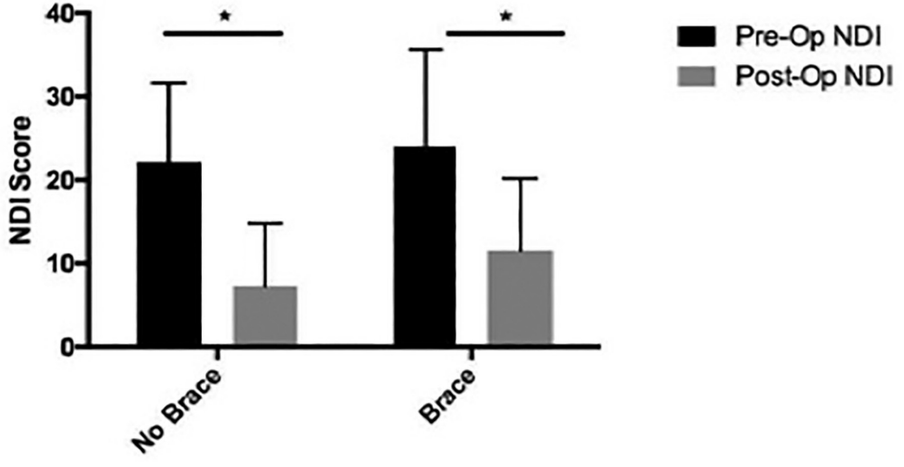
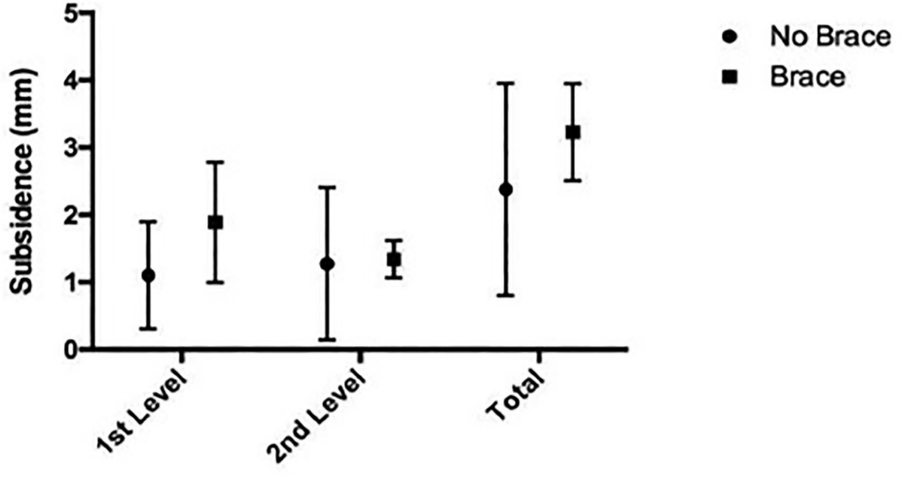


Figure 2. Points comparing the average subsidence of 1st level fused, 2nd level fused, and total subsidence for multi level fusions of patients with and without a cervical brace. Error bars indicate



See Disclosure Index pages 39–89.

Presentation #2

The Effect of Local vs. Intravenous Steroids on Dysphagia and Dysphonia following Anterior Cervical Discectomy and Fusion (ACDF): A Single-Blinded, Prospective, Randomized Control Trial

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Wellington K. Hsu, MD, Chicago, IL
Alpesh A. Patel, MD, River Forest, IL
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Study Design: Prospective randomized controlled study

Introduction: Dysphagia and dysphonia are the most common complications following anterior cervical discectomy and fusion (ACDF). Fortunately, most post-ACDF dysphagia is mild and transient, but in the limited number of patients that develop severe dysphagia it will have profound effects on overall health and surgical outcomes. Severe dysphagia places the patient at higher risk for dehydration, malnutrition, social isolation, aspiration, pneumonia, and death. Previous studies have demonstrated that intravenous (IV) and local steroids can decrease prevertebral soft-tissue swelling, however, no standardized studies have compared the efficacy of local steroid application to controls during ACDF on post-operative dysphagia and dysphonia. We conducted a prospective randomized clinical trial to assess the efficacy of intra-operative steroid administration (intravenous or local) on dysphagia and dysphonia after ACDF.

Methods: 72 patients undergoing ACDF for the treatment of cervical degenerative disease were recruited. Inclusion criteria were patients greater than 18 years undergoing ACDF for the treatment of radiculopathy or myelopathy. Exclusion criteria included: age under 18 years, operations for trauma / infection / tumor / revision, or general metabolic diseases (diabetes, heart disease, renal disease). Patients were randomized into three cohorts: control (no steroid), IV steroid (10 mg one-time intraoperative dose of IV dexamethasone), or local steroid groups (40 mg of triamcinolone placed in the retropharyngeal space directly on the cervical plate). Subjects were blinded from which treatment arm they received. Primary outcomes were measured for dysphagia (Bazaz, Eat-10) and dysphonia (VHI-10) [6-8]. Secondary outcomes include Neck Disability Index (NDI) and Visual Analog Scale (VAS) for neck pain. Patient outcomes were collected pre-operatively, post-operative day 1, week 2, and week 6. Statistical analysis was completed with significance set at $p < 0.05$.

Results: Baseline patient reported outcomes for dysphagia, dysphonia, and neck pain were not significantly different between the groups. Day 1 post-operative patient outcomes scores showed a significant improvement in dysphonia (VHI-10 $p = 0.026$) and neck pain ($p = 0.025$) in the local steroid group (Table 1, Figure 1). There was also a trend towards significant improvement of post-operative Day 1 dysphagia with the local steroid group (Bazaz $p = 0.057$). The local steroid cohort showed significant improvement in dysphagia (Bazaz $p = 0.026$; Eat-10 $p = 0.011$) and neck pain ($p = 0.042$) at 2 weeks post-operative when compared to the other treatment groups. At 6 weeks post-operative the local group had significantly less severe dysphagia (Bazaz $p = 0.001$; Eat-10 $p < 0.001$) when compared to the other treatment groups.

Thursday, December 1, 2016, 7:18–7:24 am CSRS–2016

Presentation #2

Conclusion: Local steroid application at the conclusion of cervical plating in ACDF surgery yields better patient-reported outcomes for dysphagia, dysphonia, and neck pain, when compared to no steroid or IV steroid administration.

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

	Control Group	IV Steroid Group	Local Group	
Pre-op				**p - value**
Patients (#)	18	25	29	
Bazaz: moderate/severe (%)	0%	0%	0%	N/A
Eat-10: severe dysphagia (%)	0%	0%	0%	N/A
Abnormal VHI-10 (%)	5.6%	4.0%	3.4%	1.000
VAS: neck pain (median [IQR])	7.0 [5.25, 7.75]	7.0 [5.0, 8.0]	6.0 [3.0, 8.0]	0.341
NDI (mean % [SD])	39 [18]	33 [17]	34 [20]	0.519
1 Day Post-op				
Patients (#)	17	25	28	
Bazaz: moderate/severe (%)	35.3%	24.0%	7.1%	****0.057**
Eat-10: severe dysphagia (%)	47.1%	32.0%	17.9%	0.105
Abnormal VHI-10 (%)	5.9%	20.0%	0.0%	***0.026**
VAS: neck pain (median [IQR])	7.0 [6.00, 8.00]	5.0 [2.00, 8.00]	5.00 [2.00, 6.00]	***0.025**
NDI (mean % [SD])	27 [13]	26 [16]	26 [18}	0.981
2 Weeks Post-op				
Patients (#)	16	23	29	
Bazaz: moderate/severe (%)	18.8%	17.4%	0.0%	***0.026**
Eat-10: severe dysphagia (%)	25.0%	17.4%	0.0%	***0.011**
Abnormal VHI-10 (%)	18.8%	17.4%	3.4%	0.147
VAS: neck pain (median [IQR])	5.0 [4.00, 7.00]	4.0 [2.00, 5.00]	3.0 [2.00, 5.00]	***0.042**
NDI (mean % [SD])	30 [18]	22 [15]	19 [16]	0.110
6 Weeks Post-op				
Patients (#)	14	21	28	
Bazaz: moderate/severe (%)	35.7%	9.5%	0.0%	***0.001**
Eat-10: severe dysphagia (%)	35.7%	0.0%	0.0%	***<0.001**
Abnormal VHI-10 (%)	7.1%	9.5%	3.6%	0.813
VAS: neck pain (median [IQR])	3.0 [1.25, 6.75]	3.0 [1.00, 5.00]	4.0 [2.00, 6.25]	0.543
NDI (mean % [SD])	22 [18]	20 [15]	22 [18]	0.941

*indicates that the p-value reached clinical significance ($p<0.05$) set value for significance);
**indicates that the p-values is approaching clinical significance
IQR, Interquartile range; SD, standard deviation; % indicates present of patients in given cohort with abnormal patient reported outcomes, (Eat-10 severe dysphagia score>15, Abnormal VHI-10 score>11, Bazaz Classification of moderate or severe dysphagia considered abnormal)

See Disclosure Index pages 39–89.

Presentation #2 (cont.)

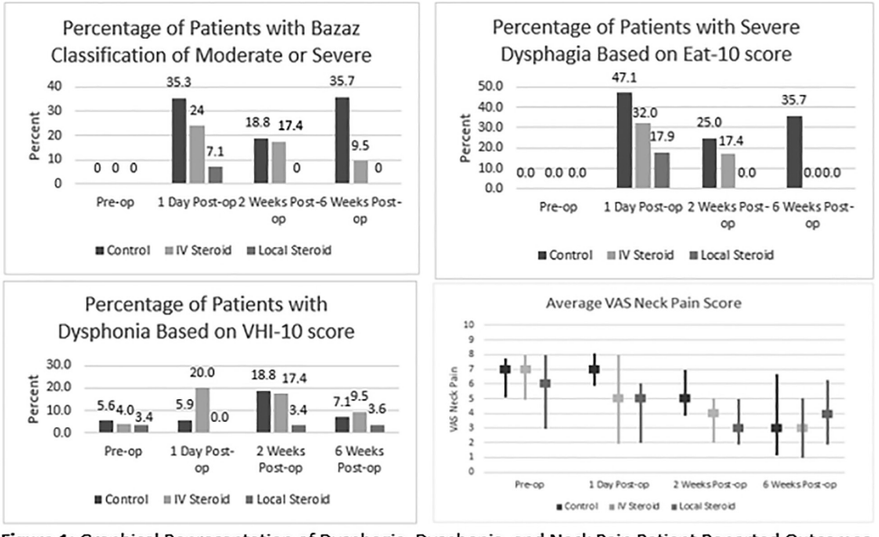

Figure 1: Graphical Representation of Dysphagia, Dysphonia, and Neck Pain Patient Reported Outcomes After by Treatment Arm

• **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 #3

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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Introduction: 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 and Methods: Total of 56 patients undergoing a 1- or 2-level ACDF were randomized to depomedrol (DEPO) or no depomedrol (NODEPO) cohorts, receiving 1cc depomedrol or 1cc saline, respectively, applied to the surgical site using a gel-foam carrier (retroesophageal). The results of the SWAL-QOL questionnaire were compared between cohorts. Using pre- and postoperative lateral radiographs, a ratio of the prevertebral swelling distance to the anterior-posterior diameter of each vertebral body level was calculated for the index level (operative level), 2 vertebral levels above and below to obtain a swelling index. Similarly, the air index was calculated using the tracheal air window diameter. Any changes in these ratios (preoperative, 1-day, 6-weeks, and 12-weeks postoperatively) were compared between cohorts.

Results: Of the 56 patients, 32 patients (57.1%) and 24 patients (42.9%) were randomized to the DEPO and NODEPO groups, respectively. The DEPO cohort demonstrated a higher percentage of smokers (15.6% vs. 0.0%; $p = 0.042$). There were no differences in patient demographics, preoperative characteristics, or the mean change in scaled total SWAL-QOL score between the DEPO and NODEPO patients at any postoperative time point (6-weeks: $p = 0.505$; 12 weeks: $p = 0.487$). Lastly, the mean change in both swelling and air indices were no different between cohorts.

Conclusions: The preliminary results of this prospective, randomized, single blinded study do not demonstrate a significant 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 12-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 dysphagia.

See Disclosure Index pages 39–89.

Presentation #3 (cont.)

Table 1. Baseline characteristics.*

	NODEPO (N = 24)	DEPO (N = 32)	p-value
Age (Mean ± SD, years)	46.6 ± 9.5	50.4 ± 8.3	0.116
Sex (n)			0.140
Female	33.3% (8)	53.1% (17)	
Male	66.7% (16)	46.9% (15)	
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)			**0.042**
Non-smoker	**100.0% (24)**	**84.4% (27)**	
Smoker	**0.0% (0)**	**15.6% (5)**	
Operative Level (n)			0.151
C3-C4	4.2% (1)	6.3% (2)	
C3-C5	4.2% (1)	3.1% (1)	
C4-C5	0.0% (0)	15.6% (5)	
C4-C6	4.2% (1)	15.6% (5)	
C5-C6	16.7% (4)	15.6% (5)	
C5-C7	25.0% (6)	25.0% (8)	
C6-C7	45.8% (11)	15.6% (5)	
C7-T1	0.0% (0)	3.1% (1)	
Number of Operative Levels (n)			0.483
1-level	62.5% (15)	53.1% (17)	
2-level	37.5% (9)	46.9% (15)	
Comorbidity Burden (CCI)	1.5 ± 1.6	1.6 ± 2.0	0.802
Preoperative VAS (Mean ± SD, min)	5.4 ± 2.4	6.6 ± 2.8	0.112

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

Presentation #3

Table 2. Outcomes.*

	NODEPO (N = 24)	DEPO (N = 32)	†p-value
Operative Time (Mean ± SD, min)	39.9 ± 26.6	38.2 ± 22.4	0.986
Estimated Blood Loss (mL)	28.1 ± 8.4	32.0 ± 11.4	0.180
Length of Hospital Stay (hours)	17.4 ± 15.7	17.0 ± 11.8	0.495
SWAL-QOL Results (Mean ± SD) ‡			
Preoperative	94.8 ± 7.1	91.6 ± 9.5	0.268
6-weeks Postoperative	91.5 ± 11.0	89.1 ± 14.9	0.597
12-weeks Postoperative	93.9 ± 7.1	87.8 ± 13.3	0.127
Changes in SWAL-QOL (Mean ± SD) ‡			
Δ Preoperative to 6-weeks	-3.2 ± 12.9	2.8 ± 28.8	0.680
Δ Preoperative to 12-weeks	1.4 ± 7.7	3.8 ± 27.2	0.986

SD = Standard deviation; 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.

See Disclosure Index pages 39–89.

Presentation #3 (cont.)

Table 3. Radiographic outcomes.*

	NODEPO (N = 24)	DEPO (N = 32)	†p-value
Swelling Index Average (Mean ± SD) ∫			
Preoperative	72.9 ± 18.0	60.2 ± 18.2	0.109
1-day Postoperative	91.5 ± 16.8	89.1 ± 19.4	0.614
6-week Postoperative	82.4 ± 20.3	70.8 ± 14.4	0.089
12-week Postoperative	80.0 ± 18.5	70.3 ± 16.6	0.194
Swelling Index Difference (Mean ± SD) º			
1-day Postoperative	22.7 ± 20.6	38.6 ± 16.9	0.811
6-week Postoperative	6.8 ± 8.2	10.0 ± 10.1	0.414
12-week Postoperative	4.0 ± 8.3	9.4 ± 6.8	0.241
Air Index Average (Mean ± SD) ∫			
Preoperative	107.7 ± 11.0	105.4 ± 18.9	0.393
1-day Postoperative	94.9 ± 23.8	98.3 ± 16.5	0.805
6-week Postoperative	109.5 ± 19.0	97.9 ± 21.0	0.311
12-week Postoperative	106.3 ± 17.8	100.0 ± 19.2	0.577
Air Index Difference (Mean ± SD)º			
1-day Postoperative	-10.9 ± 14.2	-7.7 ± 18.5	0.604
6-week Postoperative	-1.4 ± 10.1	-7.3 ± 19.4	0.076
12-week Postoperative	-3.4 ± 8.2	-4.4 ± 16.7	0.421

SD = Standard deviation; 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 #4

A Prospective Comparative Study in Skin Antiseptic Solutions for Posterior Spine Surgeries: Chlorhexidine-Gluconate Ethanol vs. Povidone-Iodine

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Introduction: Surgical site infection (SSI) in spinal surgeries is associated with increased morbidity, mortality, length of hospitalization, and medical costs. Since the patient's skin is a major source of pathogens that can cause SSI, use of effective antiseptic solutions before surgery is important in limiting wound contamination and in preventing SSI. Previous studies have shown that chlorhexidine-gluconate (CHG) is more effective for skin antisepsis than povidone-iodine (PD-I) in general surgeries and joint surgeries. However, to date, few studies have investigated the preoperative antiseptic solutions in spine surgery. Therefore, we conducted prospective comparative study to evaluate the efficacy of two standard antiseptic solutions, CHG and PD-I, in eliminating bacterial pathogens from the surgical site in posterior spine surgeries.

Methods: A total of 190 patients who received posterior spine surgeries were included in this study. Surgical skin preparation solutions were quasi-randomized based on the month when the surgery was performed: 0.5% CHG with ethanol for 98 patients and 10% PV-I for 92 patients. Sterile culture swabs were used to obtain samples from skin adjacent to the planed incision site before preparation, after preparation, and after wound closure. Swab samples were evaluated for bacterial growth on sheep blood agar plates using a semi-quantitative technique. Unpaired t-test and Fisher's exact test were used for statistical analysis. Minimum sample size calculated in the power analysis for skin antisepsis was 168 under the condition of the effect size of 0.22, $\alpha = 0.05$, $\beta = 0.8$.

Results: No difference was found in patients' age, gender, diseases, surgical site (cervical or thoracolumbar), operating time, and intraoperative blood loss between the CHG and PD-I group (Table 1). Prior to surgical skin preparation, bacteria grew on culture of specimens from 83.7% of the patients: no significant difference was found between the CHG (81.5%) and PD-I group (85.7%). The common organisms isolated from surgical sites were Staphylococcus sp., Corynebacterium sp. and Bacillus sp. both in cervical and lumbar spine. After the preparation, there were no significant differences in the culture positive rate between the CHG (3.1%) and PD-I group (5.4%)(Table 2). The culture positive rates were increased after wound closure (pre-ope 4.2, post-ope 8.4%: $p = 0.07$), and the positive samples were more common in cervical spine (15.6%) compared with lumbar spine (6.4%). The positive rates after wound closure in the PD-I group (14.1%) was higher compared with the CHG group (5.1%) ($p = 0.05$). However, no difference was found in infection rates between the 2 groups (CHG:1.0%, PD-I: 3.3%, $p = 0.29$).

Presentation #4 (cont.)

Conclusions: While CHG ethanol and PD-I were equally effective to eliminate the bacterial flora from the surgical site, CHG ethanol showed more favorable long-lasting effect for skin antisepsis in posterior spine surgeries.

Table 1. Patients' data

	CHG-ethanol (n=98)	PD-I (n=92)	*P*
Age	65.5±14.0	66.7±15.2	0.58
Gender (M/F)	49/49	40/52	0.23
Cervical/Thoracolumbar	16/82	16/76	0.50
Operating time	219.7±129.1	232.8±129.5	0.49
Intraop blood loss	374.5±465.8	461.2±617.7	0.28

Mean ± standard deviation

Table 2. Culture positive rates

	CHG-ethanol (n=98)	PD-I (n=92)	*P*
Before preparation	84 (85.7%)	75 (81.5%)	0.28
After preparation	3 (3.1%)	5 (5.4%)	0.33
After wound closure	5 (5.1%)	13 (14.1%)	0.05

Presentation #5

Prospective Study of Deep Vein Thrombosis in Patients Associated with Degenerative Cervical Spine Surgery

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Introduction: Deep vein thrombosis (DVT) is a potentially fatal complication because of the risk of pulmonary thromboembolism development. Prevention, early detection and timely treatment of DVT are very important during the perioperative period of spine surgery. It is reported that DVT has a high incidence in patients with spinal cord injury. However, there have been few reports on perioperative DVT in patients undergoing degenerative cervical spinal surgery. The purpose of this study is to elucidate the incidence and risk factors for DVT associated with degenerative cervical spinal surgery.

Materials and Methods: Between April 2008 and March 2015, 761 patients who underwent cervical spinal surgery in our hospital were enrolled in this study. The exclusion criteria were spinal cord injury, traumatic disease, infectious disease, inflammatory disease including rheumatoid arthritis, neoplastic disease and receiving anticoagulation medication. Leg vein ultrasonography was carried out performed preoperatively and 4 days after surgery. All patients received treatment with intermittent pneumatic compression and elastic stockings for primary DVT prophylaxis. No anticoagulation medications were used for DVT prophylaxis. Statistical analysis was performed using binomial logistic regression analysis and Fisher exact probability test.

Results: A total of 289 patients with cervical degenerative disease undergoing cervical spinal surgery (203 males, 86 females; average age: 66.5 yr) met the inclusion criteria in this study. The overall incidence of DVT was 3.1% (9/289) in degenerative cervical spinal surgery. All 9 cases with positive DVT were women and had distal DVT without proximal DVT. There were no patients with clinical signs of DVT. The incidence of preoperative DVT was 1.1% (3/284, excluding 5 cases of not examined). The incidence of postoperative DVT was 2.1% (6/286, excluding 3 cases of preoperative positive DVT cases). Statistically significant risk factor for preoperative DVT included female sex ($P = 0.024$) in the univariate analysis. The risk factors related with the surgery, including operation time, intraoperative blood loss and surgical approach, were not significantly associated with postoperative DVT. The univariate analysis showed that statistically significant risk factors for perioperative DVT included female sex ($P < 0.001$), old age ($P = 0.04$), low Japanese Orthopaedic Association score ($P = 0.03$), rapidly progressive myelopathy ($P = 0.001$) and Frankel grade A-C ($P = 0.01$). The multivariate analysis showed that rapidly progressive myelopathy ($P = 0.04$) was risk factor.

Conclusion: The incidence of perioperative DVT in patients undergoing degenerative cervical spine surgery was 3.1%. Female sex, advanced age, gait inability and rapidly progressive myelopathy could be at high risk of developing DVT during the perioperative period of cervical spine surgery. This result indicates that screening for DVT is needed in patients who are at high risk for DVT.

See Disclosure Index pages 39–89.

Presentation #6

Long-Term Clinical Outcomes of Cervical Disc Arthroplasty: A Prospective, Randomized, Controlled Trial

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Introduction: Degeneration of the cervical discs causing neurological symptoms is a frequent source of surgical intervention, commonly treated with ACDF. Positive clinical outcomes are associated with arthrodesis techniques, yet there remains a long-term concern for adjacent segment change. Cervical disc arthroplasty has been designed to mitigate some of the challenges associated with arthrodesis while providing for a similar positive neurological outcome. As data has been collected from numerous prospective U.S. FDA IDE trials, longer term outcomes regarding adjacent segment change may be examined. This investigation is designed to prospectively compare the 7 and 10-year outcomes of cervical arthroplasty to anterior cervical discectomy and fusion (ACDF).

Materials and Methods: As part of an FDA IDE trial, a single center collected prospective outcomes data on 47 patients randomized in a 1:1 ratio to single-level, subaxial ACDF or Bryan® arthroplasty (Medtronic Sofamor Danek, Memphis, TN). Assessments over the 10-year period were prospectively collected and recorded including NDI and VAS neck and arm pain scales. Data was statistically analyzed and reported at 7 and 10-year intervals.

Results: Success of both surgical interventions remained high at the 10-year interval. Both arthrodesis and arthroplasty demonstrated statistically significant improvements in NDI, VAS neck and arm pain scores at all intervals including 7 and 10-year periods. Arthroplasty demonstrated an advantage in comparison to arthrodesis as measured by final 10-year NDI score (8 vs. 16, $p = 0.0485$). Patients requiring re-operation were higher in number in the arthrodesis cohort (32%) in comparison to arthroplasty (9%) ($p = 0.055$).

Conclusions: At 7 and 10 years, cervical arthroplasty compares favorably to ACDF as defined by standard outcomes scores in a highly selected population.

Presentation #7

• Similar Outcomes of Hybrid TDR/ACDF at 5-Year Follow-up

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• Synthes Prodisc, LDR Mobi-C

Introduction: Cervical total disc replacement, TDR, is increasingly being accepted by third party payers in the U.S. as a surgical treatment option for patients who have failed conservative care of single level conditions. However, coverage for multilevel disease, which is more common, is still restricted to fusion surgery. The purpose of this study was to compare off-label hybrid TDR/ACDF to multilevel ACDF for multilevel cervical disease.

Materials and Methods: Four cohorts of patients were evaluated pre- and postoperatively with self-assessment patient-based outcomes questionnaires (VAS pain for neck and arm, pain drawing, disability, and use of pain medication). All patients had a minimum of three years of follow-up. Multilevel TDR/ACDF hybrid cohort, $n = 43$, were compared to multilevel ACDF cohort, $n = 90$. Control groups were included consisting of single level TDR and ACDF patients to validate the study against published single level TDR vs. ACDF studies. Secondary surgeries were also analyzed for all cohorts.

Results: There were no demographical differences between the two cohorts. Both hybrid TDR/ACDF and multilevel ACDF groups had similar preoperative pain and disability and both had significantly improved outcomes after surgery. There were no differences in outcomes for any of the measures between hybrid and multilevel ACDF patients. Pain medication usage was decreased; preoperatively in the hybrid group 50% took narcotics and 81% NSAIDs. Two years postop, 13% used narcotics and 45% used NSAIDs. Secondary surgeries were similar for the multilevel cohorts. At 5 years postop, adjacent level surgery was 9% in both the hybrid and the multilevel ACDF cohort. Pseudarthrosis repair was 9% vs. 11% in the hybrid and multilevel ACDF cohorts respectively. Although implant costs were less for the single level TDR patients compared to single level ACDF; for the multilevel case, costs were greater for the hybrid relative to the multilevel ACDF group. The study appears valid in that our single level TDR vs ACDF results were similar to that reported in multiple prior studies and found slightly better outcomes for single level cervical TDR relative to ACDF.

Conclusions: Hybrid TDR/ACDF, used off-label, gives comparable outcomes to multilevel ACDF patients at short term follow-up. Secondary surgeries due to pseudarthroses and adjacent segment disease was similar in both multilevel cohorts at the 5-year follow-up period. A hybrid procedure is a viable treatment option for patients with multilevel cervical disease.

See Disclosure Index pages 39–89.

Presentation #8

Prestige Cervical Disc Arthroplasty vs. Anterior Cervical Discectomy / Fusion: 84 Month IDE Outcomes of Two Level, Prospective, Randomized Clinical Trial

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Introduction: Cervical disc degeneration remains one of the most common spinal disorders requiring treatment. Patients failing conservative care have frequently been treated with anterior cervical discectomy and fusion (ACDF). Concern regarding rapid development of adjacent segment degeneration (ASD) has lead to the rapid development of motion sparing cervical disc arthroplasty prosthesis. Cervical disc degeneration requiring surgical management is contiguous at two levels in up to 40% of patients. Meta analysis of single level CDA vs. ACDF have shown superiority with lower rates of adjacent segment degeneration and fewer adjacent segment reoperations in the CDA group. Five year follow up of two level Cervical Disc Arthroplasty (CDA) vs. ACDF IDE study show similar findings as one level. There is greater probability of success for adjacent segment degeneration and lower reoperation at adjacent segments in the CDA group. The current study evaluates the outcomes and results in efficacy and safety of two level contiguous cervical arthroplasty vs. ACDF in a level 1 IDE control, randomized, prospective trial. CDA group has superiority in results compared to anterior cervical discectomy and fusion (ACDF).

Materials and Methods: A FDA approved level one clinical trial was carried out at 30 centers in the US comparing the radiographic and clinical results of a low profile ball and trough titanium-ceramic prosthesis vs. ACDF in 397 total patients with C3-7 two level radiculopathy and or myelopathy. All patients have failed at least 6 weeks conservative care and were randomized to investigational CDA (209) vs. Control ACDF (188). Patient follow up was 7 years (84 months). Bayesian statistical analysis was used to evaluate primary endpoints of overall success as well as safety and efficacy endpoints. The overall success is a composite of the following criteria: 1.) neck disability index (NDI) improvement of ≥ 15 points, 2.) maintenance or improvement in neurologic status, 3.) No serious adverse events caused by the implant or both the implant and the surgical procedure, no additional surgery (non elective implant removal, revision surgery, or supplemental fixation). Other endpoints included neck and arm pain numeric rating, work status, patient satisfaction, disc height, SF-36, and adverse events (AE).

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Presentation #8

Results: Clinical and radiographic follow up was 73.7% for the investigational CDA group and 67% for the control ACDF group. In the overall success category the CDA outcomes were statistically superior to ACDF (observed rate of 78.6% vs. 62.7%; Posterior Probability of Superiority (PPS) = 99.8%). The neurological success observed rate (91.6% vs. 82.1%; PPS = 99.0%) and the NDI success observed rate (87.0% vs. 75.6%; PPS = 99.2%) both were superior for the CDA vs. ACDF. Both groups have statistical improvement from base line for both neck and arm pain scores, neurologic success, SF-36 scores, and NDI. CDA and ACDF groups had no statistical differences in overall implant / surgical procedure related adverse events (26.6%, 27.7% respectively). When considering grade 3-4 adverse events, CDA group had statistically fewer (3.2% vs. 7.2%, Log Hazard Ratio (LHR) 95%, Bayesian Credible Interval (BCI): -1.19(-2.29 – 0.15)) secondary surgical procedures at the index level in the CDA group were less in the CDA group vs. ACDF (4.2% vs. 14.7%, LHR = 95%, BCI: -1.29 (-2.12, -0.46)). The CDA group vs. ACDF group had fewer adjacent segment surgeries (6.5% vs. 12.5%). The CDA group maintained angular motions of 6.5°superiorly and 6.3° inferiorly. Heterotopic ossification grade 4 occurred in 8.6% of superior level and 7.3% of inferior level patients.

Conclusion: Seven year outcomes of this low profile cervical disc arthroplasty compared to ACDF for cervical degenerative disc disease at two continuous levels had overall success superiority and shows CDA to be a safe and effective treatment while allowing maintenance of motion at both levels.

See Disclosure Index pages 39–89.

Presentation #9

Elevated Risk for Repeated Surgery after ADR Compared to ACDF in a Cohort of 715 Patients–A Retrospective Study with Minimum Five-Year Follow-up

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Introduction: Rates of repeated surgery after artificial disc replacement (ADR), has in several comparative studies shown to be lower than after fusion (ACDF) surgery in the cervical spine. The main causes for reoperation after ACDF has shown to be adjacent segment disease (ASD) and pseudarthrosis. One of the aims with ADR is to maintain motion and thus prevent ASD, which could be a long-term side effect of ACDF. Long-term side effects from ADR surgery as wear, instability, migration and heterotopic ossification also must be considered. The purpose of this retrospective study was to compare the incidence of repeated surgery between the different surgical techniques in a cohort with long-term follow-up.

Material and Methods: 715 patients treated with ACDF, ADR or a posterior procedure (PP) because of cervical radiculopathy or myelopathy over a time period of ten years (2000–2010), were followed regarding rates of repeated surgery. Repeated surgery was defined as any secondary cervical surgery. Cause for repeated surgery as well as choice of new intervention was evaluated. Data was collected from a single-center setting.

Results: 79 (11%) patients underwent a new operation during follow-up, which was minimum five years. Average time between primary and secondary intervention was 35 months. 50/504 (10%), 27/172 (15%) and 2/39 (5%) were registered with a secondary intervention in the ACDF group, ADR group and PP group respectively. There was a statistically significant higher risk of repeated surgery in the ADR group compared to the ACDF group, OR 1.7 (C.I. 1.06–2.8), $p = 0.03$. Risk for repeated surgery at index level was even higher for ADR, OR 5.1 (C.I. 2.4–10.7), and $p < 0.001$. Among the patients who underwent a second intervention, operation because of adjacent segment disease (ASD) were more likely in the ACDF group, OR 3.1 (C.I. 1.1–8.6), $p = 0.03$. Reoperation rate because of ASD in the whole cohort did not differ between ACDF and ADR groups, $p = 0.40$. Nor could any statistically significant difference be seen in comparison between the PP group and the ADR or the ACDF group regarding reoperation for ASD.

Conclusion: Artificial disc replacement showed higher risk for repeated surgery in this cohort and was not protective against secondary intervention because of adjacent segment pathology. It was more common with repeated surgery at the index level after disc replacement, indicating more implant related problems.

Presentation #10

Artificial Disc Replacements do Not Prevent Adjacent Segment Degeneration in the Cervical Spine

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Introduction: Adjacent segment degeneration (ASD) is degenerative changes in the level immediately adjacent to a fused level. It has been described to be a consequence of increased stress in the adjacent disc as a side effect of cervical immobilization. Artificial disc replacements (ADR) have been developed to preserve motion in the index level and subsequently prevent development of ASD. There are no sufficient data that they actually succeed with that and the question remains if ASD is caused by the influence of the fusion or by intrinsic disc aging processes. The aims of this study were to compare two surgical treatment methods for cervical radiculopathy, fusion and ADR, regarding development of symptomatic and radiologic ASD as well as reoperations for ASD, at a five-year follow-up.

Methods: A prospective randomized controlled study with 151 patients undergoing surgery for cervical radiculopathy due to degenerative disc disease (DDD) was performed. The patients were randomized to either anterior decompression and fusion (ACDF) or anterior decompression and insertion of an ADR. There were 73 men and 78 women with the mean age of 46.85 years. MRI and neurologic examination was done preoperatively and at five years. Reoperations for ASD were also accounted for. A neuroradiologist examined all the MRI´s according to a five level grading system describing the nucleus signal intensity, the nucleus structure, distinction of nucleus and annulus and the disc height. Symptomatic ASD was defined as radiculopathy confirmed with a neurologic examination and consistent with degenerative changes on MRI at the five-year follow-up. Fisher´s exact test was used for comparison between groups according to symptomatic ASD and a two-sample t-test compared the radiologic ASD measured as delta-MRI grade in the two groups.

Results: 26 patients were lost to follow-up and in 13 patients the quality of the MRI was not sufficient for the grading assessment, remaining 112 patients to analyze. There were 10 patients, 3 females and 7 males, with symptomatic ASD in the ACDF group compared to 16 patients, 10 females and 6 males, in the ADR group. The difference was not statistically significant, $p = 0.66$. The mean increase in degeneration grade between preoperative MRI and five years MRI was 0.67 in the ACDF group and 0.39 in the ADR group. That was statistically significant with a p-value of 0.015. Five patients in the ACDF group and five patients in the ADR group had been reoperated for ASD within the five year follow up.

Conclusions: There are no differences in the development of symptomatic ASD five years after surgery with either ACDF or ADR. An increase of radiologic ASD seen on MRI, disregarding if the patients have symptoms or not, is more frequent in the ACDF group. The same amount of patients in the ACDF- and ADR group has so severe ASD that they have to go through with a second surgery within five years.

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Presentation #11

Tobacco Smoking and Outcomes of Decompressive Surgery in Patients with Symptomatic Degenerative Cervical Myelopathy

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Introduction: Tobacco smoking has been associated with poor outcomes following surgery for cervical radiculopathy. However, the impact of tobacco smoking on outcomes following surgery for degenerative cervical spondylotic myelopathy (DCSM) has not been extensively evaluated.

Materials and Methods: This study analyzed prospectively-collected data from two large multicenter international cohort studies. Outcome measures were preoperative smoking status, modified Japanese Orthopedic Association scale (mJOA), Nurick score, Neck Disability Index (NDI), Short Form 36v2 (SF-36v2™), and the 30-meter walk test (30MWT). Analysis of Covariance was used to evaluate differences in outcomes at 12 months between smokers and nonsmokers while controlling for relevant baseline characteristics.

Results: 749 patients with symptomatic DCSM underwent surgical decompression at 24 international sites. There were 547 (73%) nonsmokers and 202 (27%) smokers. After imputation of missing 12-month scores, 694 (92.66%) subjects had 12-month data. Smokers were younger (average 53.40 vs 57.42 years) and had worse preoperative NDI, SF-36v2 Physical Component Score (PCS) and SF-36v2 Mental Component Score (MCS) ($p < 0.1$). There were no differences in gender, race, symptom duration, etiology, number of operated levels, disease severity, or complication or reoperation rates. At 12 months, improvements in mJOA, NDI, and SF-36v2 PCS outcomes were 15.59%, 31.61%, and 28.57% lower in smokers compared to nonsmokers. Following adjustment for confounders, these differences remained significant.

Conclusions: Preoperative tobacco smoking is strongly associated with suboptimal clinical, functional, and quality of life outcomes in patients undergoing surgery for DCSM. While both nonsmokers and smokers benefited from surgical decompression, the extent of improvement was higher in nonsmokers than smokers.

Presentation #12

Comparative Effectiveness between Laminectomy with Fusion and Laminoplasty for the Treatment of Multilevel Cervical Spondylotic Myelopathy

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Introduction: The optimal management of multilevel cervical spondylotic myelopathy (CSM) remains unknown. Both laminectomy with fusion and laminoplasty have been demonstrated to offer a clinical benefit in small retrospective investigations. However, given the cost of spinal fusion, laminoplasty may represent a more cost-effective alternative that is equally efficacious.

Methods: A retrospective cohort study was conducted among patients undergoing cervical decompression for the treatment of multilevel CSM. The EQ-5D, PDQ, and PHQ-9 instruments were prospectively-collected between 2008 and 2015. These instruments served as measures of overall quality of life (QOL), pain-related disability, and depression. Postoperative QOL improvement exceeding the EQ-5D minimum clinically important difference (MCID) was the primary outcome. Secondary outcomes included the total surgical episode of care cost, PDQ MCID, and PHQ-9 MCID. The surgical episode of care was defined in three periods: 30 days prior to admission, the index admission, and discharge to 365 days after admission. To present costs from the payer's perspective, costs were normalized to national Medicare reimbursement and presented in 2014 USD. Unpaired continuous and categorical data were compared via Wilcoxon rank-sum and Fisher's exact tests, while paired data were compared with Wilcoxon signed-rank tests. Multivariable logistic and log-transformed linear regression were used to model EQ-5D MCID and total episode of care costs.

Results: 186 patients were eligible for inclusion; among these, 142 (76%) underwent laminectomy with fusion, while 44 (24%) underwent laminoplasty. No significant differences in demographic or comorbid characteristics were observed. Preoperatively, the mean EQ-5D index was marginally greater in the laminoplasty cohort (0.530 vs. 0.581, $p = 0.17$). Similarly, mean EQ-5D perceived health (41 vs. 50, $p = 0.06$), PHQ-9 (4.7 vs. 2.9, $p = 0.20$), and total PDQ (41 vs. 31, $p = 0.47$) demonstrated poorer preoperative QOL in the laminectomy cohort. Within 30 days prior to admission, median disease-specific costs were not significantly different between cohorts ($818 vs. $716, $p = 0.21$). However, median costs for the index admission were significantly greater among patients undergoing laminectomy ($25,888 vs. $19,427, $p < 0.001$). Postoperatively, mean EQ-5D index improved to 0.592 ($p = 0.02$) and 0.664 ($p = 0.01$) in the laminectomy and laminoplasty cohorts, respectively. The proportion of patients achieving an EQ-5D MCID did not significantly differ between cohorts (36% vs. 30%, $p = 0.47$). Following multivariable logistic regression, surgical type was not significantly associated with EQ-5D MCID (laminectomy vs. laminoplasty: OR 0.86, $p = 0.70$). In the period following discharge, costs were not significantly different between cohorts ($3,450 vs. $3,424, $p = 0.46$). However, total episode of care costs were greater in the laminectomy with fusion cohort ($34,718 vs. $25,260, $p < 0.001$). Following multivariable linear regression, total episode of care costs remained significantly greater in the laminectomy cohort ($\beta = 0.572$, $p < 0.001$), corresponding to a mean difference of $16,392.

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Presentation #12 (cont.)

Conclusions: Poorer preoperative QOL was observed among patients undergoing laminectomy with fusion relative to laminoplasty, and therefore these populations may differ with respect to expected surgical benefit. However, the proportion of patients achieving a clinically-relevant QOL improvement did not significantly differ, suggesting similar efficacy. After controlling for differences in baseline characteristics, laminoplasty appeared to be more cost-effective relative to laminectomy with fusion.

Table 1. Patient and Operative Characteristics

Statistic	Laminectomy + Fusion	Laminoplasty	P Value
No. Patients	142 (76)	44 (24)	
Age (years)	65 ± 11	63 ± 12	0.24
Male	85 (60)	34 (77)	0.10
Married	78 (55)	31 (70)	0.32
Caucasian	112 (79)	35 (80)	0.96
BMI	29 ± 7	28 ± 10	0.83
CCI ≥ 2	43 (30)	9 (20)	0.25
Length of Stay (days)	3 [2–6]	3 [2–4]	0.04
Discharge Status			0.05
Home	40 (28)	20 (45)	
Home Health	18 (13)	10 (23)	
SNF	47 (33)	7 (16)	
Rehabilitation	35 (25)	7 (16)	
Other	2 (1)	0 (0)	
Spinal Disease			
Spinal Stenosis	51 (36)	17 (39)	0.74
Scoliosis	24 (17)	7 (16)	0.88
Kyphosis	16 (11)	4 (9)	0.79
Spondylosis	56 (39)	15 (34)	0.52
Spondylolisthesis	29 (20)	7 (16)	0.50
Degenerative Disc Disease	55 (39)	18 (41)	0.80
Disc Herniation	12 (8)	8 (18)	0.08
Episode of Care Costs	$34,718 [27,936–52,098]	$25,260 [15,211–35,875]	< 0.001
Pre-Admission (1 month)	$818 [535–1,537]	$716 [199–1,613]	0.21
Admission	$25,888 [22,883–32.898]	$19,427 [13,860–32,029]	< 0.001
Post-Discharge (1 year)	$3,450 [859–6,497]	3,424 [859–6,497]	0.46

Values are presented as number (percent), mean ± standard deviation, or median [interquartile range]. No., number; CCI, Charlson Comorbidity Index; BMI, Body Mass Index. SNF, Skilled Nursing Facility.

Presentation #12

Table 2. Quality of Life Outcomes

Health Status Measure	Preoperative			Last Follow-Up		
	Laminectomy + Fusion	Laminoplasty	P-Value	Laminectomy + Fusion	Laminoplasty	P-Value
EQ-5D Index	0.530 ± 0.245	0.581 ± 0.244	0.17	0.592 ± 0.265	0.664 ± 0.213	0.06
MCID	-	-	-	51 (36)	13 (30)	0.47
Perceived Health Status	41 ± 28	50 ± 29	0.06	57 ± 25	64 ± 18	0.21
MCID	-	-	-			
PHQ-9	4.7 ± 6.4	2.9 ± 5.5	0.20	4.4 ± 5.6	4.3 ± 5.1	0.89
MCID	-	-	-	11 (8)	1 (2)	0.30
PDQ Functional	27 ± 32	21 ± 26	0.43	31 ± 28	26 ± 25	0.26
PDQ Psychosocial	14 ± 18	11 ± 15	0.57	17 ± 16	15 ± 15	0.53
PDQ Total	41 ± 49	31 ± 40	0.47	48 ± 42	40 ± 39	0.29
MCID	-	-	-	21 (15)	9 (20)	0.36
QOL Follow-up (mo.)	-	-	-	13 ± 12	10 ± 11	0.07

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Presentation #13

Comparisons of Anterior and Posterior Surgery for Cervical Spondylotic Myelopathy– A Propensity Score Matched Analysis using AOSpine CSM North America and International Database

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Introduction: Both anterior and posterior approaches are established as decompression for cervical spondylotic myelopathy (CSM) with similarly optimal neurological recovery. They are often chosen by surgeons' preferences based on the factors including the patients' history, radiographic features of spinal cord compression and 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 (Fehlings, Spine 2013). Designing a randomized controlled trial for surgical decision making is challenging due to ethical constraints. The objective of the present study is to compare the postoperative outcome between anterior and posterior decompression surgery for CSM by the propensity score matched analysis using the multicenter prospective database.

Materials and Methods: AOSpine CSM North America and International studies are prospective, multicenter databases for surgical CSM patients, which enrolled 278 and 479 consecutive cases in 12 and 16 sites, respectively. 59.0% of patients were treated anteriorly and 37.9% were treated posteriorly. A minority (3.0%) underwent a 2-stage anteroposterior surgery and was excluded from the analysis. Patient demographic data, pre- and 2-year post-operative radiographic images (MRI and x-ray), surgical details, pre- and post-operative neurological status and complication data were reviewed. Among them, age, sex, body mass index, the spectrum of degenerative changes that contributed to the spinal cord compression investigated in pre-operative MRI (single-level disc pathology, multi-level disc pathology, enlargement of PLL, enlargement of LF, subluxation / listhesis, congenital fusion and number of compression levels), C2-7 Cobb angle on pre-operative x-ray and pre-operative mJOA score were used in multiple logistic regression analysis to determine the propensity score for anterior approach for decompression. One-to-one matching was performed to adjust for patients' background characteristics, and neurological recovery and spinal alignment and complication rates were compared between anterior and posterior group.

Presentation #13 (cont.)

Results: 260 cases were included in propensity score calculation, and one-to-one matching resulted in 40 pairs of anterior and posterior surgery. Operation time (173 vs. 173 mins, $p = 0.76$), length of stay (12.0 vs. 9.3 days, $p = 0.57$), post-operative mJOA (15.0 vs. 14.9, $p = 0.67$), recovery rate of mJOA (46.5% vs. 47.3%, $p = 0.85$), SF-36 PCS (41.6 vs. 41.2, $p = 0.85$) and NDI (21.8 vs. 22.1, $p = 0.75$) were not statistically significantly different between anterior and posterior surgery. The differences in postoperative C2-7 Cobb angle (15.5° vs. 10.4°, $p = 0.14$), T1 slope – cervical lordosis mismatch (34.7° vs. 28.2°, $p = 0.09$) and C2-7 sagittal vertical axis (26.5 vs. 26.6 mm, $p = 0.45$) did not reach statistical significance. Dysphagia was only reported in anterior group (2.5% vs. 0%), and C5 palsy was only reported in posterior group (2.5% vs. 0%). Perioperative complications were equally reported in both groups (10% vs. 10%).

Conclusion: Anterior and posterior decompression for CSM showed similar post-operative neurological recovery and outcomes, although the spectrums of complications were different.

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Presentation #14

Postoperative Walking Ability of Non-Ambulatory Cervical Myelopathy Patients

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Introduction: Many researchers have reported the outcome after surgical treatment in cervical myelopathy, however, regarding to severe gait disturbance, what extent of improvement could be obtainable has not been clarified yet. We investigated the postoperative improvement of the ambulatory level and prognostic factors in non-ambulatory patients with cervical myelopathy.

Materials and Methods: A total of 131 non-ambulatory patients surgically treated due to cervical myelopathy (78 males, 53 females; mean age 71.5 years) were followed for an average of 3.0 years (range 1.0–8.6 years). Their walking ability at the follow-up period was compared to the preoperative condition by Japanese Orthopaedic Association (JOA) scores and lower-extremity function subscores (L/E subscores); graded "excellent" (2 points or more), "good" (1.5 points), "fair" (one point), and "poor" (0.5 or 0 points). Disease durations (from the onset of myelopathy symptoms or gait disturbance to the time of surgery) were also investigated. The data were analyzed by the Wilcoxon signed-rank test and the chi-squared analysis ($p < 0.05$).

Results: Preoperative L/E subscore was one point in 71 patients, 0.5 in 30 patients, and 0 in 30 patients. The mean L/E subscore improved significantly from 0.7 to 1.6 points ($p < 0.01$). Fifty patients were graded as "excellent" (38%) and 21 patients as "good" (16%), indicating 54% of the improvement of non-ambulatory condition as to walk without support at the follow-up period. Seventy one patients whose preoperative L/E subscores presented one point improved significantly better than the other 60 patients (preoperative L/E subscores were less than one point), where the mean L/E subscore was 1.7 and 1.4 points respectively ($p < 0.05$). On the assessment of the 60 non-ambulatory patients even with any support (preoperative L/E subscore; 0.5 or 0 points), 26 patients (43%) recovered enough to walk without support and 17 patients (28%) were graded as "excellent". Of those 60 patients, 17 patients graded as "excellent" had shorter durations of myelopathy symptoms and/or gait disturbance (7.9 and 3.8 months respectively) than the others (29.5 and 8.9 months respectively) ($p < 0.05$). In these 60 patients, ROC curve showed the cut-off values of the duration of myelopathy symptoms and gait disturbance provided the improvement to "excellent" were three and two months. Twelve of 22 patients operated within three months from the onset of myelopathy were evaluated as "excellent", which was significantly high compared to five of 38 patients operated after three months ($p < 0.01$). Likewise, the onset of gait disturbance influenced their recoveries significantly in the patients operated within two months (12 of 27 patients) compared to after two months (5 of 33 patients) ($p < 0.01$).

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Presentation #14

Conclusion: We demonstrated that 54% of non-ambulatory patients due to cervical myelopathy recovered up to the level without need for a support after surgery. To expect better walking ability, surgery should be performed while walking ability is reserved. Also, we concluded surgical treatment should be performed within three months after the onset of myelopathy or two months after the onset of gait disturbance for obtaining improvement from non-ambulatory condition with imperative support to stable gait (L/E subscore; 2 points or more).

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Presentation #15

Impact of Preoperative Cervical Sagittal Balance on Surgical Treatment for Cervical Spondylotic Myelopathy Caused by Ossification of the Posterior Longitudinal Ligament

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Introduction: Recently, cervical sagittal balance has received increased attention as an important determinant of radiological and clinical outcomes after surgery. However, little is known about the precise impact of cervical sagittal balance on surgical outcomes, especially for patients with cervical myelopathy caused by ossification of the posterior longitudinal ligament (OPLL). We retrospectively investigated the surgical outcomes of cervical myelopathy caused by OPLL with special attention to the concept of the cervical sagittal balance.

Materials and Methods: The study included a total of 97 consecutive patients (78 male, 19 female; mean age 64.3 years) who underwent surgery for cervical myelopathy caused by OPLL at our hospital from 2008 and completed at least 1-year of follow-up. The average follow-up period was 3.1 years. We selected surgical procedures as follows: (1) For patients with massive OPLL or preoperative kyphotic cervical alignment, we performed anterior decompression and fusion with floating method (ADF) as the 1st choice, and posterior decompression and fusion (PDF) as the 2nd choice. (2) For patients with slight OPLL and normal cervical alignment, we performed laminoplasty (LAMP). ADF was performed in 39 cases, PDF in 18 cases and LAMP in 40 cases. Cervical lateral x-ray images taken in the neutral standing position were evaluated preoperatively and at the final follow-up visit. Radiographic measurements included the following: (1) CSVA, which was measured as the distance between a plumb line dropped from the anterior margin of the external auditory canal and the posterior-cranial corner of the C7 vertebral body, (2) CL (C2-7 lordotic angle) and (3) C7 slope. Clinical results were evaluated using the Japanese Orthopedic Association scoring system for cervical myelopathy (C-JOA score). We divided patients into two groups based on the preoperative CSVA: the Balance (CSVA $<$ 40 mm) and Imbalance (CSVA $\geq$ 40 mm) groups.

Results: Sixty-nine patients were in the Balance group, and 28 patients were in the Imbalance group. In the Balance group, none of the three operations had an effect on the CL. In contrast, in the Imbalance group, while ADF and PDF had no effect on the CL, LAMP worsened the CL postoperatively (Figure 1). None of three operations had an effect on the C7 slope in either group. The recovery rates of the C-JOA scores in the Balance group showed no significant differences among the three operations; however in the Imbalance group, LAMP resulted in worse recovery rate of the C-JOA score than ADF or PDF (Figure 2). In 7 cases where LAMP was performed in the Imbalance group, postoperative cervical kyphosis was observed in 4 cases (57.1%), and recurrence of myelopathy was observed in 3 cases (42.9%).

Conclusion: LAMP is not suitable for patients with cervical myelopathy caused by OPLL who have cervical sagittal imbalance, even in cases with normal preoperative alignment and slight OPLL.

Thursday, December 1, 2016, 9:17–9:23 am CSRS–2016

Presentation #15

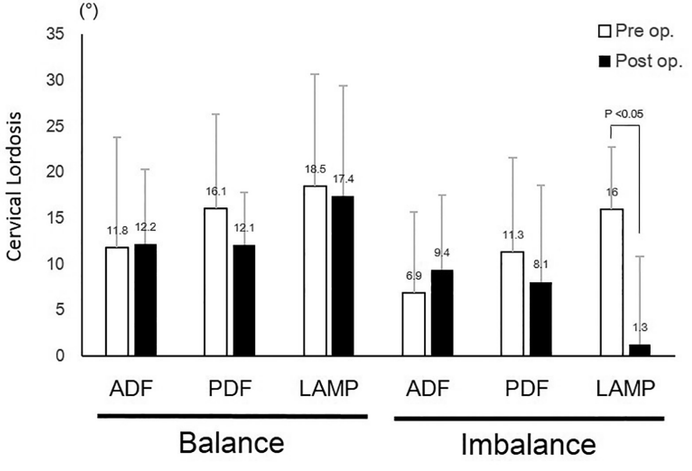

Figure 1

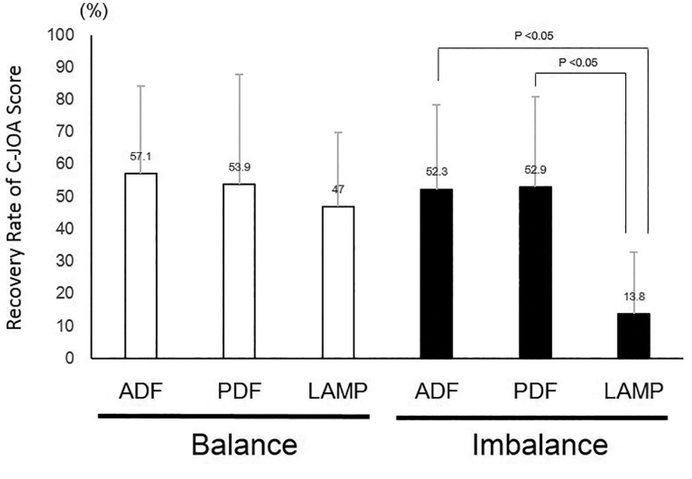

Figure 2

See Disclosure Index pages 39–89.

Presentation #16

A Health Economic and Patient-Centered Analysis on the Value of Surgery for Degenerative Cervical Myelopathy: Strong Support for Surgical Intervention

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Michael G. Fehlings, MD, PhD, Toronto, ON, Canada

Introduction: Degenerative Cervical Myelopathy (DCM) is the most common cause of non-traumatic spinal cord impairment in adults. Surgery has been shown to improve neurological symptoms and functional status, but it is costly. As healthcare sustainability concerns rise, the value of care has come to the forefront of policy decision-making. Evidence for both health related quality of life outcomes and costs are needed to inform medical policies. The aim of this analysis is to determine if surgery for DCM is cost effective and to provide an estimate of the lifetime incremental cost utility of the intervention.

Methods: All patients undergoing surgery for DCM at a Canadian tertiary care center between 2005 and 2011, who were enrolled in either the AOSpine CSM-North America or CSM-International studies were included. Health utility was measured at baseline and then 6, 12 and 24-months following surgery using the Short Form-6D (SF-6D) health utility score. Costs were calculated on a patient level, from the hospital budgetary expenditures over the 24-month follow-up period. All costs were obtained from a micro-cost database and reported in Canadian dollars; inflated to January 2015 values. Quality adjusted life year (QALY) gain was estimated as an area under the curve with a linear interpolation. Lifetime incremental cost utility ratios (ICUR) for surgery were estimated using a Markov state transition model (Figure 1). Sensitivity to structural uncertainly arising from lifetime extrapolation and the single arm cohort design of the study was assessed by constructing supplementary constrained models. Deterministic and probabilistic sensitivity analyses were used to account for parameter uncertainty. All QALY gains and costs were discounted at 3% per annum.

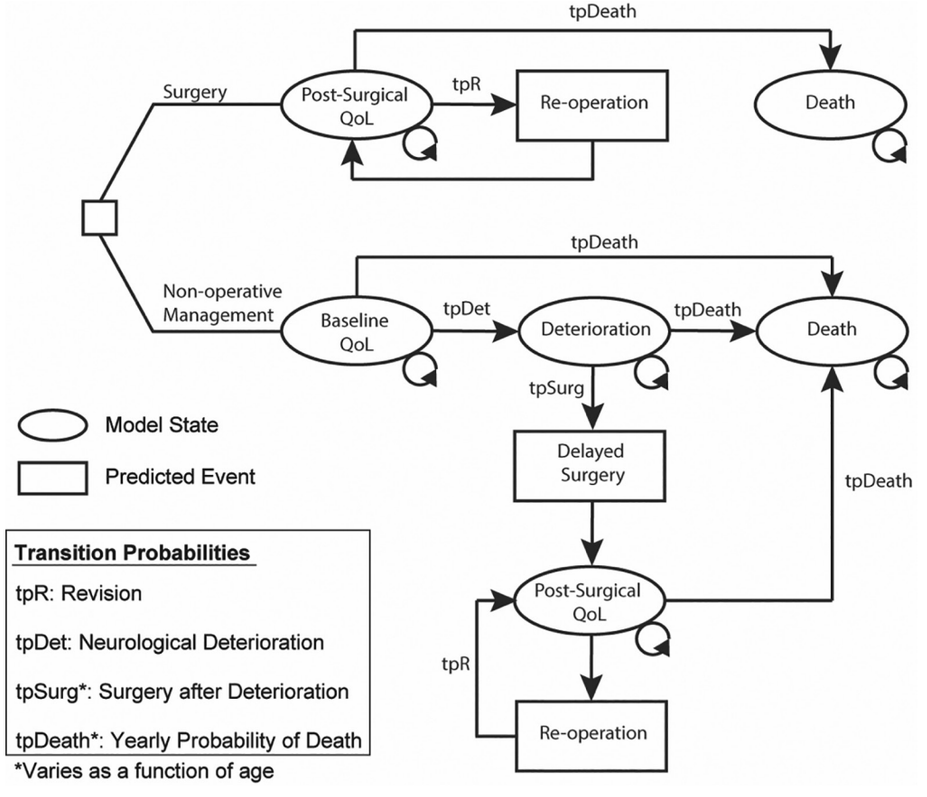
Results: The analysis included 171 patients; follow-up at 2-years was 96.5%. Mean age was 58.2 ± 12.0 years and baseline health utility was 0.56 ± 0.14. Average QALY gained over the 24-month following surgery was 0.14 (95% CI: 0.11–0.17, $p < 0.001$). The average 2-year cost of treatment was $\$19{,}218 \pm 12{,}404$. Cost associated with the surgery accounted for two-thirds (65.7%) of the total costs. The remainder of the costs were for pre-surgical preparation, post-surgical recovery and re-operations. Three patients required a re-operation over the 2-year follow-up period, and accounted for 1.85% of the total costs. The estimated lifetime ICUR of surgical intervention was \$11,496.02/QALY gained (Figure 2A), with 97.9% of model estimates (Figure 2B and 2C) meeting the criteria to be considered 'very cost effective' (\$54,000 CAD). Model structure sensitivity assessments revealed ICUR estimates that remained within the 'very cost effective' threshold, suggesting the findings are robust to the estimations of the lifetime model.

Conclusion: Our study suggests that surgery for DCM is associated with significant and clinically meaningful improvements in quality of life and is cost effective.

Thursday, December 1, 2016, 10:04–10:10 am CSRS–2016

Presentation #16

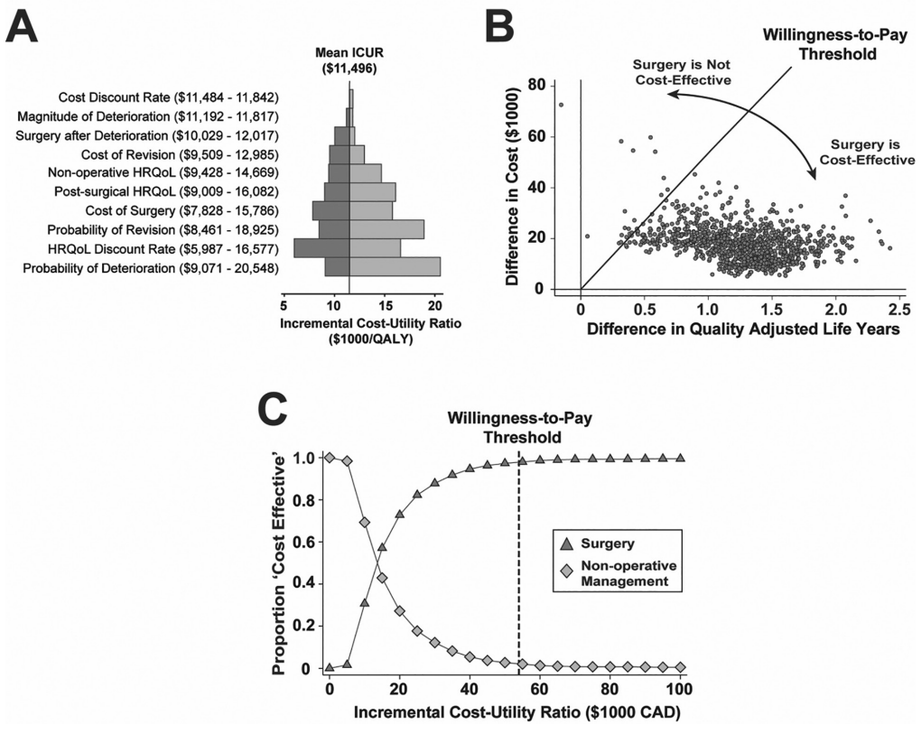
Figure 1: Diagrammatic representation of the state transition Markov model. Cycle length 1 year, with half cycle correction.



See Disclosure Index pages 39–89.

Presentation #16 (cont.)

Figure 2. Results of Markov state transition modeling.
A, multiple single way deterministic sensitivity analyses;
B, cost-utility plane with probabilistic sensitivity analysis;
C, cost-utility acceptability curve showing proportion of ICUR estimates within a willingness-to-pay threshold. Willingness-to-pay defined using World Health Organization definition of 'very cost-effective' ($54,000 CAD).



Presentation #17

Resource Utilization for Anterior Compared to Posterior Surgical Approaches for Cervical Spondylotic Myelopathy: An Analysis of Private Payer and Medicare Databases

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Introduction: Cervical spondylotic myelopathy (CSM) is a progressive spinal condition that often necessitates surgery. Studies have shown the clinical equivalency of anterior vs. posterior approaches for CSM surgery. There has been no study comparing reimbursement from private third party payers and Medicare for anterior vs. posterior approaches for CSM surgery. This is important especially in the era of value-based clinical decision making. The purpose of this study is to determine the amount and type of resources used for anterior compared to posterior surgical treatment of CSM.

Methods: A retrospective review of two national claims databases was performed. This study comprised of two large cohorts of patients that underwent either an anterior or posterior approach for treatment of CSM. These patients were selected from a database of patients with Medicare and another database of patients with private payer health insurance.

The outcome measures were cost of a 90 day episode of care as well as a breakdown of cost components for each surgical procedure. A private payer database (HORTHO) and Medicare database (SAF5) were used to evaluate clinical and financial information between 2005 and 2014 for patients undergoing surgery for CSM. Reimbursement information was collected from the day of surgery to 90 days after the index procedure.

Results: A total of 16,444 patients were included within this analysis. Within the HORTHO database there were 10,332 and 1,556 patients treated with an anterior or posterior approach for CSM respectively. Within the SAF5 database there were 3,851 and 705 patients treated by an anterior or posterior approach for CSM respectively. The average reimbursement for anterior vs. posterior approaches within the HORTHO database was $20,863 (+/- 2,014) and $23,813(+/- $4,258) respectively (p = 0.048). The average reimbursement for anterior vs. posterior approaches within the SAF5 database was $18,219 (+/- $1,053) and 25,598 (+/- $1,686) respectively (p = <0.0001). There was also significantly higher reimbursement for rehab/Skilled Nursing Facility and hospital/inpatient care for the patients undergoing a posterior approach in both private payer (Figure 1) and Medicare databases (Figure 2). In all cohorts within this study, the hospital related reimbursement more than doubled the surgeon related reimbursement.

Conclusion: This study compares resource utilization for a 90-day episode of care for anterior and posterior approaches for CSM surgery. There is a statistically significant higher resource utilization for patients undergoing posterior approach for CSM. Understanding reimbursement patterns for anterior vs. posterior approaches for CSM will help providers design a bundled payment for patients requiring surgery for CSM. The data also suggests that hospital related reimbursement is the major driver of payments.

See Disclosure Index pages 39–89.

Presentation #17 (cont.)

Figure 1. Breakdown of reimbursement for ACDF and posterior approach for private payer patients. A corresponding p value indicates whether there was a statistically significant difference in the proportion of costs allocated.

Aspect of Care	Average reimbursement per patient – ACDF private payer	Average reimbursement per patient – Posterior approach private payer	P Value
Hospital/Inpatient Reimbursement (including inpatient hospitalization, inpatient lab tests, inpatient imaging)	$12,280 (+/- $194)	$13,725 (+/- $171)	0.0015
Intra-Op Surgeon Reimbursement	$5,469 (+/- $151)	$5,246 (+/- $267)	0.32
Rehabilitation/Skilled Nursing Care Facility Reimbursement	$1,044 (+/- $394)	$2,256 (+/- $199)	0.0043
Intra-Op Anesthesiology	$809 (+/- $15)	$782 (+/- $6)	0.0125
Revision/Readmission and Emergency Department reimbursement	$638 (+/- $141)	$1,320 (+/- $322)	<0.0001

Figure 2. Breakdown of reimbursement for ACDF and posterior approach for Medicare patients. A corresponding p value indicates whether there was a statistically significant difference in the proportion of costs allocated.

Aspect of Care	Average reimbursement per patient – ACDF Medicare	Average reimbursement per patient – Posterior approach Medicare	P Value
Hospital/Inpatient Reimbursement (including inpatient hospitalization, inpatient lab tests, inpatient imaging)	$12,392 (+/- $657)	$15,260 (+/- $411)	0.0045
Intra-Op Surgeon Reimbursement	$3,144 (+/- $60)	$3,631 (+/- $95)	0.005
Rehabilitation/Skilled Nursing Care Facility Reimbursement	$1,379 (+/- $166)	$4,828 (+/- $309)	<0.0001
Intra-Op Anesthesiology	$388 (+/- $24)	$469 (+/- $12)	0.0005
Revision/Readmission and Emergency Department reimbursement	$419 (+/- $18)	$999 (+/- $120)	0.018

Presentation #18

Trends in Resource Utilization and Rate of Cervical Disc Arthroplasty and Anterior Cervical Discectomy and Fusion throughout the United States from 2006 to 2013

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Introduction: Given the increasing national focus on healthcare utilization and value-based care, spine surgeons, administrators, and policy makers must compare not only health based outcomes but also resource consumption in the management of spinal pathology. The purpose of this study was to compare anterior cervical discectomy and fusion (ACDF) to cervical disc arthroplasty (CDA) from 2006–2013 throughout the United States with regard to national incidence, hospital costs, length of stay (LOS), routine discharge, and revision burden.

Materials and Methods: Patient data from the National Inpatient Survey (NIS) database for primary ACDF, revision ACDF, primary CDA, and revision CDA from 2006–2013 were included in this study. Demographic and economic patient data were determined for the following ICD-9 CM codes: 81.02, 81.32, 84.62, and 84.66, respectively. The NIS database represents a 20% sample of discharges from U.S. hospitals and was weighted to provide national estimates. Revision burden was defined as the ratio of revision procedures to the sum of primary and revision procedures.

Results: An estimated 1,059,403 primary ACDF and 13,099 primary CDA surgeries were performed in the U.S. from 2006 to 2013 ($p < 0.0001$). The annual total number of surgeries for both ACDF and CDA showed a gradual increase over the 8-year period. The annual number of ACDF surgeries increased 5.7% in a non-linear fashion from 120,617 in 2006 to 127,500 in 2013 (mean per year: 132,425; range: 120,617–147,966). The annual total number of CDA surgeries increased 190% in a similarly non-linear fashion from 540 in 2006 to 1,565 in 2013 (mean per year: 1,637; range: 540–2,381) (Figure 1).

Demographic data were compared demonstrating that the CDA patients tended to be younger and have private insurance or 'other' insurance, which includes worker's compensation, compared to the ACDF patients ($p < 0.0001$). Mean LOS was longer for ACDF than for CDA (ACDF: mean 2.3 days, range: 2.2–2.4; CDA: 1.5 days, range: 1.3–2.0; $p < 0.0001$). The mean percentage of patients with routine discharge was significantly higher in the CDA group (ACDF: 89%, range 86–92%; CDA: 96%, range 94–98%; p-value < 0.0001). The overall mean hospital costs per ACDF procedure was $16,178, significantly more expensive than the overall mean cost per CDA of $13,197 (p-value $= 0.0007$) (Figure 2).

The CDA mean revision burden, at 5.9% (range: 3.9–7.4%), was greater than the ACDF mean revision burden of 2.3% (range: 2.1–2.8%) (p-value $= 0.01$). The mean cost of revision ACDF remained steady and averaged $19,270 (range: $17,423–$21,256). The mean cost of revision CDA was significantly less with a mean of $14,153 (range: $11,723–$16,555) (p-value < 0.0001).

See Disclosure Index pages 39–89.

Presentation #18 (cont.)

Conclusion: In this large, national cohort, patients who underwent CDA experienced lower hospital costs, shorter length of stay, and a higher rate of routine discharges than patients who underwent ACDF. However, the CDA revision burden (5.9%) was more than double compared to ACDF (2.3%). Following an initial steep increase in CDA from 2006 to 2009, CDA procedures have decreased nearly 400% more than ACDF procedures over the same period. Additionally, the ratio of ACDF to CDA in the U.S. was 81:1. Given that studies have found CDA to be more cost-effective than ACDF, further research is needed on the relative decline of CDA from a national health care cost perspective.

Figure 1. Comparison of the Number Primary Cervical Disc Arthroplasty and Anterior Cervical Discectomy and Fusion Procedures

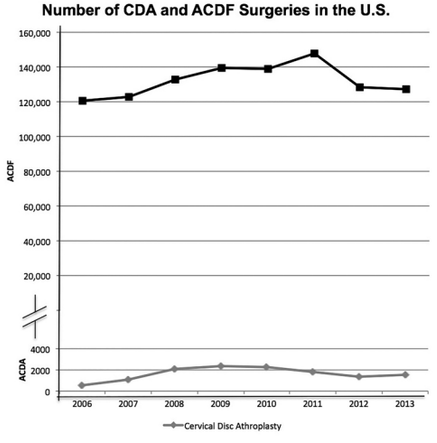
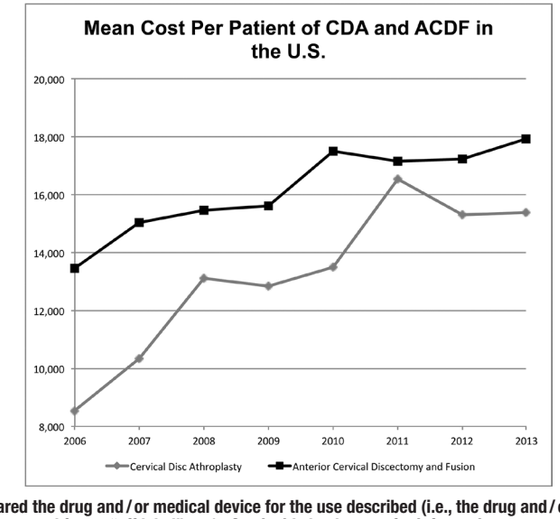


Figure 2. Mean Hospital Cost in US Dollars for Each Surgical Intervention for CDA and ACDF in the U.S.



• 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 #19

Impact of Type of Graft on Patient Reported Outcomes and Costs following Anterior Cervical Discectomy and Fusion

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Background: Autograft harvested from iliac crest, variety of allografts, and structural cage including polyetheretherketone (PEEK) interbody spacer remains the most common graft choices for ACDF surgery. The impact of type of graft on outcomes and costs continues to be a debate. We set out to determine the patient reported outcomes (PROs), cost, complications, readmission and RTW associated with the autograft, allograft and PEEK.

Methods: Patients undergoing elective ACDF for degenerative cervical conditions were enrolled into prospective longitudinal registry. Patient-reported outcomes were recorded at baseline, and 24-months postoperatively. Hospital discharge and billing records were collected prospectively. Bivariate analyses were conducted to compare the PROs, cost of surgery, 90-day complications, readmission and return to work (RTW) following ACDF surgery with autograft vs. PEEK vs. allograft.

Results: Total 260 patients were included in the analysis. ACDF with autograft was performed in 69 patients (26.5%), allograft in 25 patients (9.6%) and PEEK spacer in 166 patients (63.8%). There was no significant difference in change scores at postoperative 24-month for NDI, NRS-NP, and NRS-AP and EQ-5D between the groups. The patients undergoing autograft (4.2 ± 19.6) and PEEK (4.2 ± 16.3) had higher improvement in SF-12 PCS compared to those undergoing ACDF with allograft (-9.3 ± 19.9) (P = 0.002). There were no significant differences in cost of surgery (autograft: $14683 ± $6841 vs. PEEK: $14,410 ± $6,386, vs. allograft: $1,4261 ± $7,870, P = 0.27), 90-day complications (autograft: n = 4, 5.8%, PEEK: n = 7,4.2%, allograft: n = 2, 8%, P = 0.47), readmission (autograft: n = 4,5.8%, PEEK: n = 5,3%, allograft: n = 0, P = 0.51) and RTW (autograft: n = 33,47.8%, PEEK: n = 74,44.5% and allograft: n = 9, 36%, P = 0.59).

Conclusion: ACDF with autograft or PEEK had higher improvement in general physical health compared to ACDF with allograft. The patients undergoing ACDF with autograft had higher length of hospital stay, however the overall cost of surgery did not differ significantly between the groups. In the current era of value-based reimbursements, the choice of graft might not influence the cost and outcomes following ACDF surgery, as previously thought.

See Disclosure Index pages 39–89.

Presentation #20

Factors Associated with Financial Relationships between Spine Surgeons and Industry: An Analysis of the Open Payments Database

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Introduction: Over the past decade, there has been growing media perception that financial relationships between physicians and industry influence clinical judgment, potentially undermining patient care. This has the potential to blemish the fragile relationship between patients and the medical community–one that is grounded in the ethical principal of beneficence. Although there have been a number of studies that have utilized the Open Payments database, it is a cumbersome conglomeration of individual payments and difficult to conceptualize. We aimed to present the most recent Open Payments data as it applies to orthopaedic and neuro spine surgeons in a comprehensible format, providing metrics to better understand how demographic characteristics–including type of surgeon, years in practice, type of practice, type of medical degree, type of graduate, gender, and region of practice–may be associated with both the quantity and magnitude of industry-surgeon payments.

Methods: A comprehensive database of 5,898 spine surgeons in the United States with corresponding data of industry payments from 2013–2014 were derived from the Open Payments website. Demographic data for each surgeon was collected including the type of residency training each surgeon completed, years of experience since last formal training, practice setting, type of medical degree, place of training, gender, and the region of practice. Generalized linear mixed models using a Beta distribution with a logit link were utilized to determine the relationship between demographics and industry payments.

Results: A total of 5,898 spine surgeons practicing in the United States who performed spine fusion on Medicare patients from 2011–2013 met inclusion criteria for this study. In this dataset, 91.6% of surgeons within our cohort reported at least one financial relationship with industry. The median number of payments from industry to surgeon over the reporting period was 14, worth a median total value of $994.07 (Table 1). Surgeons receiving over $1,000,000 from industry during the reporting period represented 6.6% of the database and accounted for 83.5% of the total value exchanged. Demographic factors associated with increased median industry payments included: orthopaedic training ($p < 0.001$), academic practice setting ($p < 0.0001$), male gender ($p < 0.0001$), and West or South region of practice ($p < 0.0001$). Linear regression analysis revealed a strong inverse relationship between years of experience and number of payments from industry ($r = -0.967$, $p < 0.0001$) (Figure 1).

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Presentation #20

Conclusions: Financial relationships between spine surgeons and industry are highly prevalent. A small subset of high earning spine surgeons in our cohort received very large payments, which accounted for a majority of the total transactional value provided by industry. Surgeon demographics (practice setting, gender, years in practice, type of training, and geographic region of practice) have a significant impact on financial relationships with industry.

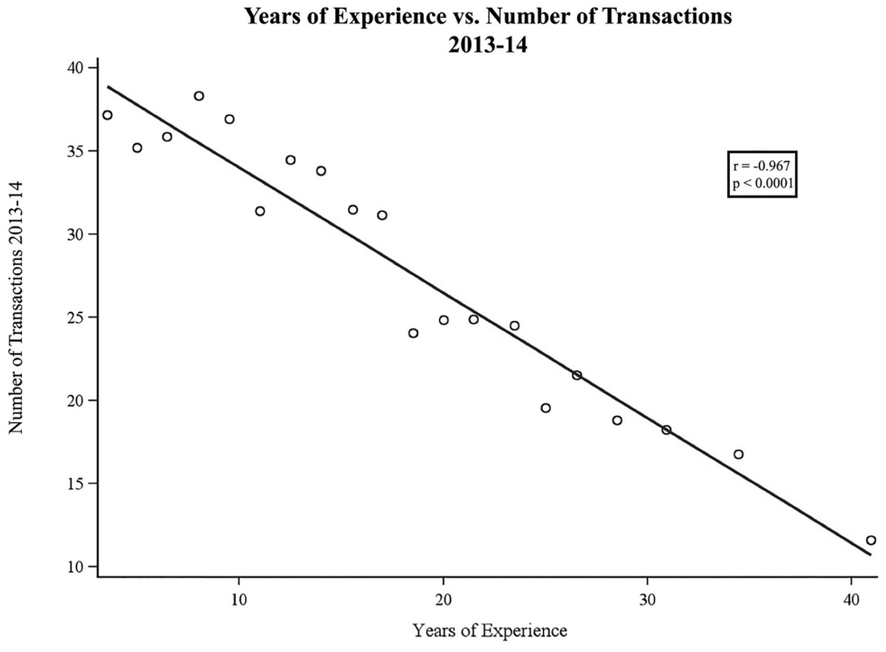
Table 1. Summary of spine surgeons included in our database, organized by type of spine surgeon.

	Orthopaedic Spine Surgeons (N = 2,603)	Neurosurgeons (N = 3,295)	Total (N = 5,898)
Proportion of Cohort	44.1%	55.9%	100.0%
Proportion with Financial Relationship	93.3%	90.2%	91.6%
Total General Transactions	83,064	79,748	162,812
Total General Payments	w$134,476,039.51	$87,504,875.39	$221,980,914.90
Median General Transactions	18	12	14
Median General Payments	$1,557.26	$689.37	$994.07

See Disclosure Index pages 39–89.

Presentation #20 (cont.)

Figure 1. Linear regression analysis of number of transactions as a function of years of experience. X-axis is the average of years of experiences of 20 physician groups ranked by years of experience. 5,898 U.S. spine surgeons were included in the analysis.



Presentation #21

Cervical Sagittal Imbalance is Associated with a Higher Rate of Reoperation for Adjacent Segment Disease following Anterior Cervical Discectomy and Fusion

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Introduction: Adjacent segment disease (ASD) following anterior cervical discectomy and fusion (ACDF) is relatively common, and is the result of several proposed etiologies including increased biomechanical stresses on adjacent motion segments and the natural course of disc degeneration. Despite the evolving understanding of regional and global sagittal alignment, the effect of sagittal alignment on adjacent level breakdown following an ACDF remains unknown. Therefore, the purpose of this study was to evaluate cervical sagittal alignment parameter effect in ASD following an ACDF.

Methods: A retrospective case-control study was performed using a prospectively maintained surgical database of patients who underwent 1- or 2-level ACDF by a single-surgeon. Patients who underwent reoperation for ASD following index ADCF were identified and compared to matched controls with an uncomplicated postoperative course. The ASD and control cohorts were analyzed with regard to baseline demographics and comorbidity burden, operative characteristics, patient reported outcomes, arthrodesis rate of the index procedure, and cervical sagittal alignment parameters. Differences in patient demographics and preoperative characteristics were assessed using independent sample t-tests and Chi-squared tests. The association between cervical sagittal alignment parameters and ASD reoperation was analyzed using Poisson regression with robust error variance (binary outcomes) or multivariate linear regression (continuous outcomes) adjusted for preoperative characteristics.

Results: A total of 435 patients who underwent 1- or 2-level ACDFs were included in the analysis, with an overall reoperation rate for ASD of 2.1% (N = 9). Patients who underwent reoperation for ASD had slightly higher preoperative Visual Analogue Scale (VAS) pain scores (7.0 ± 2.2 vs. 5.4 ± 1.7, p = 0.047) compared to the controls. All other preoperative characteristics were no different between cohorts (Table 1). Patients who required reoperation for ASD had a higher baseline C2-C7 Sagittal Vertical Axis (SVA) (30.3 ± 8.6 vs. 22.2 ± 8.4, p = 0.048; Table 2). There were no differences with regard to C2-7 Cobb Angle, T1 Slope, or Cranial Tilt. Additionally, there was a higher rate of pseudoarthrosis at the index level in the ASD cohort (22.2% [N = 2] vs. 0.0% [N = 0], p = 0.141; Table 2) compared to the controls, however this was not statistically significant.

Conclusions: Regional sagittal malalignment in the cervical spine may be associated with a higher rate of adjacent segment breakdown following ACDF. In the current study, C2-7 SVA was the most predictive parameter for requiring a reoperation, and should be evaluated with other contributing factors in prognostic and risk-based discussions for ASD. Future studies are necessary to determine the effect of overall global sagittal imbalance on regional cervical parameters and the risk of reoperation for ASD following ACDF.

See Disclosure Index pages 39–89.

Presentation #21 (cont.)

Table 1. Baseline characteristics.*

	Controls (N = 24)	Reoperation for ASD (N = 9)	p-value
Age (Mean ± SD, years)	49.6 ± 7.7	50.0 ± 7.1	0.887
Sex (N)			0.943
Female	54.2% (13)	55.6% (5)	
Male	45.8% (11)	44.4% (4)	
Body Mass Index			0.619
Non-obese (BMI < 30)	54.2% (13)	44.4% (4)	
Obese (BMI ≥ 30)	45.8% (11)	55.6% (5)	
Smoking status (N)			0.074
Non-smoker	91.7% (22)	66.7% (6)	
Smoker	8.3% (2)	33.3% (3)	
Number of Levels (N)			0.886
1-level ACDF	58.3% (14)	55.6% (5)	
2-level ACDF	41.7% (10)	44.4% (4)	
Comorbidity Burden (CCI)	2.9 ± 1.3	3.8 ± 1.9	0.119
Preoperative VAS Back (Mean ± SD, min)	5.4 ± 1.7	7.0 ± 2.2	0.047

SD = Standard deviation; BMI = Body Mass Index; CCI = Charlson comorbidity index; VAS = Visual Analogue Scale; N = number of patients

***Boldface** indicates statistical significance**.**

Presentation #21

Table 2. Outcomes.*

	Controls (N = 24)	Reoperation for ASD (N = 9)	†p-value
Operative Time (Mean ± SD, min)	58.6 ± 14.9	58.3 ± 11.7	0.923
Estimated Blood Loss (mL)	46.0 ± 11.7	50.0 ± 0.0	0.707
Length of Hospital Stay (hours)	27.3 ± 8.3	35.6 ± 10.5	0.430
Change in VAS Back (Mean ± SD) Δ			
ΔVAS at 6 weeks	-2.2 ± 2.1	-2.2 ± 1.6	0.891
ΔVAS at 12 weeks	-1.7 ± 2.8	-1.7 ± 1.7	0.980
ΔVAS at 6 months	-2.1 ± 2.3	-0.5 ± 3.1	0.551
Postoperative Radiographic Measurements (Mean ± SD)			
C2-C7 Cobb Angle	10.3 ± 11.3	7.1 ± 7.8	0.272
C2-C7 Sagittal Vertical Axis	22.2 ± 8.4	30.3 ± 8.6	0.048
T1 Slope	25.7 ± 6.8	28.9 ± 10.9	0.577
Cranial Tilt	20.0 ± 7.9	16.1 ± 10.0	0.675
Arthrodesis at 1 year (N) ∫	100.0% (23)	77.8 % (7)	0.141
Revision (N)	0.0% (0)	100.0% (9)	< 0.001

SD = Standard deviation; VAS = Visual analogue scale

***Boldface** indicates statistical significance
† P-value is from Poisson regression with robust error variance (binary outcomes) or multivariate linear regression (continuous outcomes) adjusted for sex, smoking status, number of operative levels, comorbidity burden, and preoperative VAS pain scores
Δ Change in VAS = Postoperative VAS (6 weeks, 12 weeks, 6 months, 1 year) – Preoperative VAS
∫ 1 patient in the control cohort underwent primary ACDF within 1 year of this analysis
‡ Revisions include Adjacent Segment Disease (9)

See Disclosure Index pages 39–89.

Presentation #22

A Novel Score Predicting Spine Sagittal Imbalance Based on a Lateral Cervical Plain Radiograph

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Introduction: Sagittal imbalance is recognized as a significant variable that contributes to spinal deformity. Clinical outcomes after spine surgery are known to correlate with sagittal balance (SB). SB is traditionally measured by the C7-S1 plumb line as demonstrated on a 36-inch long-cassette film. Abnormal positive alignment induces compensatory changes within the cervical spine, including increased cervical lordosis and T1 slope. Patients presenting clinically with cervical pathology are not routinely assessed with long-cassette films. A validated tool that could determine the likelihood of overall spine malalignment using cervical radiographs alone would be of significant clinical and cost saving value.

Methods: A retrospective review of 930 patients that were part of awwcluding demographics, cervical lordosis, and T1 slope were analyzed. Patients were randomized in a 2:1 fashion into either a derivation cohort or a validation cohort.

Results: Of the 930 patients, 384 (41.3%) had a positive SB. The final score for predicting SB greater than +50mm included: BMI > 25 (1 point), age > 55 years (2 points), and T1 slope > 27o (2 points). A score of ≥ 3 had a specificity of 63.6% (CI 58.7–68.3%) and a sensitivity of 82.9% (CI 77.6–87.3%). The ROC area under the curve was 0.82 (CI95% 0.78–0.85) and 0.81 (CI95% 0.76–0.86) in the derivation and validation cohorts, respectively.

Conclusions: This large multicenter study internally validated a simple score to assess SB based upon cervical radiographs, BMI, and age alone. The preoperative awareness of abnormal SB in patients with cervical pathology might change surgical treatment and clinical outcomes. Patients with high scores would benefit from long-cassette film evaluation.

Presentation #22

Table 1. Pittsburgh, PA Baseline characteristics of patients in the derivation cohort

Baseline Characteristic	With sagittal imbalance (n = 251)	Without sagittal imbalance (n = 401)	p value[1]
Age, years – mean (SD)	63.3 (12.0)	49.3 (16.1)	< 0.01
BMI, Kg / m2 – mean (SD)	29.7 (11.3)	25.2 (5.5)	< 0.01
Male sex – no. (%)	194 (77.9)	337 (85.8)	0.01
Charlson score – median (IQR)	2.0 (3.0)	0.0 (1.0)	< 0.01
Medical history – no. (%)			
Current smoker	16 (6.7)	54 (14.1)	< 0.01
Chronic heart failure	33 (13.2)	17 (4.2)	< 0.01
Chronic pulmonary disease	17 (6.8)	12 (3.0)	0.03
Chronic renal failure	10 (4.0)	5 (1.3)	0.03
Chronic arthritis	108 (43.0)	88 (22.0)	< 0.01
Malignancy	32 (12.8)	29 (7.2)	0.03
Osteoporosis	50 (19.9)	36 (9.0)	< 0.01
Anemia	15 (6.0)	27 (6.7)	0.75
Major depression disorder	67 (26.7)	78 (19.5)	0.03
Cervical X-Ray findings – mean (SD)			
Cervical lordosis C2-C7	14.6 (18.7)	4.3 (13.7)	< 0.01
Cervical lordosis C2-T3	15.1 (18.4)	1.7 (14.4)	< 0.01
Plumbline C2-T3	70.9 (24.1)	52.3 (22.2)	< 0.01
Plumbline C2-C7	35.6 (17.7)	28.7 (16.2)	< 0.01
T1 cervical lordosis	18.4 (14.1)	17.2 (9.2)	0.31
T1 Slope	33.2 (12.7)	21.3 (10.9)	< 0.01
Lumbar X-Ray findings – mean (SD)			
Sacral slope	29.0 (12.1)	35.0 (11.0)	< 0.01
Pelvis tilt	27.6 (10.7)	17.2 (9.6)	< 0.01
S1 pelvis incidence	56.7 (13.0)	52.2 (12.4)	< 0.01
Pelvic incidence LL	25.3 (18.5)	0.6 (15.2)	< 0.01
Lumbar lordosis L1-S1	31.3 (20.1)	51.6 (16.1)	< 0.01

LL: lumbar lordosis, SD: standard deviation, IQR: interquartile range
1. Two sided p value. Means are compared with Student's T-test (unequal variances), medians with Wilcoxon rank sum and proportions with Fisher's exact test.

See Disclosure Index pages 39–89.

Presentation #22 (cont.)

Table 2. Test performance for sagittal imbalance in derivation cohort.

Point score1	Specificity (95% CI)	Sensitivity (95% CI)	Negative predictive value (95% CI)	Positive predictive value (95% CI)	Likelihood ratio (+) (95% CI)	Likelihood ratio (-) (95% CI)
>=1	24.9 (20.8–29.5)	99.2 (97.2–99.9)	98.0 (93.1–99.8)	45.3 (41.1–49.5)	1.32 (1.25–1.40)	0.03 (0.01–0.13)
>=2	41.9 (37.0–46.9)	93.2 (89.4–96.0)	90.8 (85.7–94.6)	50.1 (45.5–54.7)	1.60 (1.47–1.75)	0.16 (0.10–0.26)
>=3	63.6 (58.7–68.3)	82.9 (77.6–87.3)	85.6 (81.1–89.4)	58.8 (53.4–63.9)	2.28 (1.98–2.62)	0.27 (0.20–0.36)
>=4	81.8 (77.7–85.5)	61.0 (54.6–67.0)	77.0 (72.7–80.9)	67.7 (61.2–73.7)	3.35 (2.66–4.21)	0.48 (0.41–0.56)

CI: confidence interval

1. T1 slope³27o: 2 points, Age³55 years: 2 points, BMI³25: 1 point

Presentation #23

Relationship between T1 Slope and Cervical Alignment following Multi-level Posterior Cervical Fusion Surgery: Impact of T1 Slope Minus Cervical Lordosis

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Study Design: Retrospective study.

Objective: (1) To assess the relationship between sagittal alignment of the cervical spine and patient-reported health-related quality-of-life (HRQOL) scores following multilevel posterior cervical fusion and (2) to explore whether an analogous relationship exists in the cervical spine using T1 slope C2-C7 lordosis ('T1S CL').

Summary of Background Data. A recent study demonstrated that, similar to the thoracolumbar spine, the severity of disability increases with sagittal malalignment following cervical reconstruction surgery.

Methods: From 2007–2013, 38 consecutive patients underwent multilevel posterior cervical fusion for cervical stenosis, myelopathy, and deformities. Radiographic measurements included: (1) C0-C2 lordosis, (2) C2-C7 lordosis, (3) C2-C7 sagittal vertical axis (SVA), (4) T1 slope, and (5) T1S CL. Pearson correlation coefficients were calculated between pairs of radiographic measures and HRQOL.

Results: C2-C7 SVA positively correlated with neck disability index (NDI) scores (r = 0.495). C2-C7 lordosis (P = 0.001) and T1S-CL (P = 0.002) changes correlated with NDI score changes after surgery. For significant correlations between C2-C7 SVA and NDI scores, regression models predicted a threshold C2-C7 SVA value of 50 mm, beyond which correlations were most significant. The T1S CL also correlated positively with C2-C7 SVA and NDI scores (r = 0.871 and r = 0.470, respectively).

Results of the regression analysis indicated that a C2-C7 SVA value of 50 mm corresponded to a T1S CL value of 26.1°.

Conclusions: This study showed that disability of the neck increased with cervical sagittal malalignment following surgical reconstruction and a greater T1S CL mismatch was associated with a greater degree of cervical malalignment. Specifically, a mismatch greater than 26.1° corresponded to positive cervical sagittal malalignment, defined as C2-C7 SVA greater than 50 mm.

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Presentation #24

Outcomes of Operative Treatment for Adult Cervical Deformity: A Prospective Multicenter Assessment with One-Year Follow-up

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Introduction: Despite the potential for profound impact of adult cervical deformity (ACD) on function and health-related quality of life, there remains a paucity of high-quality studies that assess outcomes of surgical treatment for these patients. Our objective for the present study was to provide a prospective multicenter assessment of 1-year outcomes following surgical treatment for ACD.

Materials and Methods: Surgically treated ACD patients eligible for 1-yr follow-up were identified from a prospectively collected multicenter database with consecutive enrollment. Baseline deformity characteristics, surgical parameters, and 1-year outcomes were assessed. Standardized outcomes measures included Neck Disability Index (NDI, range 0–100), neck pain numeric rating scale (NRS) score (range 0–10), and EQ5D-3S index (range 0–1) and subscores (range 1–3). Paired sample t-tests were used to compare 1-year and baseline measures.

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Results: Of 77 ACD patients, 55 (71%) had 1-year follow-up (64% women, mean age 61 yrs, mean Charlson Comorbidity Index [CCI] of 0.6, previous cervical surgery in 44%). Diagnoses included: cervical sagittal imbalance (62%), cervical kyphosis (60%), proximal junctional kyphosis (8%), and coronal deformity (10%). Posterior fusion was performed in 85% (mean number of vertebral levels = 10), and anterior fusion was performed in 29% (mean number of vertebral levels = 5). Three-column osteotomy was performed in 24% of patients. Mean operative time was 6.5 hrs and mean estimated blood loss was 0.9 L. At 1-year following surgery, ACD patients had significant improvement in NDI (50.5 to 38.0, $p < 0.001$), neck pain NRS (6.9 to 4.3, $p < 0.001$), EQ5D index (0.51 to 0.66, $p < 0.001$), and EQ5D subscores: mobility (1.9 to 1.7, p=0.019), usual activities (2.2 to 1.9, p=0.007), pain/discomfort (2.4 to 2.1, $p < 0.001$), anxiety/depression (1.8 to 1.5, $p = 0.014$). A nonsignificant trend favoring improvement was observed for EQ5D self-care (1.5 to 1.3, $p = 0.070$). Compared with patients that achieved 1-year follow-up, those lost to follow-up did not differ significantly with regard to age, gender, CCI, number of fused anterior or posterior vertebral levels, or baseline NDI, neck pain NRS, or EQ5D scores.

Conclusions: Adult cervical deformity can produce significant pain and disability. Based on a prospective multicenter series of adults with cervical deformity, surgical treatment provided significant improvement in multiple measures of pain and function, including the NDI, neck pain NRS score, and EQ5D. Further follow-up will be necessary to assess the durability of these surgical procedures and the resulting improved outcomes.

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Presentation #25

Postoperative Cervical Sagittal Realignment after Debridement and Reconstruction in Cervical Spinal Tuberculotic Kyphosis

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Introduction: Cervical TB is not a rare disease in developing countries and can erode vertebra which results in the development of cervical kyphosis and myelopathy. However, no literature reported the correlation of the cervical spine realignment after debridement and reconstruction surgery with the improvement of HROQLs.

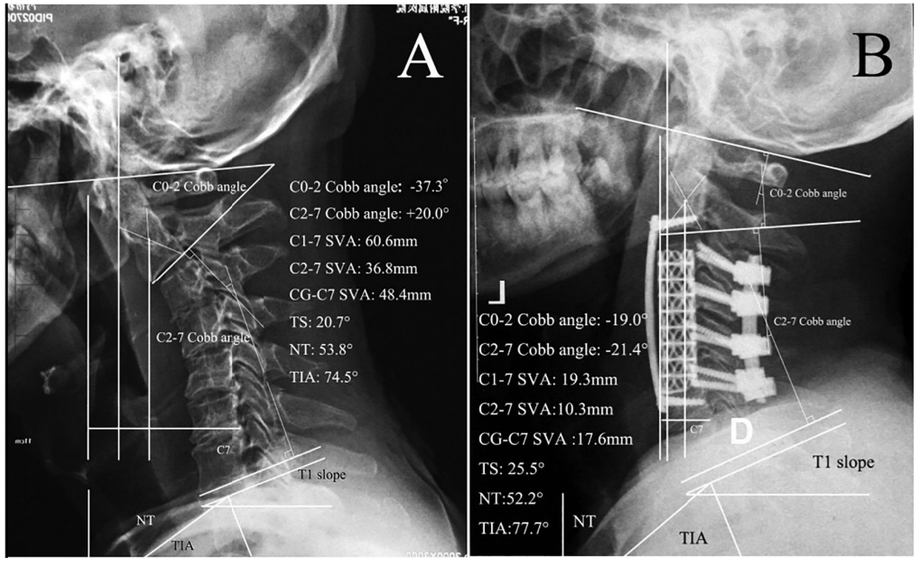
Methods: Forty-six kyphotic cervical tuberculosis (TB) cases were included in this study. Preoperative and 2-year follow-up radiological parameters were measured, including C0-2 Cobb angle, C2-7 Cobb angle, C2-7 SVA, center of gravity to C7 SVA (CG-C7 SVA), thoracic inlet angle (TIA), T1 slope (TS), neck tilt (NT). NDI was recorded to analyze the improvement of HROQLs. The correlation between cervical alignment and NDI were analyzed. CT scans was used to assess the bone fusion after surgery.

Results: Forty-three cases showed bone fusion on CT scan, the fusion rate was 93.5 %. The preoperative C0-2 Cobb angle, C2-7 Cobb angle, TS, TIA, was -27.9 ± 10.6°, 16.8° ± 5.2°, 15.8 ± 8.1°, 62.7° ± 15.8°, improved to -22.9 ± 4.2° ($P < 0.01$), -16.1° ± 7.5° ($P < 0.01$), 21.8 ± 7.3° ($P < 0.01$), 70.7° ± 12.6°($P < 0.05$), but the pre- and postoperative values of NT had no significant change ($P > 0.05$). The preoperative C2-7 SVA, CG-C7 SVA was 38.1 ± 6.7mm, 46.5 ± 8.3mm, and improved to 10.2 ± 5.8mm ($P < 0.01$), 20.5 ± 6.2mm ($P < 0.01$), respectively (Figure1). The preoperative NDI was 33.6 ± 5.1, improved to 16.7 ± 4.6 ($P < 0.01$). NDI was significantly correlated with C0-2 Cobb angle, C2-7 Cobb angle, TS, TIA, C2-7 SVA and CG-C7 SVA.

Conclusion: Debridement and cervical reconstruction can make kyphotic tuberculotic cervical spine realigned normally, and meanwhile significantly improve the HROQLs.

Presentation #25

Figure 1. Preoperative tuberculotic kyphotic cervical spine and the alignment parameters(A), postoperative lordotic cervical spine and realignment parameters(B)



See Disclosure Index pages 39–89.

Presentation #26

Management of Hangman Variant Fractures of the Axis

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Introduction: Traumatic spondylolisthesis of the axis with the fracture extending into the vertebral body has been incompletely characterized. Small case series have demonstrated high rates of neurological injury and cite difficulty treating closed due to greater instability secondary to extensive ligamentous injury. We hypothesize that this fracture pattern has minimal risk of ligamentous injury and can be adequately treated with closed methods.

Methods: Acute C2 fractures were identified retrospectively at a Level I trauma center from 2004 to 2015 from ICD-9 coding and confirm with three dimensional imaging. Fractures that displayed separation of the axis body from the posterior arch such that one or both vertically oriented fracture defects involved the posterior cortex of the axis body were classified as hangman variants. Displacement was determined based on horizontal displacement of the C2 vertebral body as well as angulation between the C2-3 vertebras.

Results: 107 hangman's variant fractures (14.5%) were identified from a database of 735 acute C2 fractures. Average age on presentation was 54 years with over 90% occurring secondary to high-energy blunt trauma. Forty-four percent sustained other spine fractures including 35% with cervical spine or occipital condyle fractures. 106 of the 107 patients displayed no neurologic injury related to the cervical spine. One patient with a widely displaced fracture (>8mm) sustained a complete neurologic injury that did not recover despite surgical stabilization. 90 patients received treatment in either hard collar orthosis or halo (14 underwent surgery and 3 deaths) with 83% followed as outpatients for an average of 32 weeks and median of 12 weeks. All patients treated in halo or hard collar demonstrated horizontal translation of less than 5mm and C2-3 angulation of less than 15 degrees. MRI obtained in 29 patients (32%) treated nonoperatively showed no evidence of C2-3 disk or ligamentous injury. No patients treated in halo or hard collar sustained late neurologic injury, progression of displacement or instability (>2mm change in displacement or >5 degree change of C2-3 angulation) on follow-up radiographs. No difference was observed in radiographic outcome between patients treated in a hard collar or halo orthosis.

Conclusion: While widely considered a difficult fracture to treat with closed means, hangman variants are relatively neurologically benign injuries with low incidence of ligamentous injury. Fractures with less than 5mm of horizontal translation and 15 degrees of angulation can be treated nonoperatively without the necessity of MRI. Our results suggest no advantage of halo immobilization versus hard collar orthosis.

Presentation #27

Risk Factors for Failure of Non-operative Treatment for Unilateral Cervical Facet Fractures

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Introduction: Approximately 5% of subaxial cervical spine fractures involve isolated non-displaced facet fractures without spinal cord injury. Despite being relatively common, no consensus exists with regards to the optimal management of these injuries, and the failure rate and predictors of failure after conservative management remain unknown. The aims of this study were to determine the clinical failure rate with non-operative management of isolated unilateral subaxial facet fractures, to determine the percentage of patients who develop radiographic spondylolisthesis during follow-up, and to identify risk factors for clinical failure and spondylolisthesis.

Methods: This study was a retrospective review of the trauma registry at a Level I trauma center. All patients evaluated between 2002 and 2014 with isolated unilateral subaxial cervical facet fractures who underwent initial non-operative management were included in this study. All patients were treated in a hard cervical collar with frequent clinical and radiographic follow-up.

Computed tomography (CT) scans were used to define the level and pattern of the fracture and to measure fracture displacement, angle, spondylolisthesis, and percentage of the facet height and area involved in the fracture (Figure 1). Radiographic spondylolisthesis was defined as greater than 2 mm on the initial CT scan and greater than 10% of the anterior-posterior dimensions of the inferior vertebral endplate on follow-up radiographs.

Results: 74 patients were included in the study. Mean follow-up was 9 months +/- 22 months (0-121 months). Fracture characteristics are listed in Table 1.

7/74 patients (9%) underwent surgery during follow-up. In patients who underwent surgical intervention, time between injury and surgery ranged from 2 to 10 weeks. Procedures included 5 anterior cervical discectomy and fusions (ACDF) (62.5%), 2 posterior cervical fusions (25%), and 1 laminectomy (12.5%). Risk factors for failure of conservative management included presence of radiculopathy at the time of presentation, higher body mass index (BMI), increased Injury Severity Score (ISS), greater initial fracture displacement, and more than 2 mm of spondylolisthesis on the initial post-injury CT scan.

15/74 patients (20%) had spondylolisthesis greater than 10% on follow-up radiographs. Risk factors for presence of spondylolisthesis included higher BMI, higher Charlston comorbidity score, greater initial fracture displacement, and greater percentage of the facet height involved in the fracture. Only 2/15 (13%) of patients with spondylolisthesis on follow-up imaging developed radicular symptoms and none developed myelopathy or catastrophic neurologic deterioration.

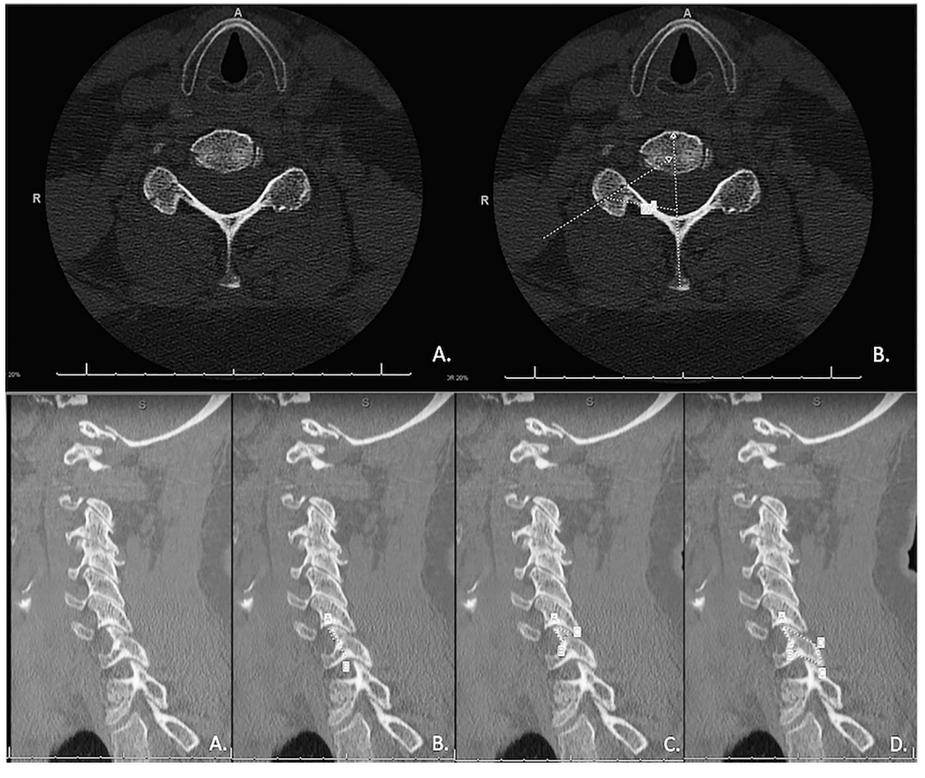
See Disclosure Index pages 39–89.

Presentation #27 (cont.)

Conclusion: The clinical failure rate of isolated unilateral subaxial cervical facet fractures in the present study (9%) was significantly lower than that reported in previous studies. Despite a 20% rate of radiographic spondylolisthesis on follow-up imaging, only a small percentage of patients developed radicular symptoms and none developed catastrophic neurologic deterioration. The results of this study, therefore, suggest that patients with non- or minimally displaced facet fractures who do not have neurological symptoms at the time of presentation can safely and often successfully be managed conservatively with careful observation and follow-up.

Figure 1A. A. Axial CT scan image showing a unilateral facet fracture. B. Angle of the fracture line as measured on the axial CT image, relative to the sagittal plane.

Figure 1B. A. Sagittal CT image showing a unilateral facet fracture. B. Measurement of the height of the fracture (line A) and height of the facet (line B) used to calculate the percentage of the facet height involved in the fracture (A/B*100%). C. Measurement of the 2-dimensional area of the fracture and D. the facet used to calculate the 2-D percentage of the facet involved in the fracture ((AxBxC)/(AxBxCxD)*100%).



Presentation #27

Table 1. Facet Fracture Characteristics	
Side: n (%)	Right 38 (52%); Left 36 (49%)
Location: n (%)	Superior facet 59 (80%); Inferior facet 15 (20%)
Cervical level: n (%)	C3 7 (10%); C4 2 (3%); C5 8 (11%); C6 23 (31%); C7 34 (46%)
Fracture pattern: n (%)	Simple 55 (74%); Comminuted 19 (26%)
Listhesis: n (%)	< 2mm: 70 (95%); >2mm: 4 (5%)
Displacement (mm)	Mean 1.1 ± SD 1.7
Fracture angle (°)	Mean 48 ± SD 20
% Facet involved in fracture (mm)	Mean 74 ± SD 24
% Facet involved in fracture (mm^2)	Mean 1.8 ± SD 1.3
SD = standard deviation	

See Disclosure Index pages 39–89.

Presentation #28

An Economic Case for the Surgical Treatment of Type-II Odontoid Fractures in the Elderly: A Markov Cost-Utility Analysis based on the Prospective AOSpine Geriatric Odontoid Fracture Study

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Introduction: Type-II odontoid fractures are the most common cervical fractures encountered in the elderly, with an overall incidence that appears to be rising. Substantial uncertainty continues to surround optimal management of these injuries; while non-operative treatment is associated with a high rate of non-union, surgery is more costly and may be associated with high complication rates in this age group. To provide further evidence on this topic, we performed a value based assessment comparing costs and health gains between these treatment strategies.

Methods: We constructed a Markov cost-utility model, with a life-long time horizon, comparing quality-adjusted survival and costs of surgical vs. non-operative treatment (external orthosis), from the perspective of the payer, for the base case of a 75 year-old person with a type-II odontoid fracture. Mean utility values, corresponding to the health states of interest, were calculated from primary data (SF-6D scores) prospectively collected during the AOSpine GOF Study. Probability rates for mortality, complications, failure/fusion were estimated based on a systematic review of the literature. Per patient treatment costs, presented in 2016 US dollars, were obtained from the Healthcare Cost and Utilization Project, National Inpatient Sample, averaged over a 7-year period (2003–2010). Incremental Cost Effectiveness Ratios (ICERs) were evaluated relative to a Willingness to Pay (WTP) threshold of 50,000USD/QALY. One- and two-way sensitivity analyses were performed to identify threshold values for age, cost, utility and probability values. Finally, probabilistic sensitivity analysis, using Monte Carlo Simulation with 1,000 sample iterations, was performed to generate an ICER scatterplot and cost-effectiveness acceptability (CEA) curve.

Presentation #28

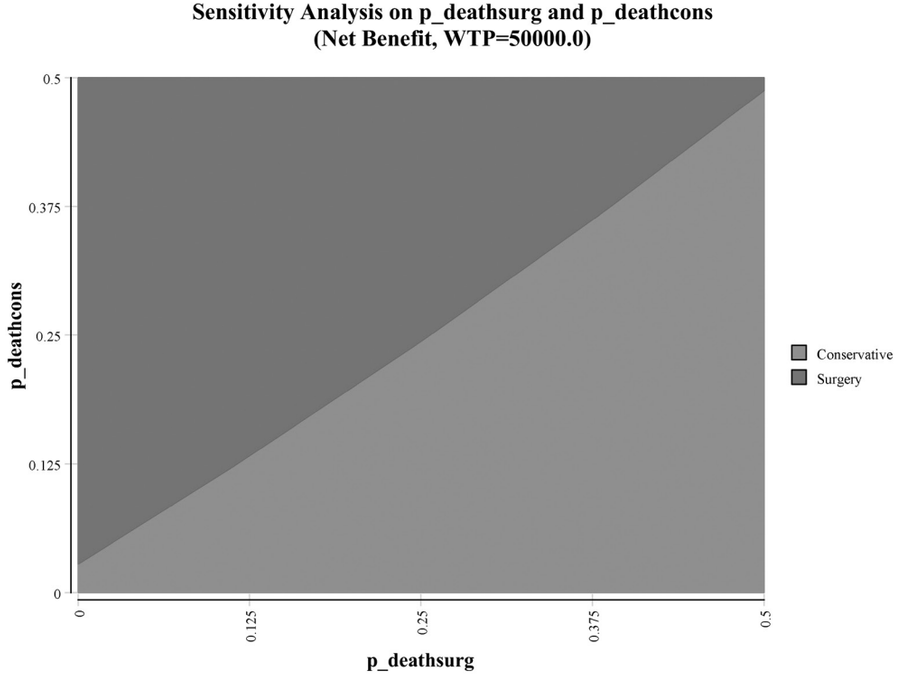
Results: Over a lifetime, as compared to non-operative treatment, surgery was associated with an average gain of an additional 0.81 QALYs and additional costs of 12,788USD, resulting in an ICER of 15,725USD/QALY for the base case analysis. With increasing age, surgery became less cost-effective, with age 96 representing the threshold beyond which the ICER exceeded the WTP threshold (ICER at age 85:26,069USD/QALY; ICER at age 95:46,049USD/QALY). Results were also found sensitive to variation in year 1 post-op mortality rates, with surgery becoming less cost-effective as surgical mortality increased and as non-operative treatment morality decreased (Figure 1). Model results were less sensitive to variation in costs or fusion and complication rates for each strategy. Probabilistic sensitivity analysis revealed surgery to be the most cost-effective strategy in 79.3% of the 1000 iterations sampled, as depicted in the ICER scatterplot (Figure 2). Generation of CEA curve demonstrated surgery to the preferred strategy above a WTP threshold of 20,000USD.

Conclusion: Surgical treatment for type-II odontoid fractures in the elderly appears to provide better value with respect to costs and health gains as compared to non-operative management with external orthosis alone. However, surgery becomes less cost effective with increasing patient age and increasing probability of early postop death. This implies that while surgery is likely to be the preferred approach for the younger healthier patient, conservative management may be more appropriate for the older patient with a higher probability of short-term mortality. Further studies are needed to confirm the findings presented here.

See Disclosure Index pages 39–89.

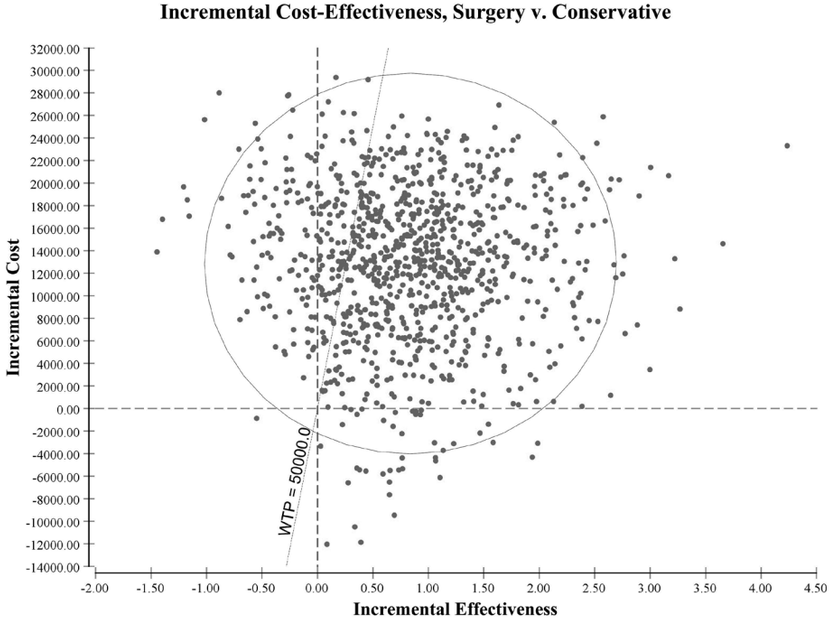
Presentation #28 (cont.)

Figure 1. Two-way Sensitivity Analysis demonstrating the impact of variation of the probability of 1-year mortality with conservative/non-operative therapy (Y-axis) and surgical therapy (X-axis). Red shaded region indicates where surgery is most effective, Blue shaded region indicates where conservative therapy is most cost-effective.



Presentation #28

Figure 2. Incremental Cost Effectiveness Scatterplot demonstrating model results across the 1000 iterations of the Probabilistic Sensitivity Analysis (each point represents single iteration). 79.3% of points lie to the right side of the WTP line, indicating surgery to be the cost-effective strategy in the vast majority of iterations.



Presentation #29

Minimally Clinical Important Difference (MCID) of a Clinical Impairment Measure Specific for Traumatic Tetraplegia: A Multi-Centre Assessment of the GRASSP Version 1.0

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Introduction: GRASSP Version 1.0 is a clinical impairment measure designed specifically to assess the upper limb after traumatic cervical spinal cord injury (SCI). The GRASSP consists of 5 subtest scores that characterize the upper limb; it captures subtle changes in neurological impairment during the acute, sub-acute, and chronic phases of recovery. Psychometric properties of reliability validity, responsiveness and minimally detectable difference are established.

The remaining psychometric property to be established is Minimally Clinical Important Difference (MCID), which is required to establish use in efficacy and interventional studies. The objectives of this study were to: 1) Establish the MCID values for the GRASSP and 2) To summarize how the GRASSP can be applied in clinical / interventional trials as a tool to define effectiveness of new therapies.

Methods: A prospective longitudinal study including 53 individuals with acute traumatic cervical SCI was conducted as a multi-centre study. Serial testing consisted of GRASSP, International Standards for Neurological Classification for Spinal Cord Injury (ISNCSCI) and a patient questionnaire designed to acquire the patients perception of change over time were administered 0 to 10 days, 1, 3, 6, and 12 months post injury. Analysis: Using a validated anchor-based approach patients rated their status as same, better and much better related to the specific domains of the GRASSP, the mean change in GRASSP scores was calculated for these groups.

Results: 53 individuals sustaining a traumatic cervical SCI with NLI ranging from C2 to T1 (AIS A = 11, B = 5, C = 16, D = 23) at baseline. MCID and minimally important different (MID) values for the group of individuals perceiving their upper limb impairment to be much better are presented in Table 1. Three calculations were done, anchor-based, standard deviation and standard error of measure.

Conclusion: MCID of the GRASSP has been established and can be a useful measure to establish efficacy of interventions as well as meaningfulness of the change as it relates to the patient. Although, MCID remains to be an elusive psychometric property, the benefit of an available value / s contributes to the investigators understanding of the treatment effect. We recommend application of these MCID values for group-level analysis when conducting research and interpreting data examining groups of patients as opposed to assessing individual patients. These MCID values may provide a basis for sample size calculations for future investigation using the GRASSP.

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Table 1. MCID Values GRASSP subtests

	Anchor-Based Method X (CI)	0.5 Standard Deviation	1 SEM
GRASSP Strength (GR-Str)	16 (10.9–21.1)	9.5	13.4
GRASSP Sensation (GR-Sen)	5 (2.3–7.7)	6.0	3.7
GRASSP Pre Ability (GR-pa)	4 (0.9–7.1)	3.5	4.9
GRASSP Pre Performance (GR-pp)	9 (4.2–13.8)	8.5	12.0

MCID values represent the whole sample from 1-month post injury to 6 months post injury

See Disclosure Index pages 39–89.

Presentation #30

Principal Radiographic Characteristics for Cervical Spinal Deformity: A Health-Related Quality of Life Analysis

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Introduction: Despite that cervical kyphosis was traditionally recognized as the presentation of cervical deformity, increasing studies demonstrated that cervical kyphosis may not imply definitely cervical deformity and may be a potential mechanism to maintain horizontal gaze. Therefore several other criteria for cervical deformity should be investigated, especially based on health-related quality of life (HRQOL). This study aims to propose radiographic characteristics of patients with cervical disability and to investigate the relevant parameters when assessing cervical alignment.

Methods: Patients (pts) with normal thoracolumbar alignment (T1 pelvic angle $<15°$), Neck Disability Index (NDI) and no prior cervical surgery were included. Pts were stratified into cervical asymptomatic (Asymp: NDI$\leq$15, VAS neck$\leq$3 and VAS arm$\leq$3) or symptomatic (Symp: NDI$>$15 or VAS neck$>$3 or VAS arm$>$3) groups. Sagittal parameters including SLS (Slope of Line of Sight), McGS (McGregor Slope), and CC (C2-C7 cervical curvature) were compared between groups. Logistic regression and principle component analysis (PCA) were performed to distinguish cervical symptomatic pts.

Results: There were 171 Patients (mean 44 y/o) included, with groups Asymp N=64 and Symp N=107. Symp pts were older (35y vs. 50y; $p<0.001$) and had worse NDI (5.4 vs. 41.3, $p<0.001$). C2-C7 SVA, McGS and SLS were significantly different between groups (all $p<0.05$), while CC was comparable ($p=0.09$). Logistic regression revealed that C2-C7 SVA (OR=1.043, $p=0.049$) and SLS (OR=0.936, $p=0.029$) were independent risk factors for poor HRQOL. Using PCA, the equation $0.55\times$C2C7 SVA$+0.34\times$C0C2 angle$+0.77\times$CC was calculated and showed significant correlations with NDI, VAS-Arm, VAS-Back and EQ5D scores (r=0.30, 0.26, 0.24 and 0.28, respectively). ROC analysis revealed improved predictability of regression and PCA formulas formula for HRQOL compared to single radiographic parameters.

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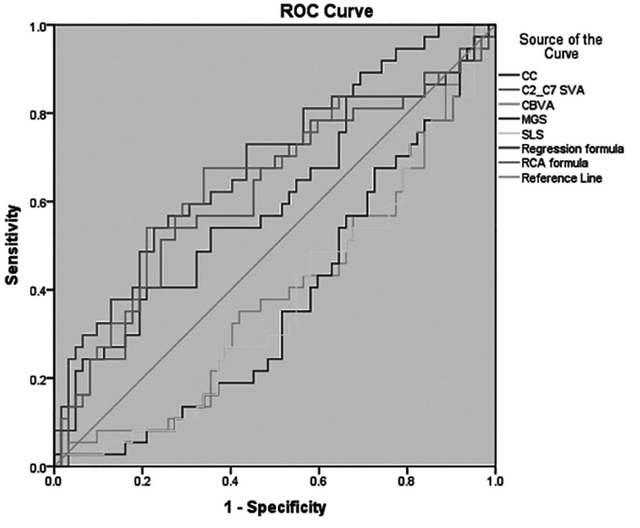
Conclusion: CC alone is unable to distinguish different cervical HRQOL status and thus should not be regarded as the only criteria for CSD. Gaze parameters should be integrated in evaluation of HRQOL-defined CSD, although the predictability of gaze parameters is lower than that of cervical alignment. This data supports the integration of both gaze and alignment parameters into cervical spinal deformity classification.



Parameters	Area under the curve	S.E.	p	95% CI
SLS	0.374	0.057	0.037	0.262-0.486
McGS	0.374	0.057	0.036	0.263-0.484
CBVA	0.393	0.058	0.075	0.278-0.507
C2-C7 SVA	0.62	0.060	0.046	0.502-0.738
CC	0.615	0.058	0.057	0.501-0.728
Regression formula (C2-C7 SVA + SLS)	0.667	0.059	0.006	0.551-0.783
PCA formula	0.649	0.060	0.013	0.532-0.766

See Disclosure Index pages 39–89.

Presentation #31

Diffusion Tensor Imaging Can Predict Surgical Outcomes of Patients with Cervical Compression Myelopathy

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Introduction: Surgical decompression is often recommended for symptomatic cervical compression myelopathy (CCM). It is important to know the prognosis of surgical outcomes and to recommend appropriate timing for surgery. Diffusion tensor imaging (DTI) can be used to evaluate patients with CCM quantitatively because it can provide microstructural information regarding the spinal cord with quantitative diffusion parameters. The objective of this study was to assess whether preoperative DTI parameters can predict surgical outcomes of patients with CCM.

Methods: We enrolled 20 patients with CCM who had undergone surgery and were followed up for more than 6 months. Japanese Orthopaedic Association (JOA) score for cervical myelopathy was evaluated before and 6 months after surgery. Surgical outcomes were measured by both change and recovery rate of JOA score, and were regarded as good if change in JOA score was 3 points or higher or the recovery rate of JOA score was 50% or higher. The patients were examined using a 3.0 T magnetic resonance system before surgery. For DTI acquisitions, reduced field of view (rFOV) diffusion-weighted spin-echo single-shot echo-planar imaging was used. rFOV is a new method that enables acquisition of high-resolution DTI. Regions-of-interest were determined based on the geometry of the cord on the B0 map and DTI parameters were measured using DTIStudio software (Johns Hopkins Medical Institute, Johns Hopkins University). Measured DTI parameters were fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD). The correlations between DTI parameters and surgical outcomes were analyzed. For statistical analysis, a Mann–Whitney U test and Spearman correlation coefficient were used. The predictive performance of FA value for good surgical outcomes was evaluated by the area under the receiver operator characteristic (ROC) curve. $p < 0.05$ was considered significant.

Results: JOA score was 8.9 preoperatively and 11.6 at 6 months after surgery and improved significantly ($p < 0.001$). Change of JOA score moderately correlated with FA ($r = 0.51$, $p = 0.02$). Moreover, the recovery rate of JOA score correlated moderately with FA ($r = 0.49$, $p = 0.03$). Change of JOA score and the recovery rate of JOA score tended to correlate with AD ($r = 0.41$, $p = 0.07$ and $r = 0.43$, $p = 0.06$, respectively), but this tendency was not significant. Change of JOA score and the recovery rate of JOA score did not correlate with MD and RD. The area under the ROC curve for prognostic precision for surgical outcomes evaluated by change and recovery rate of JOA score were 0.76 and 0.89, respectively, indicating good model prediction by FA. The cut-off value of FA for predicting good surgical outcomes evaluated by change and recovery rate of JOA score were 0.60 and 0.57, respectively.

Conclusion: It is feasible to predict surgical outcomes of patient with CCM using DTI. DTI can be used as an imaging biomarker for surgical prognosis of CCM patients.

Presentation #32

Posterior Cervical Spinal Cord Shift following Posterior Decompression and Prediction of Persistent Anterior Spinal Cord Compression using K-Plane: A Three Dimensional Modification of K-Line on MRI

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Introduction: Posterior spinal cord shift (PS) following posterior cervical decompressive surgery plays a key role in recovery of myelopathy, and persistent anterior spinal cord compression (AC) is a well-known factor related to unfavorable prognosis. Although a K-line or modified K-line, connects C2 and C7 central canal, is useful parameters to predict insufficient decompression after laminoplasty (LP), these concepts only considered the midsagittal images. In addition, there have been no studies on characteristics of PS and difference between LP and laminectomy with fusion (LF). The purpose of this study is to evaluate related factors of PS and predict AC using the authors' novel K-plane, a three dimensionally modification of K-line.

Materials and Methods: We retrospectively reviewed preoperative and follow-up cervical spine MR images of patients underwent LP or LF for cervical myelopathy. The changes of C27 angles by Cobb method, PS and midsagittal diameter of the spinal cord at the level of maximal compression, and alignment of the center of spinal cord were measured on MR images and their correlations were analyzed. K-plane was decided either (+) or (-) by the combination of sagittal K-line (+: any part of the line posterior to spinal canal, N: within spinal canal, -: anterior to spinal canal,) and coronal K-line (-: asymmetric cord compression, +: symmetric, Figure 1). The relationship between K-plane and presence of AC was analyzed.

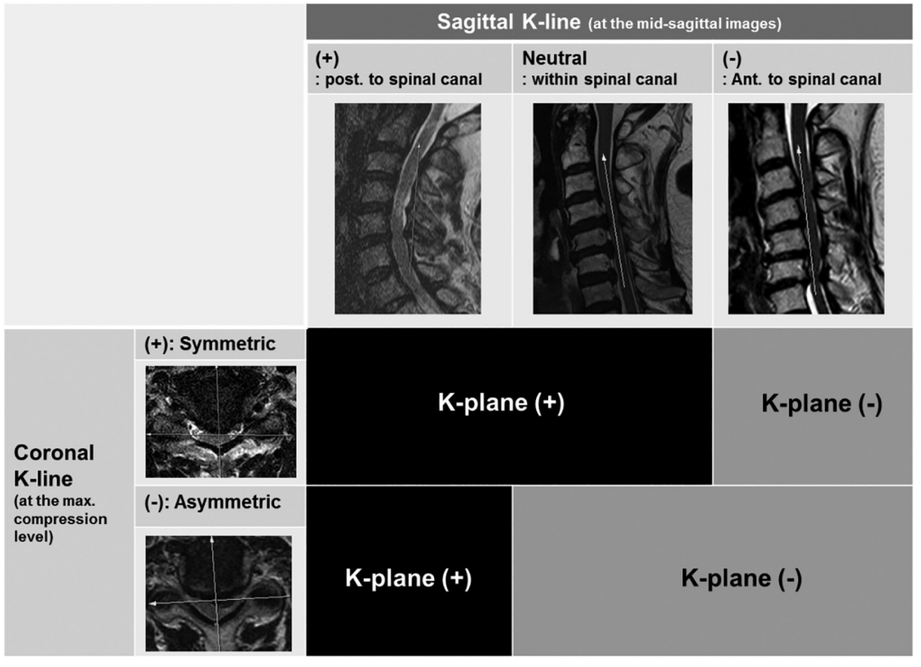
Results: A total of 62 patients (M:F = 43:19, mean age 58.9, CSM: OPLL = 56:6, LP: LF = 40:22,) were enrolled. Mean time interval of follow-up MR was 2.2 months and mean number of the level decompressed was 3.97. C27 angle showed significant positive relationship with PS and kyphotic change of the spinal cord. Mean C27 angle changes (LP:LF = 4.4 vs. -2.5°), mean PS (2.6 vs. 4.8mm) and mean spinal cord alignment change (10.2 vs. 17°) were parameters showed significant differences between LP and LF groups. Mean changes of spinal cord midsagittal diameter showed no significant difference (1.7 vs. 2.2mm). The correlations between K-plane and presence of AC showed significance in LP group only (LP vs. LF: sensitivity 94.1% vs. 66.7%, specificity 95.7% vs. 57.9%, $p < 0.001$) (Figure 2).

Conclusions: Lordotic cervical spine and laminectomy with fusion produced larger posterior shift and kyphotic change of the spinal cord alignment than kyphotic cervical spine and laminoplasty, respectively. A K-plane, three-dimensional modification of K-line, could be a useful guideline to predict persistent anterior spinal cord compression following laminoplasty.

See Disclosure Index pages 39–89.

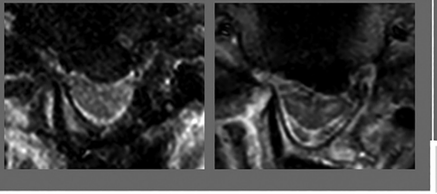
Presentation #32 (cont.)

Figure 1. A classification table shows K-plane using both sagittal K-line and coronal K-line.



Presentation #32

Figure 2. Prediction accuracy of K-plane for persistent anterior spinal cord compression in total group, laminoplasty (LP) group and laminectomy with fusion (LF) group.

* At the max. compression level, any part of the spinal cord is located anterior to the max. compression point Ex) 		Persistent anterior spinal cord compression *	
		(+)	(-)
Total (sensitivity 90%, specificity 78.6%)			
	K-plane (-)	18	9
	K-plane (+)	2	33
LP group (sens. 94.1%, spec. 95.7%, p<0.01)			
	K-plane (-)	16	1
	K-plane (+)	1	22
LF group (sens. 66.7%, spec. 57.9%, p=0.43)			
	K-plane (-)	2	8
	K-plane (+)	1	11

Presentation #33

Modular Organization of Whole-Brain Resting-State Functional Connectivity in Spinal Cord Injury: A Comparative Study

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Introduction: The application of graph theory to functional connectivity involves modeling the brain as a complex network comprising of nodes and edges. This allows for the inspection of whole brain connectivity patterns and the calculation of quantifiable network metrics for comparison between groups. To date, large-scale network analysis modeled on graph theory has not been applied to resting-state functional networks in complete spinal cord injury (SCI) patients. The purpose of the present study was to evaluate the topological architecture of the whole brain resting-state functional connectivity to characterize the pattern of modular reorganization in patients with cervical SCI both qualitatively and quantitatively.

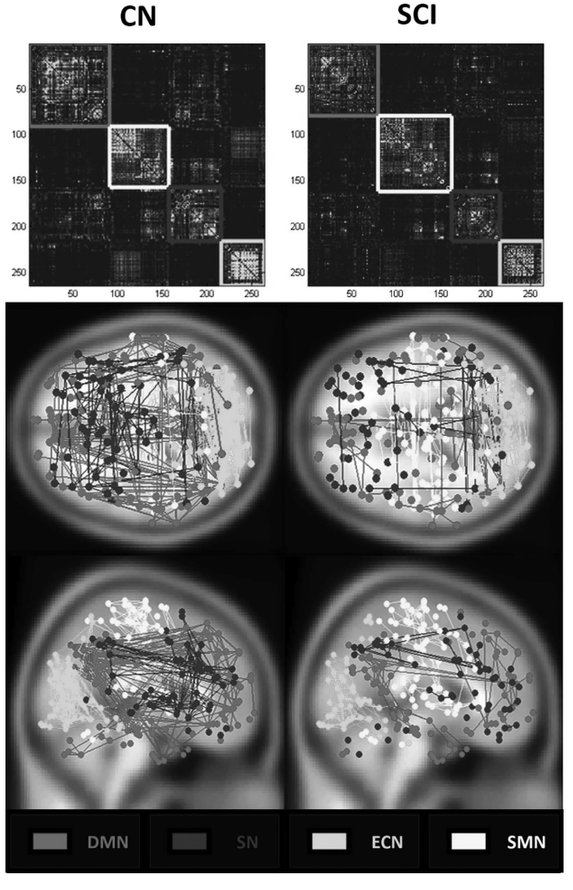
Methods: After obtaining the necessary IRB approval, 15 subjects with chronic (duration > 2 years) complete (ASIA A) cervical SCI and 15 neurologically intact controls were scanned. The data were preprocessed and then parcellated into 264 regions of interest (ROI). Correlation analysis was performed between the average time course obtained from each ROI for every possible ROI pair. The correlation values obtained resulted in the creation of an association matrix following which the threshold of 0 was applied to include only the positive correlation values. Then a modularity algorithm from brain connectivity toolbox (BCT) was applied to organize the data into modular patterns using MATLAB. Subsequently, statistical analysis was carried out to check for differences in the number of connections and the network density (cost) associated with those connections for a particular module between the SCI and the control groups using the two sample t-test.

Results: The modular organization pattern for the control and the SCI groups is shown in Figure 1. Both groups assembled into 4 distinct modules, namely the default mode network (DMN), salient network (SN), executive control network (ECN), and sensorimotor network (SMN). Upon visual inspection of individual modules, qualitative differences were noted in the number and the membership of constituent ROIs comprising a particular module. Quantitative comparison showed a decrease in the SCI group for all four modules in terms of the number of connections. Further, the network density (cost), defined as the number of connections present divided by the total number of possible connections also showed significant reduction in the SCI group for each of the 4 modules at cost threshold of 0.35 (Figure 2).

Presentation #33

Conclusion: The demonstration of modular organization pattern in both the SCI and the control groups highlights the applicability of large-scale network analysis modeled on graph theory for the evaluation of complex brain networks. The modules showed reductions for both the number of connections and the network density associated with those connections. The decrease might be due to reduced efficiency of information processing within specialized regions of the brain owing to the distortion in the transmission of input impulses from downstream neural structures. In addition, the alterations to modules in terms of the number and the membership of constituent ROIs is indicative of underlying neural plasticity of the cortical structures.

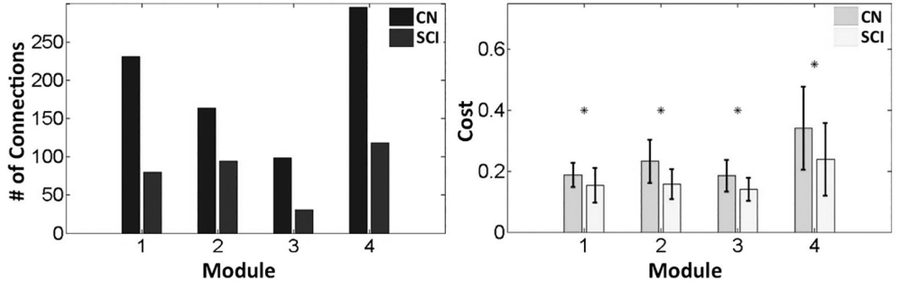
Figure 1. Modular organization of resting-state functional networks in CN and SCI groups. Top panel: Group-level average functional connectivity matrices organized according to their modular distributions (DMN = red, SN = blue, ECN = green, and SMN = yellow). Bottom panel: Corresponding color-coded anatomical representation for both the groups. CN, controls; SCI, spinal cord injury; DMN, default mode network; SN, salience network; ECN, executive control network; SMN, sensory motor network.



See Disclosure Index pages 39–89.

Presentation #33 (cont.)

Figure 2. Group comparison of individual modules. Left graph: Comparison of number of connections between CN and SCI groups. Red and blue lines designate CN and SCI subject groups respectively. Right graph: Comparison of network density (cost) between the two groups for each of the 4 modules. The asterisk (*) indicates statistical significant difference between the groups. The t-test comparison was carried out at threshold of 0.35. Green and yellow lines designate CN and SCI subject groups respectively. CN, controls; SCI, spinal cord injury.



Presentation #34

Prospective Clinical and Radiographic Assessment of the Cervical Spine in Professional Rodeo Riders after Exposure to Greater than 10G Linear Acceleration

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Introduction: Whiplash Associated Disorder (WAD) remains a controversial clinical diagnosis. Few models exist to comprehensively assess the clinical effects of rotational and linear acceleration on the cervical spine. As professional rodeo riders are subjected to repeated flexion/extension events during their rides, they represent an ideal population to assess the clinical and radiographic effects of massive acceleration and deceleration on the cervical spine. The purpose of this study is to evaluate the clinical and radiographic effect of a measurable acceleration/deceleration event on the cervical spine in professional rodeo riders using objective clinical data and validated health related quality of life (HRQoL) scores.

Materials and Methods: Adult (>18 years) professional rodeo riders were prospectively evaluated. After informed consent, each subject before their ride underwent focused physical examination by a licensed physician and completed the Visual Analogue Score (VAS) for Neck, Arm, and Back pain, the Neck Disability Index (NDI), the Short Form-36 (SF-36), and EuroQuol (EQ-5D). VAS neck, arm, and back pain scores were also assessed post-ride. Six riders also underwent pre- and post-event MRIs of the cervical-spine. Peak linear accelerometer data were recorded by a mouth-guard accelerometer. Descriptive statistics were performed and pre- and post-ride data were compared using Student's T-tests with α set at $p \leq 0.05$.

Results: Twenty-one male professional riders (bareback-8, saddle bronc-7, bull-6; average age 24.3 ± 5.6 years) were enrolled. They reported to have competed in an average of 55 ± 25 rodeos per year. The minority reported a prior neck injury (5/21) and missing rodeos due to neck injuries (4/21). No riders reported prior neck surgery.

Baseline NDI (4.9 ± 6.5), EQ-5D (0.89 ± 0.15), and SF-36 (PCS 51.9 ± 6.2, MCS 55.1 ± 4) were recorded. Seventeen riders' mouth-guards recorded events >10g. Mean linear acceleration was 23.8 ± 13.9g. Peak linear acceleration was 62.8g. Post-ride VAS for neck pain trended towards higher scores relative to pre-ride scores, although the difference was not significant (pre: 0.48 vs. post: 1.0; $p = 0.10$). Post-ride VAS scores for arm pain were not significantly different from pre-ride scores ($p > 0.25$). There were no differences in post-ride VAS scores between the bareback, saddle bronc, and bull riding groups ($p > 0.20$). Mild disk bulging adjacent to pre-existing disease was noted in 2/6 post-ride MRI scans, but no clinically significant changes were identified.

See Disclosure Index pages 39–89.

Presentation #34 (cont.)

Conclusion: Repeated high G-forces did not significantly impact the clinical incidence of neck, arm, or back pain in professional rodeo riders, nor did they produce any significant MRI changes. In this population, the G-forces experienced by the cervical spine did not produce any acute cervical symptoms or new neurological deficits. As the G-forces experienced by these riders are significantly greater than most activities of daily living and low-speed rear-end automobile collisions, these data provide a clinically useful context for evaluating patients with whiplash injuries.

Presentation #35

Anterior Cervical Discectomy and Fusion with Stand-Alone PEEK Cages with Integrated Screws Compared to an Allograft and Plate Construct

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Introduction: Traditionally anterior cervical plate (ACP) fixation with structural allograft has been used for reconstruction after anterior decompression of the cervical spine. More recently, stand-alone (SA) cages with integrated screw fixation have been popularized for cervical reconstruction; however, there is little comparative data between these two procedures.

Materials and Methods: Consecutive patients who underwent either SA or ACP procedures for one level degenerative pathology performed by one surgeon at a single institution between 2011 and 2013 were evaluated. Plain lateral radiographs of the cervical spine were performed pre-operatively, immediately post-operatively, and at final follow-up. The following radiographic parameters were assessed: pre-operative disc height, T1 slope, focal lordosis, overall cervical lordosis, C2-C7 sagittal vertebral angle (cSVA), and interbody cage subsidence. Symptomatic pseudarthrosis and reoperation rates were recorded.

Results: Sixty-two patients were included in the study (33 ACP and 29 SA). Average follow-up was 16.8 months. There were no significant differences in baseline demographic variables including age, sex, obesity, smoking, or level of operation (Table 1). Both constructs were equally effective at restoring local and segmental lordosis ($p > 0.05$) (Table 2). The SA construct was as effective as the allograft-ACP construct in terms of restoration of disc height, focal or global lordosis, and cSVA. There was no statistical difference ($p > 0.05$) between the average immediate post-operative height of the surgical segment (35.2 +/- 3.7mm) when compared to the height of the surgical segment at final follow-up (34.1 +/- 3.7mm) for all patients. Subsidence (defined as > 3mm loss of overall surgical segment height from immediate post-operative to final follow-up) occurred in 12.1% of ACP cases and 13.7% of SA constructs ($p > 0.05$). There were no significant differences in symptomatic pseudarthrosis rates requiring reoperation between the two groups at final follow-up. Independent risk factors for reoperation were male sex ($p = 0.049$) and smoking ($p = 0.017$).

Conclusion: These results indicate that SA anterior cervical discectomy and fusion results in equivalent radiographic alignment parameters when compared to ACP constructs with no difference in pseudarthrosis or reoperation rates. SA constructs generally are faster to apply and are often entirely intra-discal which may reduce swallowing difficulties associated with prominent ACPs. In addition SA constructs are less likely to impinge on adjacent level discs compared to ACPs. This information is useful for surgical decision-making and informing future studies that seek to further identify differences between these two procedures.

See Disclosure Index pages 39–89.

Presentation #35 (cont.)

Table 1. Patient Demographics

	All Patients	ACDF-AP	ACDF-SA	p
Overall	62 (100%)	33	29	
Age				0.304
18–44 years	27.4%	30.4%	24.1%	
45–54 years	37.1%	39.4%	34.5%	
55–64 years	24.2%	15.1%	34.5%	
65+years	11.3%	15.1%	6.9%	
Male sex	46.8%	45.5%	48.3%	0.824
Obesity	24.2%	24.2%	24.1%	0.992
Smoking	33.9%	36.4%	31.0%	0.658
Level				0.382
C2/3	1.6%	3.0%	0.0%	
C3/4	3.2%	3.0%	3.5%	
C4/5	21.0%	15.1%	27.6%	
C5/6	43.6%	39.4%	48.3%	
C6/7	27.4%	36.4%	17.2%	
C7/T1	1.6%	0.0%	3.5%	
C4/C6	1.6%	3.0%	0.0%	

Presentation #35

Table 2. Preoperative and Postoperative Radiographic Parameters comparing Anterior Cervical Discectomy and Fusion with Stand-Alone Cage (ACDF-SA) and Allograft with Plate (ACDF-AP) Constructs.

Measurement	ACDF-AP (mean+SD)	ACDF-SA (mean+SD)	p-value
Preoperative			
T1 slope	25.9+8.4	24.7+7.1	0.549
Anterior Disc Height	4.7+1.7	4.1+1.1	0.096
Middle Disc Height	5.7+1.2	5.2+1.0	0.054
Posterior Disc Height	3.0+1.4	2.8+1.2	0.512
C2-C7 SVA	26.5+15.8	23.4+12.0	0.396
Focal Lordosis	-1.0+4.5	-1.1+5.6	0.902
Overall Lordosis	6.4+13.9	7.2+9.5	0.789
Postoperative			
T1 slope	27.6+8.7	25.8+7.3	0.402
C2-C7 SVA	26.5+10.7	25. 9+12.8	0.836
Focal Lordosis	2.8+4.9	3.0+6.2	0.891
Overall Lordosis	8.3+12.6	8.3+10.2	0.999
Subsidence	35.0+3.5	34.7+4.2	0.796
Final			
T1 slope	26.8+8.0	26.2+7.3	0.787
C2-C7 SVA	26.0+14.1	21.6+8.9	0.157
Focal Lordosis	1.8+5.9	1.8+5.8	0.987
Overall Lordosis	8.3+12.6	9.1+7.4	0.776
Subsidence	34.0+3.2	33.9+4.4	0.957

C=cervical; SVA=sagittal vertebral alignment; ACDF-SA=anterior cervical discectomy and fusion with stand-alone cage; ACDF-AP=anterior cervical discectomy and fusion with allograft and plate constructs. Bolding denotes significance at $p<0.05$.

See Disclosure Index pages 39–89.

Presentation #36

Anterior Cervical Decompression and Fusion–Why Do Patients Proceed to Surgery? Does it Matter? Is it Neck Pain, Arm Pain or Neurological Change that Motivates the Patient?

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Introduction: The goal of an adequate surgical evaluation is to document objective evidence of specific anatomic lesions that when treated surgically, yield predictable and measurable patient perceived beneficial outcomes. A known consensus exists regarding surgical interventions for common cervical spine disorders such as radiculopathy, cervical myelopathy or traumatic cervical instability, but for patients with axial neck pain as the major complaint, the surgical indications are less clear.

Due to this uncertainty, we are hesitant on intervening surgically on patients who present with a chief complaint of mainly neck pain, but many of these patients, after further evaluation, are diagnosed with other pathologies rather than axial neck pain. Our objective was to assess the patient's specific motivation and primary reason for seeking care (neck pain, arm pain, both) and compare it to the physician's surgical diagnosis and to determine if the patient's driving factor had any effect on the surgical outcome.

Materials and Methods: IRB approved retrospective chart review of patients who underwent single or two level primary anterior cervical decompression and fusion at our institution in a two year period were analyzed. From the database 213 patients were identified who met the inclusion criteria for the study and who had completed an extensive outcome questionnaire regarding pain and self function at a 1-year follow up. Patient perceived outcomes were measured using NDI and VAS scores. Physician perceived outcome was determined using Odom's criteria. Descriptive summaries were generated overall and by patient chief complaint category.

Results: 213 patients were eligible for the study. Of these, 53 (24.9%) had a chief complaint of arm pain, 112 (52.6%) complained of neck pain, 46 (21.6%) complained of equal arm and neck pain, and 2 (0.9%) had other complaints (imbalance, weakness). No statistical difference on demographic data was noted among chief complaint groups except for worker's compensation or disability status (38.4% of patients with initial neck pain, 18.9% of those with predominant arm pain and 28.3% of neck = arm pain, $p < 0.05$).

Average decrease in VAS for all patients was 3.6 for arm VAS and 3.4 for neck VAS which meets the minimum clinically important difference. The arm pain group had a mean decrease of 5.2 and 2.3 in arm and neck VAS respectively, while the neck group decrease was 2.2 and 3.7 as well. NDI decrease was similar among groups. Physician perceived outcomes using Odom's criteria were excellent to good in 88.6% of the patient with primarily arm pain and 74.1% in those with mainly neck pain, but this difference was not statistically significant ($p > 0.05$) Table 1.

Conclusion: Patients perceived improvement with surgical management, as compared with their pre-operative status, regardless of whether they experienced mainly neck or arm pain as a chief complaint. Patients presenting with primarily neck pain may experience similar results in both physician and patient perceived outcomes to those who present with primarily arm pain.

Friday, December 2, 2016, 9:57–9:59 am CSRS–2016

Presentation #36

Table 1: Outcome Summaries Overall and by Patient Chief Complaint Category

		Patient Chief Complaint Category		
	All Patients (n=213)	Arm (n = 53)	Neck (n = 112)	Arm & Neck (n = 46)
Odom Score at follow-up – n (%)				
Excellent	59 (27.7%)	20 (37.7%)	26 (23.2%)	13 (28.3%)
Good	106 (49.8%)	27 (50.9%)	57 (50.9%)	20 (43.5%)
Fair	40 (18.8%)	5 (9.4%)	24 (21.4%)	11 (23.9%)
Poor	8 (3.8%)	1 (1.9%)	5 (4.4%)	2 (4.4%)
VAS – Arm Pain – Mean (SD)				
Initial	5.8 (3.0)	7.3 (2.3)	4.4 (2.9)	7.6 (1.9)
Follow-up	2.1 (2.7)	2.0 (2.7)	2.2 (2.6)	2.2 (2.9)
Change	-3.6 (3.5)	-5.2 (3.2)	-2.2 (3.2)	-5.4 (3.2)
VAS – Neck Pain – Mean (SD)				
Initial	6.7 (2.7)	4.5 (2.7)	7.4 (2.2)	7.3 (2.1)
Follow-up	3.2 (2.8)	2.2 (2.3)	3.7 (2.8)	3.3 (2.9)
Change	-3.4 (2.9)	-2.3 (3.0)	-3.7 (2.8)	-4.0 (2.7)
Neck Disability Index – Mean (SD)				
Initial	46.8 (17.3)	41.8 (17.9)	49.8 (15.3)	46.3 (18.9)
Follow-up	28.3 (21.2)	19.9 (20.7)	32.7 (20.3)	27.9 (21.1)
Change	-18.4 (18.7)	-21.0 (15.6)	-17.4 (17.5)	-18.2 (24.1)

[a] A chi-square test was used to see if any differences emerged in Odom scores between arm, neck and a=n categories.

See Disclosure Index pages 39–89.

Presentation #38

Longitudinal Effects of Intraoperative Neurophysiological Monitoring on Costs and Clinical Outcomes for Single Level Cervical Spine Surgery

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Introduction: Cervical spinal surgery carries serious potential neurological complications, including radiculopathy and permanent spinal cord injury. Intraoperative neuromonitoring may mitigate these complications. We investigate the effects of IONM on cost and quality of care for a large sample of cervical spine patients in a retrospective cohort study.

Methods: We used IMS's PharMetrics Plus Health Plan Claims data to identify commercially-insured patients aged 18-63 with single-level cervical spine surgery in an inpatient setting from 2008–2012. We observed patients for 6 months before and 12 months after the date of admission for their index surgery. We used the 6-month pre-index baseline period to measure patients' health status; we used the 12-month followup to evaluate post-index economic and clinical outcomes. We calculated four types of outcomes: total spending, neurological complications, readmissions, and outpatient opiate use (as a proxy for pain). We constructed a "treatment" variable to indicate whether patients received IONM during their index surgery. We also constructed variables to control for characteristics of patients' health status and demographics, ancillary services received during their index admission, and other characteristics of patients' illness and surgery. We estimated regression models of the effects on outcomes of IONM, holding constant these covariates plus fixed effects for patients' 3 digit zip code and year of procedure.

Results: Holding other factors constant, IONM was associated with increased spending for the index surgery of $1,229 ($p = 0.001$), but decreased spending post-discharge of $1,615 ($p = 0.010$), for a net effect of -$386 ($p = 0.608$) in the year after the index admission. Shorter length of stay (0.116 days, $p = 0.004$) and fewer readmissions (20.5 per thousand, $p = 0.036$) accounted for at least part of the post-discharge savings. The reduction in readmissions occurred in the month after the index admission and persisted through the entire following year. IONM was associated with decreased rates of nervous system complications (of 4 per thousand, $p = 0.048$) and post-discharge opiate use (of 17 prescriptions per thousand, $p = 0.050$) in the year after the index admission.

Conclusions: Holding other factors constant, IONM was approximately cost-neutral in a sample of nonelderly commercially-insured patients with uncomplicated cervical spine surgery, and was associated with improved patient health outcomes. Understanding the extent to which IONM has similar effects in other populations is an important topic for future research.

Presentation #39

Surgical and Functional Outcomes after Multi-Level Cervical Fusion for Degenerative Disc Disease Compared to Fusion for Radiculopathy: A Study of Workers' Compensation Population

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Introduction: Cervical fusion provides more than 90% of symptomatic relief for radiculopathy and myelopathy. However, cervical fusion for degenerative disc disease (DDD) without radiculopathy or myelopathy is considered controversial. In addition, multi-level fusion is associated with poorer surgical outcomes with increased levels fused. The objectives of this study is to 1) evaluate presurgical and surgical factors that are associated with poor return to work status after multi-level cervical fusion, 2) compare outcomes after multi-level cervical fusion for patients with degenerative disc disease without radiculopathy or myelopathy (discogenic pain) versus patients with radiculopathy.

Methods: Data of cervical comorbidities was collected from Ohio Bureau of Workers' Compensation for subjects with work-related injuries using "International Classification of Diseases, Ninth Edition (ICD-9)" and "Current Procedural Terminology" (CPT) codes. See Figure 1 for patients' selection flow diagram. Multivariate logistic regression was performed to evaluate whether stable RTW status was achieved or not. Surgical and functional outcomes were compared between groups.

Results: In the study population of patients who underwent multi-level cervical fusion, multiple factors were negatively associated with stable RTW status within 3 years after fusion: Fusion for discogenic pain (DDD without radiculopathy) (OR:0.74; 95%CI: 0.56-0.98: $p<0.05$), age older than 55 (OR:0.41; 95%CI: 0.30-0.56: $p<0.05$), opioid use prior to surgery (OR:0.60; 95%CI: 0.48-0.75: $p<0.05$), initial psychological evaluation prior to surgery (OR:0.35; 95%CI: 0.24-0.52: $p<0.05$), injury-to-surgery > 2years (OR:0.68; 95%CI: 0.54-0.82: $p<0.05$), and instrumentation (OR:0.68; 95%CI: 0.53–0.88: $p<0.05$).

Stable RTW status was achieved in 43.3% of the DDD group and 54.8% of the Radiculopathy group (p: 0.0001). DDD patients were less likely to achieve stable RTW status after surgery compared to patients with radiculopathy (OR = 0.63 [0.50–0.79]). RTW rate within the first year after surgery was achieved in 33.6% of the DDD group and 43.7% of the radiculopathy group (p: 0.0003). Compared to radiculopathy patients, DDD patients were less likely to RTW within one year after surgery (OR = 0.65 [0.52–0.82]).

Higher rate of disability benefits were awarded to patients with DDD after surgery ($p = 0.002$). Higher postoperative opioid use was also observed in the DDD group (p: 0.001). Patients with DDD received opioids for longer than 8 weeks after surgery at a higher rate than patients with radiculopathy ($p = 0.003$).

No significant difference in reoperation rate within 3 years after fusion was observed between the groups.

See Disclosure Index pages 39–89.

Presentation #39 (cont.)

Conclusion: Multiple detriments affect stable return to work status after multi-level cervical fusion including DDD. Degenerative disc disease was associated with lower RTW rates, less likelihood to return to work, higher disability, and higher opioid use after surgery. Multi-level cervical fusion for degenerative disc disease without radiculopathy or myelopathy may be counterproductive. Future studies should investigate further treatment options of DDD, and optimize patient selection criteria for surgical intervention.

Figure 1. Subjects Selection Flow Diagram

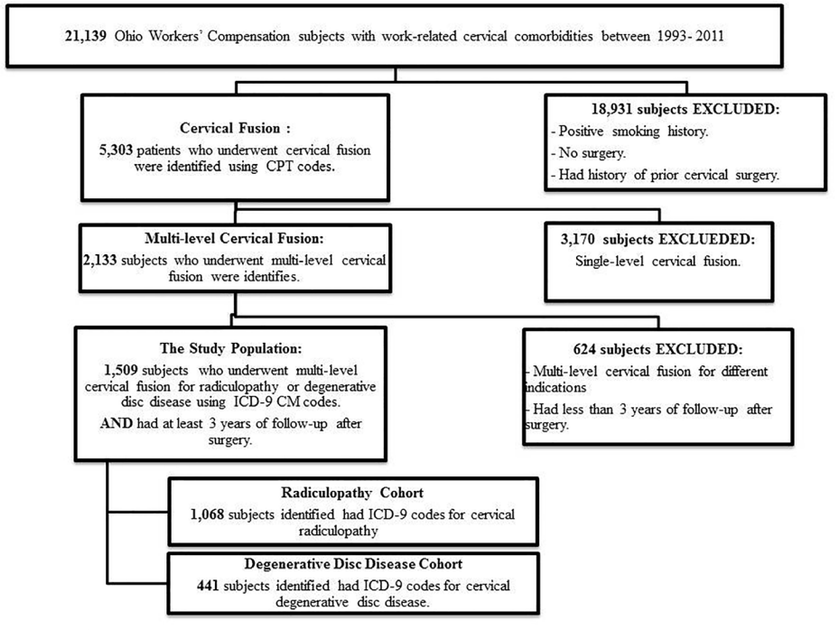

Figure 1: Subjects Selection Flow Diagram.

Presentation #40

An Analysis of Conflicts of Interest in Cervical Spine Surgery: The Effects of Industry Payments on Practice Patterns and Complication Rates

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Introduction: Recent demands from the United States Congress and the Institute of Medicine have highlighted the importance of conflict of interest among physicians. Previous studies have identified orthopaedic and neurological surgeons as receiving among the highest industry payment amounts. However, to date, no study has investigated the association or potential effects of disclosed industry payments with quality of patient care. We sought to determine whether financial relationships with industry had any impact on practice patterns or complication rates of spine surgeons.

Methods: A comprehensive database of spine surgeons in the United States with compiled data of industry payments, fusion recommendation rates, and complication rates was created. Practice pattern data was derived from a publically available Medicare-based database generated from CPT codes, which included the total number of, and rate at which each spine surgeon recommends fusion (2011–2012). Complication rate data for cervical fusion procedures for each surgeon was extracted from the ProPublica Surgeon Scorecard database (2009–2013) (https://projects.propublica.org/surgeons/), which utilizes in-hospital mortality and readmission within 30 days of discharge for designated conditions as complications of surgery. A mixed-effects model adjusting for age and health-status along with hospital and surgeon random-effects was used to risk-adjust each surgeon's raw complication rate. Data regarding industry payments were derived from the Open Payments website (2013–2014) which collects information on "transfers of value" worth more than $10 as reported by manufacturers and group purchasing organizations (https://www.cms.gov/OpenPayments/index.html). Surgeons performing fewer than 10 fusions from 2011–2012 and those without complication data were excluded from this study. Pearson correlation coefficients and multivariate regression analyses were used to determine the relationship between industry payments, cervical fusion recommendation rates, and complication rates.

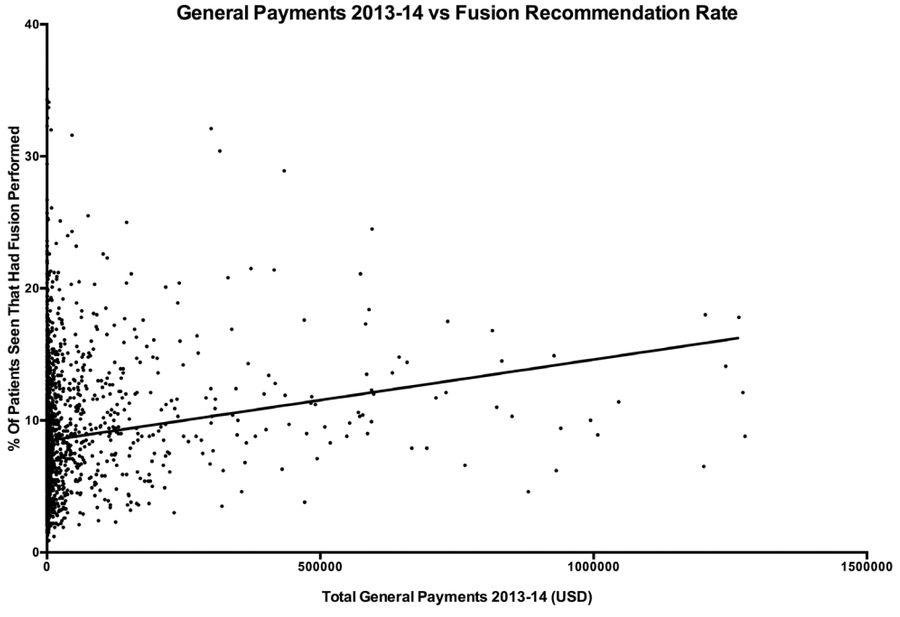
Results: A total of 2,110 spine surgeons (54% orthopedic, 46% neurosurgeon) practicing in the United States met our inclusion criteria. Pearson correlation analyses revealed a negligible relationship between industry payments and cervical fusion recommendation rates ($r = 0.13$; $p<0.01$). An r-value > 0.30 is generally accepted as a threshold for weak correlations, with values lower than this designated as negligible. Multivariate regression analysis demonstrated no significant relationships among payments and cervical recommendation or complication rates. Additionally, a comparison of 2007 surgeons receiving payments from industry and 103 surgeons without disclosed payments revealed no significant differences between the two groups with regard to fusion recommendation or complication rates.

See Disclosure Index pages 39–89.

Presentation #40 (cont.)

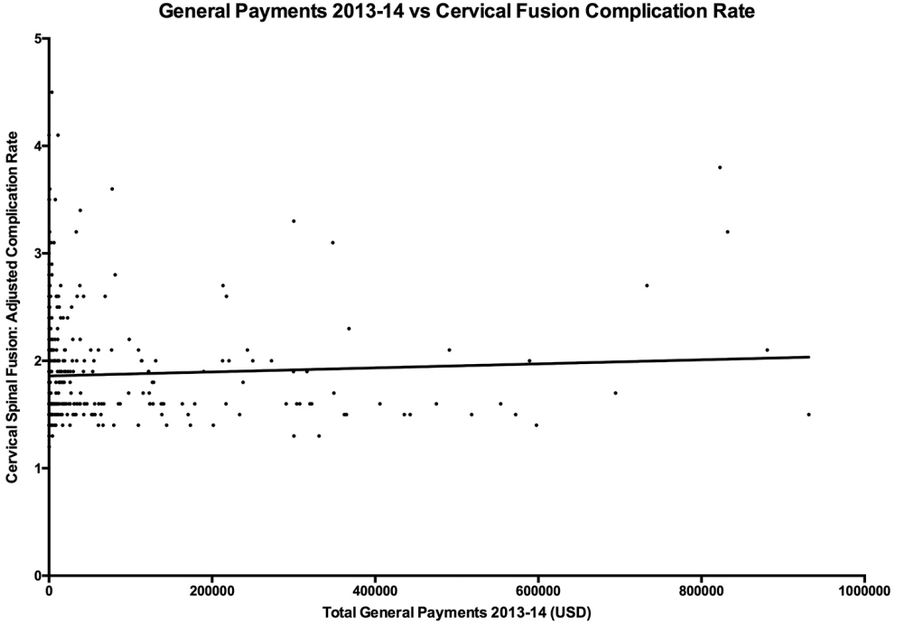
Conclusions: While spine surgeons receive the highest industry payment amounts among all subspecialties, conflict of interest does not appear to have a significant impact on practice patterns or complication rates.

Figure 1. Correlation between general industry payments and cervical fusion recommendation rate.



Presentation #40

Figure 2. Correlation between general industry payments and cervical fusion complication rate.



See Disclosure Index pages 39–89.

Presentation #41

The Effect of Surgeon Volume on Complications, Length of Stay, and Costs after Anterior Cervical Fusion

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Introduction: Increased surgeon volume may be associated with improved outcomes following surgical procedures. However, there is a lack of information on the effect of surgeon volume on short-term outcomes following anterior cervical fusion (ACF). The purpose of the present study was to identify the association between surgeon volume and inpatient complications, length of stay, and costs associated with ACF.

Materials and Methods: A retrospective cohort study of ACF patients was performed using the Nationwide Inpatient Sample (NIS) from 2003 to 2009. Surgeon volume was divided into three categories, volume less than the 25th percentile of surgeon volume, between 25th and 74th percentile of surgeon volume, and greater than or equal to the 75th percentile of surgeon volume. Multivariate regression was used to compare the rates of adverse events, hospital length of stay, and total hospital costs between surgeon volume categories.

Results: A total of 419,212 ACF patients were identified. The 25th percentile for volume was 5 cases per year, and the 75th percentile for volume was 67 cases per year. Average age was 51.7 ± 11.6 (mean ± standard deviation) and 52.9% of patients were female. Volume < 25th percentile was associated with increased rates of any adverse event (OR 3.8, $p < 0.001$), and multiple individual complications including death (OR 2.5, $p = 0.014$), pneumonia (OR 4.4, $p < 0.001$), sepsis (OR 2.4, $p < 0.001$), surgical site infection (OR 4.1, $p < 0.001$), and wound dehiscence (OR 3.5, $p < 0.001$) on multivariate analysis (Table 1). Notably, volume ≥ 75th percentile was associated with decreased rates of any adverse event (OR 0.7, $p < 0.001$), death (OR 0.6, $p = 0.028$), sepsis (OR 0.5, $p < 0.001$), and wound dehiscence (OR 0.6, $p < 0.001$).

Average length of stay was 1.7 ± 2.2 days, and the average hospitalization cost was $12,999 ± $9,058. On multivariate analysis, length of stay was significantly increased by 2.3 days ($p < 0.001$) for surgeons below the 25th percentile of volume and was decreased by 0.3 days for surgeons with volume ≥ 75th percentile (Table 2). Hospital costs were $4,569 more for surgeons with < 25th percentile of volume and $1213 less for surgeons with ≥ 75th percentile volume.

Conclusion: In this nationally representative sample, surgeons with volume less than the 25th percentile had significantly increased complications, length of stay, and costs. Conversely, surgeons with ≥ 75th percentile volume had decreased of complications, length of stay, and costs. These results indicate that patients and healthcare systems may derive significant benefits from using surgeons that perform a high annual volume of ACF procedures.

Friday, December 2, 2016, 10:17–10:19 am CSRS–2016

Presentation #41

Table 1. Rates of individual adverse events by surgeon volume*

					Multivariate Regression			
					< 25th pctle†		≥ 75th pctle†	
Adverse event	Overall	< 25th Pctle	25-74th Pctle	≥ 75th Pctle	OR	p-value	OR	p-value
Any adverse event	1.35%	8.65%	1.70%	1.05%	**3.8**	**< 0.001**	**0.7**	**< 0.001**
Death	0.08%	0.58%	0.12%	0.06%	**2.5**	**0.014**	**0.6**	**0.028**
Acute kidney injury	0.12%	1.02%	0.18%	0.08%	1.8	0.090	**0.5**	**0.007**
Cardiac arrest	0.07%	0.57%	0.09%	0.05%	2.3	0.064	**0.6**	**0.040**
Myocardial Infarction	0.12%	1.34%	0.13%	0.08%	**4.4**	**< 0.001**	0.7	0.136
Pneumonia	0.32%	2.12%	0.44%	0.23%	3.4	0.271	1.0	0.939
Sepsis	0.08%	1.13%	0.10%	0.05%	**2.4**	**< 0.001**	**0.5**	**< 0.001**
Surgical site infection	0.06%	0.49%	0.07%	0.05%	**4.1**	**< 0.001**	0.6	0.104
Urinary tract infection	0.61%	3.82%	0.84%	0.46%	**4.0**	**0.005**	0.9	0.687
Wound dehiscence	0.01%	0.00%	0.01%	0.01%	**3.5**	**< 0.001**	**0.6**	**< 0.001**
Dural tear	0.08%	0.07%	0.08%	0.08%	1.1	0.751	1.0	0.704

* **Bolding** indicates statistical significance ($p < 0.05$)
† 25th-74th percentile used as reference.

Table 2. Multivariate analysis for length of stay and hospital charges by surgeon volume*

					Multivariate Regression			
					< 25th pctle†		≥ 75th pctle†	
Outcome	Overall	< 25th Pctle (mean ± SD)	25-74th Pctle (mean ± SD)	≥ 75th Pctle (mean ± SD)	Beta	p-value	Beta	p-value
Length of Stay (days)	1.7 ± 2.2	4.4 ± 7.3	1.9 ± 2.5	1.6 ± 1.8	+ 2.3	< 0.001	-0.3	< 0.001
Cost (USD)	$12,999 ± 9,058	$18,945 ± 20,829	$13,864 ± 10,296	$12,534 ± 7,955	+ 4569	< 0.001	-1213	< 0.001

* **Bolding** indicates statistical significance ($p < 0.05$)
† 25th-74th percentile used as reference.

See Disclosure Index pages 39–89.

Presentation #42

Defining Health Utility following One- or Two-Level ACDF or CDR at Five Years

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Introduction: In the era of comparative value analysis, there is a tremendous emphasis to consider the relative costs and benefits of procedures that are performed for the same indication. Anterior cervical discectomy and fusion (ACDF) and cervical disc replacement (CDR) are two procedures that can be performed for the treatment of acute cervical disc herniation with myelopathy/radiculopathy. A critical component of the cost-effectiveness analysis remains the ability to properly define value. The purpose of this study is to determine the utility of one- and two-level ACDF and CDR at various post-operative time points.

Materials and Methods: Data from the Medtronic one- and two-level Prestige Cervical Disc investigational device exemption (IDE) studies. Data from the 36-item Short Form Health Survey (SF-36) were collected at baseline, 12 months, 24 months, 36 months, and 60 months post-operatively. Using the SF-6D algorithm, the SF-36 scores were converted into utility scores for each time point. A repeated measures ANOVA was used to compare to detect overall differences between related means. Tukey's method for multiple comparisons was used to determine which means within the groups were statistically different.

Results: Table 1 summarizes the calculated utility values for one- and two-level ACDF and CDR for each of the time points. There was a statistically significant difference between groups as determined by repeated measures one-way ANOVA ($F(2,9) = 15.63$, $p = 0.0008$) (Figure 1). A Turkey post-hoc analysis indicated that one-level ACDF had a statistically lower utility score at all time points when compared with one- and two-level CDR ($p = 0.04$, p-002) (Table 2). Similarly, two-level ACDF was shown to have a lower utility values at all time points when compared with two-level CDR ($p = 0.010$). One-level ACDF and two-level ACDF were not shown to have different utility values at any time point ($p = 0.55$). One-level CDR and two-level CDR did not differ in their utility values at any time point ($p = 0.67$).

Conclusions: The health utility values for one- and two-level ACDF and CDR were calculated for the pre-operative baseline state, 12 month, 24 month, 36 month, and 60 month post-operative state. Overall, CDR was found to have a higher health utility state for one- and two-level procedures at evert time point. One- and two-level ACDF procedures did not differ in their health utility state at any time point. Similarly, one- and two-level CDR demonstrated the same health utility score at every time point. The results of this study indicate that CDR results in a higher post-operative health utility state than ACDF, though two-level CDR does not provide any significant additional health benefit compared to single-level.

Friday, December 2, 2016, 10:20–10:22 am CSRS–2016

Presentation #42

Table 1. Heath Utility Scores for One- and Two-Level ACDF and CDR at Each Time Point

Time (months)	One-Level ACDF	One-Level CDR	Two-Level ACDF	Two-Level CDR
Baseline	0.54	0.55	0.53	0.55
12	0.68	0.73	0.69	0.72
24	0.69	0.72	0.71	0.73
36	0.69	0.73	0.72	0.74
60	0.70	0.72	0.70	0.74

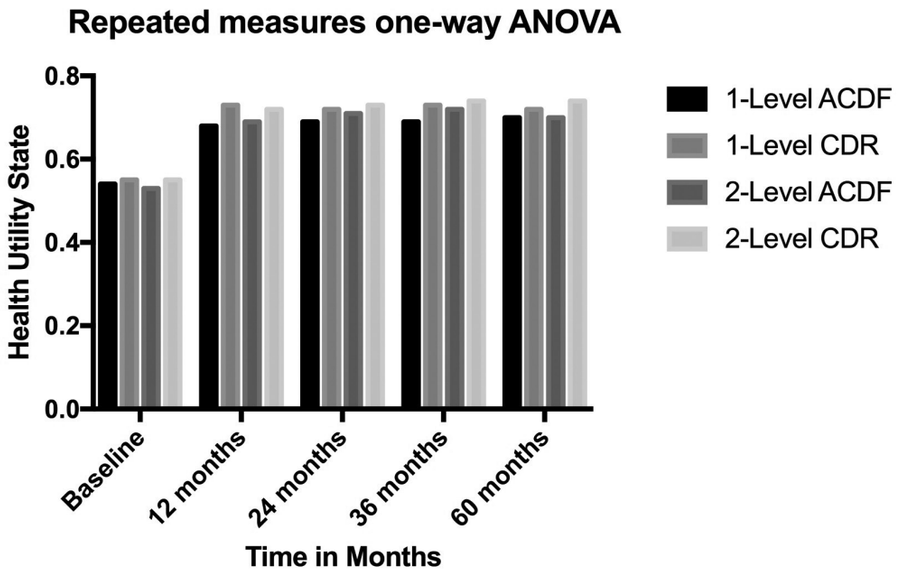
Table 2. Tukey's Post-hoc Analysis Comparing Means for Each Simulation

Levels	Mean Difference	P Value
One-Level ACDF vs. One-Level CDR	-0.03	0.04
One-Level ACDF vs. Two-Level ACDF	-0.01	0.55
One-Level ACDF vs. Two-Level CDR	-0.036	0.02
One-Level CDR vs. Two-Level CDF	0.02	0.07
One-Level CDR vs. Two-Level CDR	-0.006	0.67
Two-Level ACDF vs. Two-Level CDR	-0.026	0.010

See Disclosure Index pages 39–89.

Presentation #42 (cont.)

Figure 1. Results of the One-Way Repeated Measures Anova



Presentation #43

Patient Reported Outcomes and Costs in Revision Cervical Surgery

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Introduction: Revision rates for cervical spine surgery are steadily increasing. It is important to be able to counsel patients on expected results and financial burden following a revision procedure. However outcomes and cost of these procedures are poorly defined in the literature. The purpose of this study was to determine cost and utilize standardized outcome measures to assess the results of revision cervical spine surgery.

Materials and Methods: Patients undergoing revision cervical spine surgery at a single institution were included between October 2010 and January 2016 in a prospective registry database. Patients were divided into three cohorts depending on their etiology for revision surgery including recurrent disease, pseudoarthrosis, or adjacent segment disease. Patient reported outcomes (PROs) including Neck Disability Index (NDI), EuroQol-5D (EQ-5D), numeric rating scale-neck pain (NRS-NP), and numeric rating scale-arm pain (NRS-AP) were measured at baseline as well as 12 months following revision surgery. Mean costs at 12 months following revision surgery were also calculated. Satisfaction was determined by the NASS patient satisfaction index. Variables were compared using student t-test.

Results: A total of 115 patients (Table 1) underwent cervical revision surgery for recurrent disease ($n=21$), pseudoarthrosis ($n=45$), and adjacent segment disease ($n=49$). There was a significant improvement in all the patient-reported outcomes at 12 months (Figure 1) following surgery regardless of etiology ($p<0.0001$). Total cost of revision surgery ranged between 21294 ± 8614 to 23914 ± 15396 depending on pathology. No significant differences were seen between costs (Table 2) among different revision groups ($p=0.53$). No differences were seen between 12 month PROs among the three revision groups with regards to NDI ($p=0.66$), EQ-5D ($p=0.99$), NRS = NP ($p=0.72$), or NRS-AP ($p=0.47$) (Table 3). Satisfaction was met in 75.5-85.7% ($p=0.21$) of patients depending on the etiology of the revision need. Complication rates were between 4-9%.

Conclusion: This is one of the first studies to determine costs and outcome measures in the setting of cervical spine revision surgery. Significant improvement in PROs were seen 12 months following revision surgery regardless of etiology. The etiology of revision surgery did not affect the amount of improvement in outcome measures or cost. Satisfaction rates were similar among different groups as well ranging between 75.5-85.7%. Based on our analysis a majority of patients can expect to receive some benefit by 12 months and are satisfied with their procedure. It is imperative to counsel patients and set expectations prior to undergoing revision procedures.

See Disclosure Index pages 39–89.

Presentation #43 (cont.)

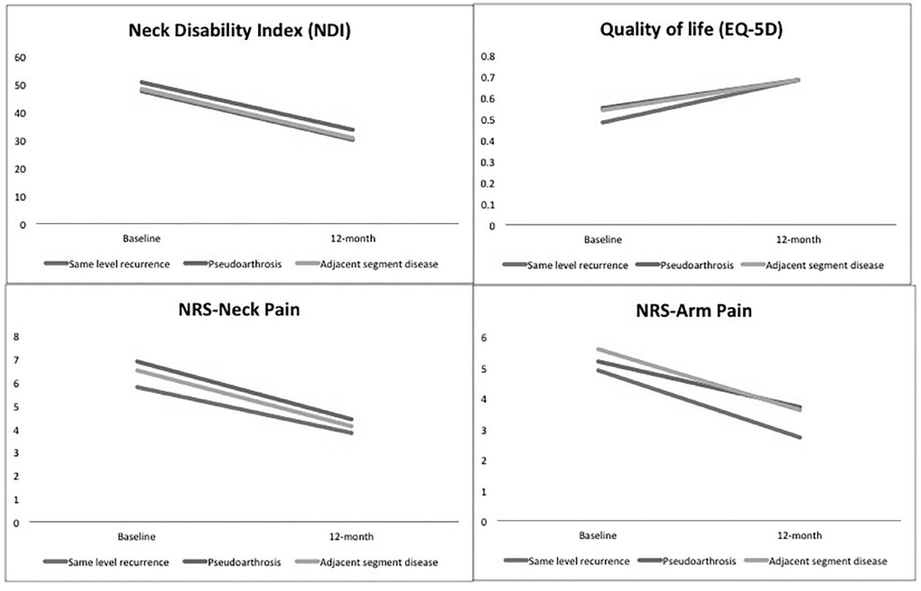
Table 1. Baseline characteristics and patient-reported outcomes of patients undergoing revision surgery for cervical degenerative pathologies

	Same level recurrence (N = 21)	Pseudoarthrosis (N = 45)	Adjacent segment disease (N = 49)	P-value
Age	52.9 ± 10.9	56.1 ± 9.9	56.1 ± 9.8	0.43
Male	9 (43%)	23 (51%)	24 (49%)	0.82
Smoker	5 (24%)	10 (22%)	11 (22%)	0.99
BMI	30.8 ± 7.6	30.7 ± 5.8	30.4 ± 6.2	0.98
DM	6 (28%)	13 (29%)	8 (16%)	0.3
MI	0	3 (7%)	1 (2%)	0.3
Hypertension	12 (57%)	28 (62%)	28 (57%)	0.86
CHF	1 (5%)	0	1 (2%)	0.38
COPD	0	2 (4%)	2 (4%)	0.63
ASA grades > 3	13 (62%)	36 (80%)	34 (69%)	0.4
Duration of symptom	13 (62%)	30 (67%)	20 (41%)	0.096
Myelopathy	15 (71%)	11 (24%)	29 (59%)	< 0.0001
Preoperative narcotic use	9 (43%)	28 (62%)	28 (57%)	0.43
Duration preop narcotic use	571.5 ± 1229	662.7 ± 1521.4	562.8 ± 1033.2	0.92
Zung	36.5 ± 10.3	36.8 ± 9.6	37.1 ± 10.1	0.97
MSPQ	6.9 ± 4.7	9.7 ± 6.5	8.1 ± 4.8	0.14
Insurance				0.24
Medicaid / Uninsured	8 (38%)	11 (24%)	4 (8%)	
Medicare	0	9 (20%)	10 (20%)	
Private	13 (62%)	25 (56%)	25 (51%)	
Surgery approach				0.04
Anterior	12 (57.1%)	16 (35.6%)	34 (69.4%)	
Posterior	9 (42.8%)	29 (64.4%)	15 (30.6%)	
EBL	294.7 ± 349.1	317.2 ± 445.2	201.8 ± 226.8	0.27
Length of hospital stay	2.3 ± 1.6	3.1 ± 2.6	1.9 ± 1.4	0.02
Length of surgery in mins	204.2 ± 104.4	184.9 ± 101.3	170.3 ± 73.7	0.35
Number of levels	2.6 ± 1.8	3.6 ± 3.2	2.3 ± 1.7	0.03
Baseline PROs				
NDI	47.6 ± 15.8	50.6 ± 17.4	48.3 ± 18.4	0.74
EQ-5D	0.48 ± 0.24	0.55 ± 0.25	0.54 ± 0.25	0.57
NRS-NP	5.8 ± 3.0	6.9 ± 1.9	6.5 ± 2.5	0.22
NRS-AP	4.9 ± 3.2	5.2 ± 3.2	5.6 ± 3.2	0.69

• **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 #43

Figure 1. PROs at baseline compared to 12 months following revision surgery. All PROs had significant improvement in all three groups ($p < 0.0001$).



See Disclosure Index pages 39–89.

Presentation #43 (cont.)

Table 2. Mean costs at 1-year for patients undergoing revision surgery for cervical degenerative pathologies

	Same level recurrence (N = 21)	Pseudoarthrosis (N = 45)	Adjacent segment disease (N = 49)	P-value
Hospital cost	18610 ± 12769	18590 ± 11164	15062 ± 5826	0.17
Surgeons professional cost	3483 ± 2420	3171 ± 1378	2924 ± 932	0.34
Health-care visit cost	1637 ± 1973	1094 ± 1092	1582 ± 1571	0.21
Medication cost	1184 ± 1040	1342 ± 1270	1331 ± 1119	0.86
Diagnostic cost	620 ± 688	499 ± 742	773 ± 1700	0.57
Post-operative resource utilization	3441 ± 2587	2936 ± 2199	3686 ± 2703	0.34
Total direct cost	21166 ± 14331	21113 ± 11895	18134 ± 7385	0.34
Indirect cost	2746 ± 3611	2632 ± 5216	2724 ± 4987	0.99
Total cost	23914 ± 15396	23745 ± 12699	21294 ± 8614	0.53

Presentation #43

Table 3. Improvement in patient-reported outcomes 1-year after revision surgery for cervical degenerative pathologies

	Same level recurrence (N = 21)	Pseudoarthrosis (N = 45)	Adjacent segment disease (N = 49)	P-value
12 month change scores				
NDI	17.6 ± 13.6	16.9 ± 16.6	17.7 ± 19.7	0.98
EQ-5D	0.14 0.36	0.04 0.21	0.06 ± 0.24	0.33
NRS-NP	2.0 ± 3.1	2.7 ± 2.6	2.4 ± 2.9	0.61
NRS-AP	2.3 ± 3.7	1.5 ± 3.8	2.0 ± 4.1	0.72
12 month PROs				
NDI	30 ± 17.5	33.6 ± 19.9	30.6 ± 17.5	0.66
EQ-5D	0.68 ± 0.21	0.68 ± 0.25	0.68 ± 0.24	0.99
NRS-NP	3.8 ± 2.5	4.4 ± 2.7	4.1 ± 2.7	0.72
NRS-AP	2.7 ± 3.1	3.7 ± 3.4	3.6 ± 3.1	0.47
Satisfaction 12 months				0.21
Satisfied (NASS 1 and 2)	18 (85.7%)	40 (88.9%)	37 (75.5%)	
Not satisfied (NASS 3 and 4)	12 (14.2%)	15 (11.1%)	23 (24.5%)	
Complications 90-days	1 (5%)	4 (9%)	2 (4%)	

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Presentation #44

Anterior Cervical Discectomy (ACDF): A More Exact, Non-traditional Activity and Resource Cost Accounting at University Center Shows $16,500 Cost Differential

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Definition: Unsustainable healthcare expenditures in U.S. challenge providers and organizations to deliver higher quality care at lower cost with increased value. To accomplish this aim, we focused on our true costs. We compared time-driven activity-based costing (TDABC) to traditional accounting methodology (TA) at our university academic medical center (AMC) for primary anterior cervical discectomy (ACDF) over care cycle from admission surgery day to 90 days post-surgery. Direct and indirect costs from consecutive ACDF patients in FY'15 were identified from various hospital cost centers at our institution.

Data: The total cost per case using TA compared to TDABC method was $29,222 versus $13,073, respectively. We identified sizeable differences in cost estimates between TA and TDABC when comparing physicians and advanced practice provider (APP) personnel costs ($894 vs $501), non-physician personnel costs ($5,264vs $1,251), space and equipment costs ($1,207 vs $151), and indirect costs ($9,964 vs $1,859). Implants ($5,126) and consumables ($4,173) costs were equivalent in both methods as these figures were based on hospital purchase price.

With TA, personnel accounted for 25% of overall costs, with physicians/APPs and non-physicians representing 4% and 21% of total costs, respectively. Space and equipment represented 16%, consumables 14%, and indirect costs 24% of overall costs. Using TDABC, personnel represented 14% of overall costs (physicians/APP 4%, non-physicians 10%), space and equipment 1%, consumables 32%, and administrative overhead 14%.

Results: TDABC suggests that TA overestimates the personnel costs of ACDF by approximately $7,400 per patient. Additionally, TA may overestimate space, equipment, and indirect costs by more than $9,074. TDABC offers patient-level granular cost data that is imperative in reducing costs and negotiating sustainable fixed-bundled payment contracts with payers. Concurrently, we improved value of longitudinal care for ACDF using new implant vendor contracts that reduced our implant cost by 24%-45%.

Presentation #45

Directly Reprogrammed Human Neural Precursor Cells – A Novel and Translationally Relevant Source for Cell Replacement Therapy in Spinal Cord Injury

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Introduction: Although induced pluripotent stem cells (iPSCs) have potential as a therapeutic strategy for spinal cord injury (SCI), several issues remain to be solved before they can be transferred to the clinic. These include challenges with karyotypic instability, the potential for tumorigenicity, issues surrounding their long-term differentiation potential and challenges with scaleability. To overcome these challenges, we have recently developed a novel approach to generate neural precursor cells which are directly reprogrammed (drNPCs) from human somatic cells without gene integration. The entire reprogramming process has an efficiency of 40% and takes less than 2 weeks; a significant improvement over the current iPSC technique which takes half a year with net efficiency of 1%. Additionally, drNPCs can be expanded >100 fold in less than one month in vitro. The objective of this study is to determine the reparative/regenerative capacity and safety profile of drNPC transplantation following SCI.

Materials and Methods: Clip compression SCI was induced at T7 in athymic nude rats. Nine days post-injury, we transplanted 1) drNPCs, 2) pro-oligodendrocyte precursor cells (pro-OPCs) differentiated from drNPCs, and 3) vehicle into the injured spinal cord (n=10 per group). Functional assessments including BBB, CatWalk system, and Tail-flick test were performed weekly. The animals were sacrificed nine weeks after SCI, and immunohistochemical analysis was performed by labeling the transplanted cells with HuN antibody. Histomorphometric analysis was performed with luxol fast blue and hematoxylin/eosin staining. To evaluate tumorigenicity, the cells were transplanted into the intact spinal cord of immunodeficient NOD/SCID mice.

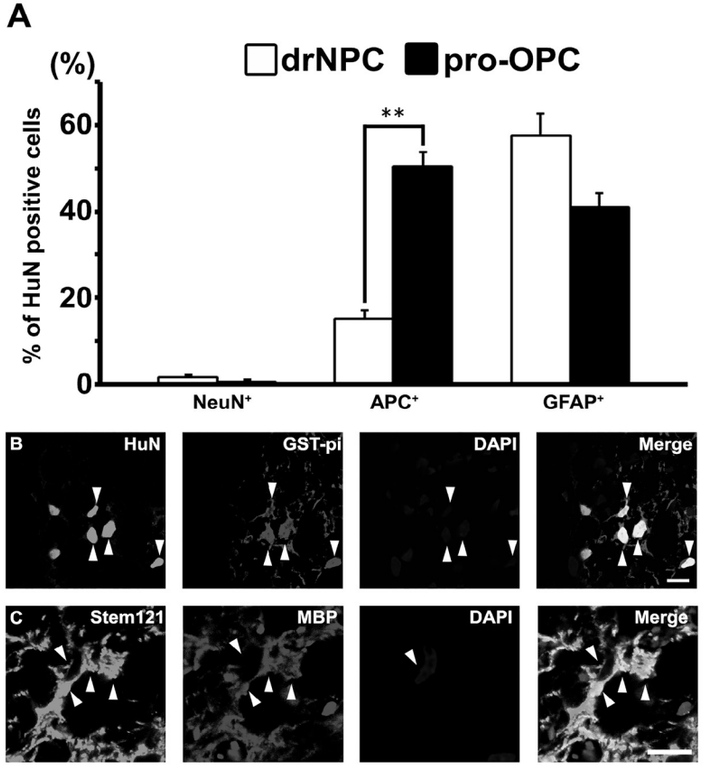
Results: Cell survival rates at nine weeks post-SCI were 28.89% and 24.14% in drNPC and pro-OPC groups, respectively. The engrafted pro-OPCs showed significantly more differentiation into APC+ oligodendrocytes compared to drNPCs (50.32% vs. 15.14%, $p<0.01$) (Figure 1A). In contrast, differentiation rates of NeuN+ neurons and GFAP+ astrocytes showed no significant differences between the groups (Figure 1A). The transplanted pro-OPCs also differentiated into mature oligodendrocytes with pi-GST and MBP expression (Figure 1B-C). Electron microscopic examination showed transplanted pro-OPCs myelinated host axons with thick lamellar structure. Histomorphometric analysis showed significantly increased white matter area and reduction of lesion area in the pro-OPC group compared to the other groups (Figure 2A-B). Motor function in the pro-OPC group was significantly improved in BBB scores and the CatWalk system (stride length and swing speed) compared to SCI injured rats that received vehicle only (Figure 2C-E). The tail-flick test to measure thermal allodynia showed no significant difference among the groups. At 150 days post spinal cord injection of cells in NOD/SCID mice, all mice remained healthy and with no histological evidence of tumorigenicity.

See Disclosure Index pages 39–89.

Presentation #45 (cont.)

Conclusions: drNPC-derived OPCs 1) promoted sparing of white matter and suppressed the expansion of the lesion, 2) contributed to motor neurological recovery without occurrence of allodynia, and 3) did not cause tumors in long-term follow-up. Additionally, the pro-OPCs predominantly differentiated into mature oligodendrocytes that myelinated host axons. For clinical application, oligogenic human drNPCs are safe and promising cell sources with the potential for tissue preservation and functional improvement after SCI.

Figure 1. Transplanted pro-OPCs mainly differentiated into oligodendrocytes in the injured spinal cord.
(A) Quantitative analysis of tri-lineage differentiation profiles with specific markers (n = 3 per each group). Note that the rate of differentiated oligodendrocytes (APC+) was significantly higher in pro-OPC group compared to drNPC group. (**p < 0.01, Student's t test)
(B and C) Representative images of GST-pi+/HuN+ and MBP+/Stem121+ mature oligodendrocytes in the spinal cord. Stem121: a marker for human cytoplasm.
Scale bar: 10 μm.



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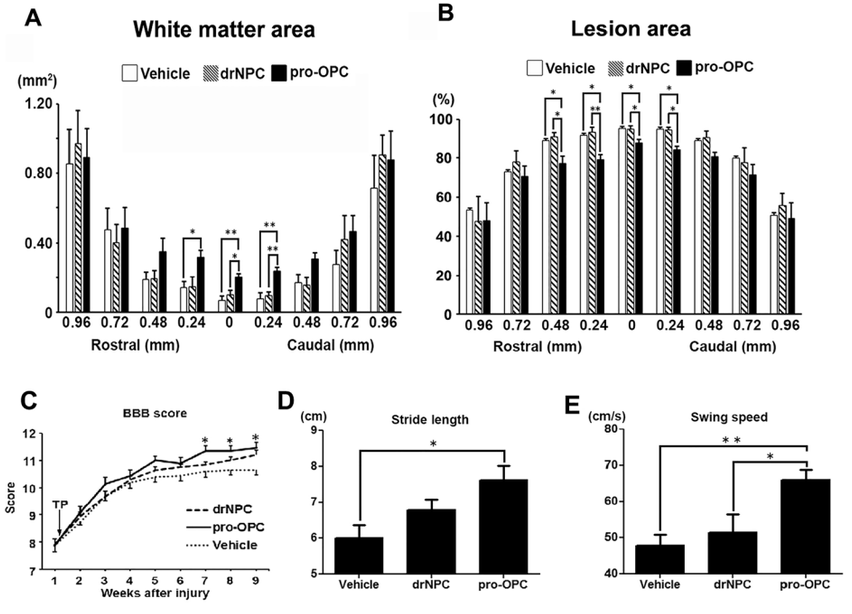
Presentation #45

Figure 2. Histomorphometric and motor functional analyses. (A and B) Calculation of white matter area
(A) and percentage of lesion area/total spinal cord area
(B) between 0.96 mm rostral and caudal from epicenter.
(C) Time course of motor functional recovery at hindlimbs in BBB score. Note that the rats with pro-OPC transplantation showed significant recovery compared to vehicle group.
(D and E) Gait analysis with CatWalk showed a significant better recovery in stride length between pro-OPC and vehicle groups (D), and swing speed in pro-OPC group compared to the other groups (E).



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Presentation #46

Therapeutic Impact of Human Induced Pluripotent Stem Cell Derived Neural Progenitor Cells for the Treatment of Cervical Spinal Cord Injury

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Introduction: Spinal cord injury (SCI) is a catastrophic event, however available treatment options remain limited. Cell replacement strategies have shown promise for recovery following SCI. Induced pluripotent stem cells (iPSCs) are a clinically relevant cell source that can be used to deliver patient-specific cellular therapy, avoiding immunological and ethical issues. Previous studies have shown that iPSCs derived from neural progenitor cells (NPCs) hold particular promise for the treatment of SCI. NPCs are multipotent, and are thus able to differentiate into neurons, oligodendrocytes and astrocytes. However, there are limited studies on the mechanism of action of human iPSCs (hiPSCs), and no studies evaluating the optimal differentiation state of hiPSCs. In addition, although the majority of the SCI population incurs cervical injuries, the efficacy of stem cells has not been extensively tested in cervical SCI. The aim of this study was to compare the regenerative therapeutic capacity of these oligogenic vs. neurogenic NPCs derived from hiPSCs in the setting of cervical SCI.

Materials and Methods: We generated pro-oligogenic NPCs (pro-OPCs), and neurogenic NPCs (NECs) from same line of hiPSCs. To generate hiPSCs, we made use of the non-viral piggyBac transposon system. We compared the regenerative therapeutic capacity of these oligogenic vs. neurogenic NPCs derived from hiPSCs in Adult Rowett Nude rats following bilateral C6-level clip contusion-compression injury.

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Results: Eight weeks after transplantation, grafted hiPSC derived pro-OPCs and NECs survived and migrated within the injured spinal cord, and differentiated into the three major neural lineages in differing proportions. pro-OPCs successfully demonstrated an in vivo propensity to form cells from the oligodendroglial lineage (APC+ and Olig2+; 53.2%), while NECs were significantly more likely to differentiate into cells with a neuronal profile (NeuN+ and TuJ1+; 52.01%) (Figure 1). Both hiPSC-NECs and hiPSC-pro-OPCs contributed to tissue sparing and reduction in cavity size (up to 65% reduction in cell transplanted groups compared to vehicle) and promoted the survival of endogenous NeuN positive neurons as well as ChAT positive neurons. Functional recovery was observed in the forelimb grip strength (Figure 2) and gait locomotor function by using CatWalk at 10 weeks after injury with both cell types, but the effect of hiPSC-NECs was more pronounced in walking speed and stride length. In addition, although increased neuropathic pain after cell-based treatment is a potential concern, no increase in thermal and mechanical allodynia was observed in either group as assessed by tail flick and von Frey test, respectively. Furthermore, we evaluated long-term safety of these cell types up to 140 days after transplantation in NOD/SCID mice. The transplanted cells survived, but did not result in any microscopic tumors.

Conclusions: Both cell transplantation therapies using pro-OPCs and NECs derived from hiPSCs induce functionally significant repair and regeneration of the injured cervical spinal cord. pro-OPCs contributed to remyelination while NECs contributed to the rebuilding of neuronal circuits following SCI. These results move stem cell therapies closer to clinical translation.

Figure 1.

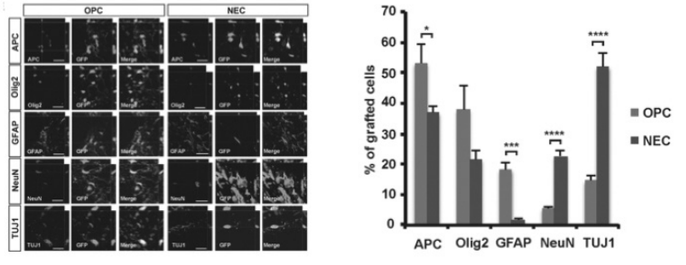
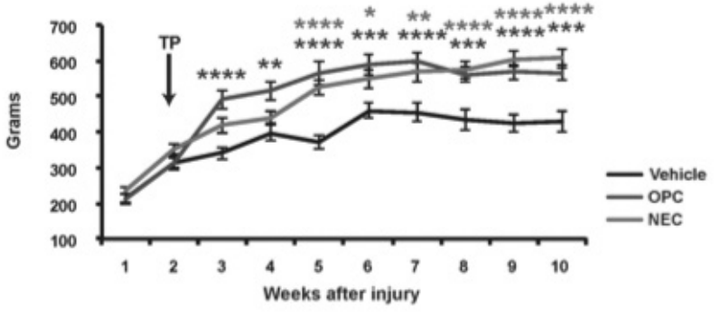


Figure 2.



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Presentation #47

Delayed Surgical Decompression for Degenerative Cervical Myelopathy Correlates with Reperfusion and Excessive Activation of the Immune System

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Introduction: Degenerative Cervical Myelopathy (DCM) is the most common cause of spinal cord impairment in the elderly population. It is caused by age-related degeneration of the cervical spine, leading to chronic compression of the spinal cord. Surgical decompression is the current treatment option for DCM patients. However, neurological complications occur in at least 9.3% of cases within six months after surgery. Previous studies have demonstrated the emergence of ischemia reperfusion injury (IRI) following surgical decompression. We found that patients with DCM sustaining longer duration of symptoms recovered less than patients who received surgical decompression earlier. Thus, we hypothesized that delayed surgical decompression may be associated with attenuated recovery due to an exacerbated immunological, glial and IRI response in the spinal cord. We tested this hypothesis in a relevant mouse model of DCM.

Materials and Methods: Experiments were undertaken in C57B/L mice in which progressive cord compression was created at the C5-6 level by inserting a biomaterial sheet underneath the corresponding laminae. Subsequently, animals were surgically decompressed at 6 and 12 weeks after DCM induction, to resemble an early and delayed decompression. We evaluated neurobehavioral recovery following decompression by assessing upper and lower limb functions, with the Catwalk system, wire hang test and Capellini handling test. Flow cytometry, immunohistochemistry and ELISA were used to characterise changes in the activation of the immune system. Furthermore, we retrieved data from the AOSpine North American and International studies to evaluate the probability of achieving a higher improvement in the mJOA score following surgical decompression, depending on the duration (shorter or longer) of symptoms in 757 patients with DCM who underwent surgical decompression.

Results: Surgical decompression caused a local increase of cytokines in the spinal cord around the level of compression at 24 hours after surgery. This response was transient in the early decompressed group but prolonged in mice that underwent delayed surgery. Moreover, early decompression increased spinal cord blood flow compared to DCM animals (Figure 1. A), without changes in the ratio of inflammatory/patrolling monocytes (Figure 1B-C). Neurological improvement of the upper and lower limb functions was also observed after early decompression. Contrary, delayed surgical decompression caused spinal cord reperfusion (Figure 1. D, $*p < 0.05$), excessive recruitment of inflammatory monocytes (Fig. 1 E-F, $**p < 0.01$) and astrogliosis. Additionally, delayed decompression led to non significant neurological improvement. In the same line, we provide evidence that DCM patients with a longer duration of symptoms at the time of surgical decompression are more likely to have a worse prognosis than those with a shorter duration of symptoms.

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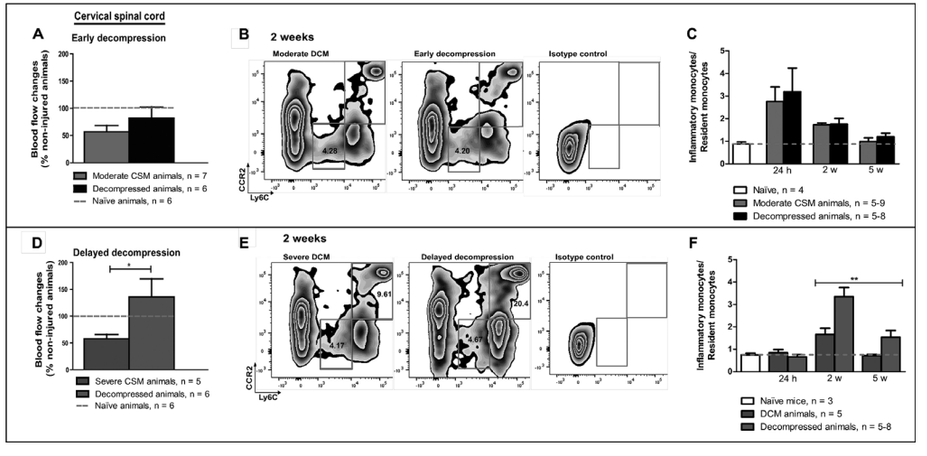
Conclusions: This study provides evidence correlating results of surgical decompression with the development of spinal cord reperfusion and excessive activation of immune and glial cells. Our findings suggest that the time of surgical decompression affects the degree of gained neurological recovery and raise the importance of early surgical treatment to provide maximal benefit for patients with CSM.

Figure 1. Delayed decompression increases systemic inflammation and spinal cord reperfusion. A, D) Quantification of regional blood flow using injection of fluorescent microparticles in age-matched naïve animals, at 11weeks after moderate DCM or five weeks after surgical decompression. Blood flow is restored to 81% compared to non-injured animals after early decompression (A), whereas delayed decompression significantly induced spinal cord reperfusion compared to 17 weeks DCM animals (D) ($*p < 0.05$, Mann-Whitney U test).B-E) Representative flow cytometry contour plots of blood monocytes for moderate DCM, early decompressed and isotype control groups at two weeks after surgical decompression (B) and delayed decompressed group (E). Inflammatory monocytes were gated as Ly6ChiCCR2+ (upper red panel) and resident monocytes as Ly6ClowCCR2- (lower red panel). The ratio of inflammatory/resident monocytes remained stable at all time points after early decompression (C), whereas the ratio of inflammatory/resident monocytes was increased at two and five weeks after delayed surgical decompression (F) ($**p < 0.01$, two way ANOVA).



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Presentation #48

Time-Dependent Vascular Remodeling and Inflammation following Decompression in Cervical Myelopathy

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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 the degenerating cervical spine. Although CSM is currently treated with decompression, little is known of the vascular and inflammatory response under chronic compression and the subsequent decompression of the cervical spinal cord. Here, we aimed to examine the role of inflammation and vascular remodeling in a mouse model of progressive compression and decompression. Moreover, using human neuropathological samples, we demonstrate the clinical relevance of our CSM mouse model and the complex processes involved in inflammation and ischemia.

Methods: A synthetic polyether material was implanted under the C6 lamina of C57B/L mice for 6 or 16 weeks, to model moderate and severe CSM respectively. The animals were subsequently followed for short-term (4 weeks) and long-term (3 months) periods after surgical decompression. 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. The animal data was complemented by immunohistochemistry results from human post-mortem spinal cord tissue from individuals with CSM.

Results: When we compared human CSM tissue with that of controls, we found significant up-regulation of the inflammatory response, including HLA-DR Antigen (human leukocyte antigen), Iba1 and CD68 positive macroglia/macrophages, oxidative injury (P22-phox and INOS), reduced anti-inflammatory IL-10 positive cells and increased anti-inflammatory M2 positive cells. We also found a significant increase in the density of blood vessels and an increase in expression of vessel wall markers (fibronectin, PDGFR-B, Von Willebrand Factor) at the compression epicenter of human CSM cases. Next, using CSM mice, we found flattening of the spinal cord, neuronal loss, inflammation and gliosis with reduced blood flow to the spinal cord and increased vascular density at the compressed epicenter in moderate and severe CSM mice. In moderate CSM followed by a short-term (4 week) period post-decompression, we found an increased inflammatory response (Iba1, glectin-3 and GFAP expression) and vessels reperfusion compared to the CSM at 10 weeks. Interestingly, in severe CSM followed by a long-term (3 month) period post-decompression, the mice had significantly increased blood flow support to spinal cord as measured by Power Doppler, a reduced inflammatory response (Iba1, glectin-3 and GFAP expression), and increased number of neurons as well as vessels. Moreover, these animals had an increased spinal cord size and improve functional recovery, determined by the rotarod test.

Conclusion: We report novel evidence that inflammation and ischemia are critical to inducing neural degeneration in the setting of progressive CSM. As decompression induces early ischemia and an inflammatory response, mice require a longer period of time (2 to 3 months) to recover their spinal cord size and functional vasculature. Taken together, this supports the clinical results that demonstrate decompression is beneficial in CSM.

Presentation #49

Are Patient Reported Outcomes Predictive of Patient Satisfaction Five Years after Anterior Cervical Spine Surgery?

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Introduction: Patient satisfaction is becoming an increasing common proxy for surgical quality; however, the correlation between patient satisfaction and surgical outcomes two and five years after anterior cervical surgery has not been evaluated. The purpose of this study is to determine if patient satisfaction is predicted by improvement in patient reported outcomes (PRO) five years after anterior cervical spine surgery.

Methods: A retrospective analysis of prospectively collected data was reviewed. Patients were randomized (2:1) to TDR or ACDF at one or two contiguous levels from C3 to C7 as part of an FDA IDE trial. For the present analysis, patients in both surgical groups were combined. Patients were assessed for satisfaction, NDI, VAS neck pain, and SF-12PCS/MCS scores at 24 and 60 months. Receiver-operating characteristic (ROC) curves were utilized to determine if improvement in different PRO metrics can accurately identify patient satisfaction.

Results: Data was available for 512 patients at 60 months with 437 patients as "very satisfied", 50 patients as "somewhat satisfied", 16 patients as "somewhat dissatisfied", and 9 patients as "very dissatisfied." There was no significant difference in the number of one- or two-level patients in each satisfaction classification ($p = 0.17$), and no difference was found among 60-month satisfaction and age ($p = 0.73$), gender ($p = 0.49$), race ($p = 0.06$), or BMI ($p = 0.69$). Baseline SF-12 PCS scores were significantly different among very satisfied (33.5), somewhat satisfied (32.2), somewhat dissatisfied (35.8), and very dissatisfied (25.9) groups ($p = 0.0023$) at 60 months. When baseline outcomes scores were compared across 60-month satisfaction groups, no difference was seen among baseline NDI, VAS neck pain or SF-12 MCS scores. A significant difference was found across baseline SF-12 PCS scores ($p < 0.0001$) (Table 1).

Patient satisfaction was significantly associated with patient outcomes at 60 months. NDI, VAS neck pain, and SF-12 MCS/PCS scores and improvement from baseline were significantly different between satisfaction classifications at 60 months ($p < 0.001$; Table 1). Mean NDI was 15.1 ± 16.0 for the very satisfied, 36.6 ± 17.5 for somewhat satisfied, 38.3 ± 18.9 for somewhat dissatisfied, and 57.6 ± 21.4 for very dissatisfied patients. Mean VAS neck pain was 15.2 ± 22.7 for very satisfied, 47.1 ± 29.6 for somewhat satisfied, 59.1 ± 30.5 for somewhat dissatisfied, and 64.7 ± 29.6 for very dissatisfied patients. The mean SF-12 MCS score was 52.2 ± 9.6, 45.7 ± 12.6, 46.6 ± 14.2 and 38.6 ± 12.1 for the very satisfied, somewhat satisfied, somewhat dissatisfied and very dissatisfied patients, respectively. Similarly, the mean SF-12 PCS score was 48.2 ± 10.6, 37.5 ± 9.2, 34.3 ± 5.5 and 29.7 ± 8.5 for the very satisfied, somewhat satisfied, somewhat dissatisfied and very dissatisfied patients, respectively.

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Presentation #49 (cont.)

The results of the ROC analysis at five years demonstrated that improvements in NDI and VAS, and the absolute NDI and VAS scores at 60 months had excellent accuracy at differentiating patient satisfaction (AUC = 0.80–0.86). Comparatively both the improvement in, and the absolute value of the SF-12 PCS had poor accuracy at differentiating patient satisfaction (AUC = 0.64–0.68; Figure 1).

Conclusion: In patients undergoing one and two level anterior cervical spine surgery, at two and five years postoperatively patient satisfaction is significantly predicted by patient reported outcomes including the VAS neck score and the neck disability index.

Table 1. Clinical outcomes and patient characteristics by satisfaction assessments at 24 and 60 months. ANOVA used to compare continuous variables; Chi-square test used to compare categorical variables.

		Very Satisfied	Somewhat Satisfied	Somewhat Dissatisfied	Very Dissatisfied	p-value
24 Months	N	467	62	15	9	
	Age	45.1	43.1	47.6	40.4	p = 0.06
	BMI	27.5	27.6	27.7	26.0	p = 0.77
	Gender (% Male)	47.1%	43.5%	46.7%	44.4%	p = 0.96
	Race (% Caucasian)	93.4%	91.9%	86.7%	55.6%	p = 0.07*
	Levels Treated (% 1-Level)	43.5%	35.5%	26.7%	44.4%	p = 0.40
	Treatment (% ACDF)	29.8%	38.7%	60.0%	33.3%	p = 0.05
	NDI Improvement	38.7	16.6	9.5	19.7	p < 0.0001
	VAS Neck Improvement	58.1	28.3	18.1	32.9	p < 0.0001
	SF-12 MCS Improvement	9.5	2.5	3.4	6.9	p = 0.0004
	SF-12 PCS Improvement	14.9	3.4	4.3	7.7	p < 0.0001
	Subsequent Surgery Rate	3.6%	12.9%	26.7%	11.1%	p = 0.0002*
60 Months	N	437	50	16	9	
	Age	44.9	44.8	47.3	45.9	p = 0.73
	BMI	27.5	28.0	27.0	26.3	p = 0.69
	Gender (% Male)	46.7%	44.0%	62.5%	33.3%	p = 0.49
	Race (% Caucasian)	93.4%	88.0%	75.0%	100.0%	p = 0.06*
	Levels Treated (% 1-Level)	44.2%	32.0%	31.3%	22.2%	p = 0.17
	Treatment (% ACDF)	27.0%	42.0%	56.3%	44.4%	p = 0.009
	NDI Improvement	38.1	17.9	15.6	4.0	p < 0.0001
	VAS Neck Improvement	55.5	26.8	12.5	16.7	p < 0.0001
	SF-12 MCS Improvement	9.7	6.8	7.4	-7.1	p = 0.0011
	SF-12 PCS Improvement	14.5	5.0	-1.2	3.8	p < 0.0001
	Subsequent Surgery Rate	6.6%	14.0%	31.3%	22.2%	p = 0.016*

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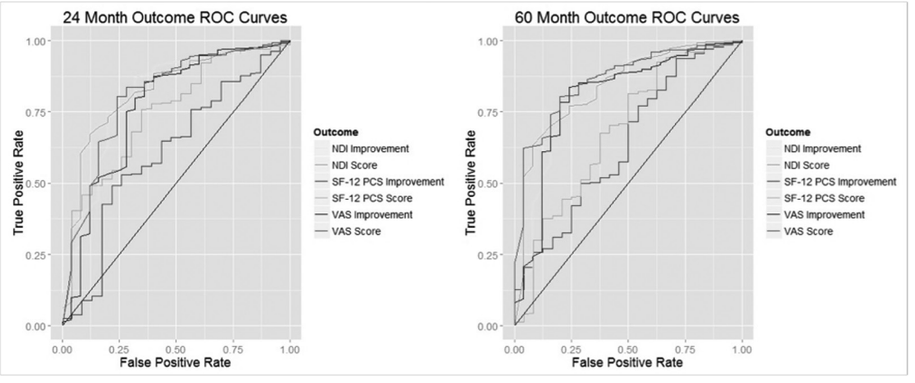
Figure 1. ROC analysis of outcomes at 24 and 60 months.



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Presentation #50

Diminished Mental Health Prior to Cervical Fusion Can Have a Profound Effect on Patient Derived Outcomes Depending on Presenting Diagnosis: Results of a Prospective Surgeon Driven Cervical Database at 2 Years

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Introduction: Optimizing outcomes is essential for effective surgical treatment of cervical spine disorders. For cervical spine pathologies, improvements in neck disability and physical functioning are important indicators of surgical success. Though mental impairment is commonly noted among patients with cervical spine complaints, comparative studies on baseline mental status and overall patient-reported improvement in specific diagnoses have not been proposed. This study analyzes patient reported outcomes over 2-years post-operative among cervical myelopathy and cervical radiculopathy diagnoses dependent on pre-operative mental status.

Materials and Methods: This was a retrospective analysis of a database of patients with cervical pathology prospectively collected from a multicenter spine registry. Inclusion criteria were patients diagnosed with either cervical spondylosis with myelopathy ('MYELO') or radiculopathy ('RADIC': cervical disc herniation, cervical stenosis, cervical spondylosis without myelopathy) and with complete follow-up through 2-years post-operative. Patients were assessed for the following health-related quality of life (HRQL) measures at baseline and 6-, 12-, and 24-months post-operative: Neck Disability Index (NDI), Short Form-36 (SF) Physical (PCS) and Mental (MCS) Component Summaries. Baseline MCS score for all included patients were dichotomized using 60th (MCS-HI) vs. 40th percentiles (MCS-LO), and in each diagnoses MCS groups were propensity score matched for baseline NDI value. Independent and paired t-tests compared improvement in each patient diagnosis group for MCS-HI and MCS-LO cohorts.

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Results: A total of 439 patients were included for analysis (mean age 53.9 ± 10.5 years; mean BMI 28.6 ± 5.6 kg/m2; 62.9% female). The mean baseline MCS score was 39.1 ± 14.2, and was dichotomized into lower-40th (MCS-LO ≤ 39.00; mean 26.7 ± 7.2) and upper-60th (MCS-HI ≥ 42.00; mean 51.5 ± 6.7) percentile groups based on the score distribution for the total cohort. For MYELO, propensity matching gave 34 patients in each MCS group. At baseline, MYELO patients in both MCS-HI and MCS-LO had statistically similar NDI and PCS scores ($p > 0.05$). However at 2-year follow-up, MYELO MCS-LO had significantly worse NDI (17.8 vs. 8.7, $p < 0.001$), despite overall baseline-2-year improvement in NDI ($p = 0.003$). Myelopathy patients in the MCS-HI group displayed significant overall improvement in both PCS and NDI by 2-years post-operative ($p < 0.015$). Following propensity matching for radiculopathy patients, N = 52 were in each MCS group. At baseline and 2-year post-operative, RADIC MCS-HI and MCS-LO were statistically similar for both NDI PCS ($p > 0.05$). However, both MCS-HI and MCS-LO radiculopathy patients demonstrated significant improvement in overall PCS and NDI scores with treatment ($p < 0.015$).

Conclusions: This study revealed that pre-operative mental status, gauged by the SF-36 Mental Component Score, may be a useful tool in identifying discrepancies in overall patient-reported outcomes depending on the specific cervical spine diagnosis. Additional screening and care should be implemented for patient with cervical myelopathy for optimization of functional outcomes and disability status following surgical intervention.

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Presentation #51

Which Domains of the NDI Improve Most after Surgery for Cervical Myelopathy?

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Introduction: The neck disability index (NDI) is an easily scored, common, ten-item questionnaire about symptoms relevant to cervical spine pathology: pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleeping, and recreation. Initial validation for the NDI considered only "whiplash"-injury patients in an outpatient clinic and was published in the physical therapy literature. However, the NDI is now widely used to evaluate the outcomes of cervical surgery. The purpose of this study was to determine which domains of the NDI improve most after cervical spine surgery for myelopathy and whether improvement in the composite NDI score or specific domains better predicts change in physical function.

Materials and Methods: Analysis of a prospectively-kept registry of patients treated at a major academic medical center. At baseline standardized outcome measures including NDI and SF12 PCS were collected. Preoperative outcome measures were compared to those at one year after surgery using paired Student's t-tests. For this study, each of the ten items was treated separately. Multiple linear regressions were performed using change in SF12 PCS as the dependent variable and change in NDI components as the independent variables.

Results: Baseline data were collected on 118 patients (mean age 58 years). A total of 66 patients had complete 1 year follow-up data. Each of the ten NDI components significantly improved from baseline ($p < 0.004$). The NDI items with the largest improvements from baseline were: sleeping (-1.5 mean change from baseline), recreation (-1.443), lifting (-1.186), work (-1.043), and pain (-1.014). Linear regression for change in NDI components versus change in SF12 PCS revealed a significant correlation ($r2 = 0.407$, $p < 0.001$). The only significant ($p = 0.001$) predictor value was change in recreation score (-2.41, 95% CI -3.81, -1.00). "Lifting" was the only other factor with a robust coefficient (-1.21, 95% CI -2.42, 0.00) although this was not significant ($p = 0.051$). Linear regression for change in the composite NDI and change in PCS was significant ($p < 0.001$), and had a weaker correlation ($r2 = 0.315$). A linear regression incorporating only "recreation" and "lifting" had an r-squared value of 0.434 ($p < 0.001$).

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Conclusion: All domains of the NDI do not improve equally after surgery for myelopathy. The pain subdomain had only a moderate observed improvement and a poor correlation to health related quality of life. Some specific domains correlate more strongly with improvement in health related quality of life than the composite NDI score. Based upon these results, we conclude that the item bank and composite scoring of the NDI are inappropriate for evaluating quality of life in studies of surgically treated cervical spondylotic myelopathy patients.

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Presentation #52

Concurrent Validity and Responsiveness of PROMIS Health Related Quality of Life Assessment in Patients with Cervical Spine Disease

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Introduction: The ability to validly and reliably measure patient-reported outcomes (PRO) is an important undertaking to ensure that we can capture how effectively our treatments are affecting our patients' wellbeing. A potential tool to demonstrate quality of care and minimum clinically important differences (MCID) following surgery is the NIH-funded PROMIS instrument, which has been psychometrically validated to measure PROs among research participants with various chronic diseases and demographic characteristics. We sought to demonstrate the concurrent validity and responsiveness of the PROMIS instrument among individuals with cervical spine disease who had undergone surgical intervention.

Materials and Methods: This was a single-institution prospective observational cohort study of all patients with spine diseases who had received surgical intervention. Fifty consecutive patients who underwent surgery for cervical spine disease were included in this analysis. Seven PROMIS health domains (pain intensity, physical function, fatigue, depression, anxiety, sleep disturbance, and satisfaction with social roles) and four legacy measures (SF12, NDI, pain intensity and interference) were collected pre-operatively, and at least once within six months post-operatively. Concurrent validity was demonstrated using correlation coefficients of PROMIS health domains with legacy measures at the pre-operative assessment. Responsiveness of PROMIS health domains was determined using the methods of Coyne, et al. (Qual Life Res, 2005). MCIDs of PROMIS health domains were determined using the change in pre-operative to post-operative (within 6 months) scores anchored to the NASS Patient Satisfaction Index (PSI) using the methods of Eton, et al. (J Clin Epi, 2004).

Results: All seven PROMIS domains showed moderate to strong correlations with NDI, MCS intensity of neck pain and pain interference while they were generally weakly correlated with the intensity of arm pain (Table 1).

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PROMIS domains were generally well correlated with PCS with the exception of physical function which showed a weak negative correlation. The PROMIS pain domain demonstrated large responsiveness (-.92), while anxiety (-.63), sleep disturbance (-.58) and social role (.59) were associated with moderate responsiveness. Physical function (.37), fatigue (-.33) and depression (-.44) had small responsiveness. Using the anchor-based method, the MCIDs for each PROMIS domain were: -4.27 for pain, + 3.18 for physical function, + .16 for fatigue, -3.9 for anxiety, -3.33 for depression, -1.94 for sleep disturbance and + .93 for social role, although statistical significance was only reached for pain.

Conclusions: PROMIS health domains can be used to validly assess post-operative patient-reported wellbeing in this. PROMIS health domains were responsive to reductions in symptoms and improvements in quality of life after surgery.

Correlation coefficients		Worst neck pain	Worst arm pain	Pain interference	SF-12 PCS	SF-12 MCS	NDI
PROMIS	Pain	**0.542**	**0.338**	**0.671**	**0.524**	**-0.667**	**0.713**
	Physical Function	**-0.201**	-0.0406	**-0.406**	-0.2642	**0.394**	**-0.393**
	Fatigue	**0.424**	0.2489	**0.562**	**0.511**	**-0.644**	**0.550**
	Anxiety	**0.438**	0.2842	**0.503**	**0.527**	**-0.654**	**0.554**
	Depression	**0.351**	0.1981	**0.510**	**0.725**	**-0.763**	**0.403**
	Sleep disturbance	**0.402**	0.2667	**0.470**	**0.404**	**-0.486**	**0.532**
	Social satisfaction	**-0.433**	**-0.308**	**-0.607**	**-0.589**	**0.698**	**-0.548**

Bolded, $p < .05$

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Presentation #53

A Comparison of Patient Centered Outcome Measures to Evaluate Dysphagia and Dysphonia after Anterior Cervical Discectomy and Fusion (ACDF)

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Introduction: Dysphagia and dysphonia are common complications after anterior cervical spine surgery. Despite their clinical importance, studies on the treatment and/or prevention of these complications are limited by the lack of valid and reliable outcome measures. Two new patient-centered outcome measures–the Eating Assessment Tool (EAT-10) Voice Handicap Index (VHI-10)–have been shown to have excellent validity and reliability in the otolaryngology patient population. These instruments may be used to document the dysphagia or dysphonia severity and monitor treatment response in patients with swallowing and voice disorders after anterior cervical spine surgery.

Materials and Methods: Following internal IRB approval, patients undergoing 1 to 3-level ACDF were recruited from two tertiary spine centers. Each patient prospectively complete the eating assessment tool (EAT-10), the voice handicap index (VHI-10), and the Bazaz score questionnaire prior to surgery, 1 day, 2 weeks, 6 weeks, 12 weeks, 6 months, and 1 year post-operatively. Mean scores were compared through ANOVA and proportion of patients with clinically significant scores (EAT-10 $\geq$ 3 and VHI-10 $>$ 11) among each follow-up time. Internal reliability of EAT-10 and VHI-10 was tested via Cronbach's α while Pearson's correlation testing was employed to assess the correlation of EAT-10 to the Bazaz score.

Results: A total of 100 patients were included in the study, from which 85 completed 6 month follow-up and 64 completed 1 year follow-up. Baseline mean NDI scores were 18.74 (+/-8.66) and improved to 7.52 (+/-7.27) at 6 months ($p < 0.05$) and 8.22 (+/-7.65) at 12 months ($p < 0.05$). Baseline EQ-5D index scores were 0.59 (+/-0.23) and improved to 0.79 (+/-0.16) at 6 months ($p < 0.05$) and 0.75 (+/-0.17) at 12 months ($p < 0.05$). EAT-10 ($\alpha = 0.978$) and VHI-10 ($\alpha = 0.900$) demonstrated excellent internal reliability, in addition to the EAT-10 showing significant correlation to Bazaz ($r = 0.794$) across all time points. Mean EAT-10 and VHI-10 scores were significantly highest at 1 day post-op ($p < 0.05$). While mean EAT-10 scores increased with severity of dysphagia as defined by the Bazaz score, 10 of 556 scores (1.8%) of patients that claimed "no dysphagia" or "mild dysphagia" by the Bazaz score had clinically significant dysphagia (EAT-10 $\geq$ 3).

Conclusions: The EAT-10 and the VHI-10 scores showed excellent internal reliability. In addition, the EAT-10 score was an accurate measure across mild to severe dysphagia, and captured significant dysphagia in patients that would have otherwise been missed using the Bazaz score. The EAT-10 and VHI-10 surveys can provide a better measure of postoperative dysphagia and dysphonia than current outcomes used in spine surgery.

Presentation #54

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 cervical myelopathy and/or radiculopathy. Studies have demonstrated non-inferiority of CDR when compared with ACDF in large randomized investigational device exemption (IDE) studies. Furthermore, economic analysis of the two procedures at two years has demonstrated that CDR may be the cost-effective treatment option. The purpose of this study is to determine the seven year cost-effectiveness of single-level ACDF versus CDR.

Materials and Methods: A Markov-state transition model (Figure 1) was used to evaluate data from the Prestige Cervical Disc IDE study. Data from the 36-item Short Form Health Survey were converted into utilities using the SF-6D algorithm for 212 CDR patients and 183 ACDF patients. Costs were calculated from the payer perspective using a 140% multiple of 2014 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 the IDE study. Quality adjusted life years (QALY's) were used to represent effectiveness. For the base case analysis, incremental cost effectiveness ratios (ICER's) 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 $172,989 for CDR and $143,714 for ACDF. CDR resulted in a generation of 4.52 QALY's while ACDF resulted in 3.85 QALY's. The ICER was calculated to be $43,522/QALY for CDR which was less than the $50,000/QALY WTP threshold. CDR and ACDF were both cost-effective procedures ($38,247/QALY vs. $37,325/QALY). The Monte Carlo simulation validated the base case scenario (Table 2). CDR had an average cost of $173,190 (CI: $144, 353;$202,479) with an average effectiveness of 4.52 (CI: 3.99; 5.01). ACDF had an average cost of $143,806 (CI: 120,668; $166,742) and an average effectiveness of 3.85 (CI: 3.39; 4.29). The ICER was calculated at $43,937/QALY in favor of CDR. Assuming a WTP $50,000/QALY, the cost-effectiveness acceptability curve indicated that CDR would be chosen 56% of the time based on 10,000 simulations (Figure 2 and 3).

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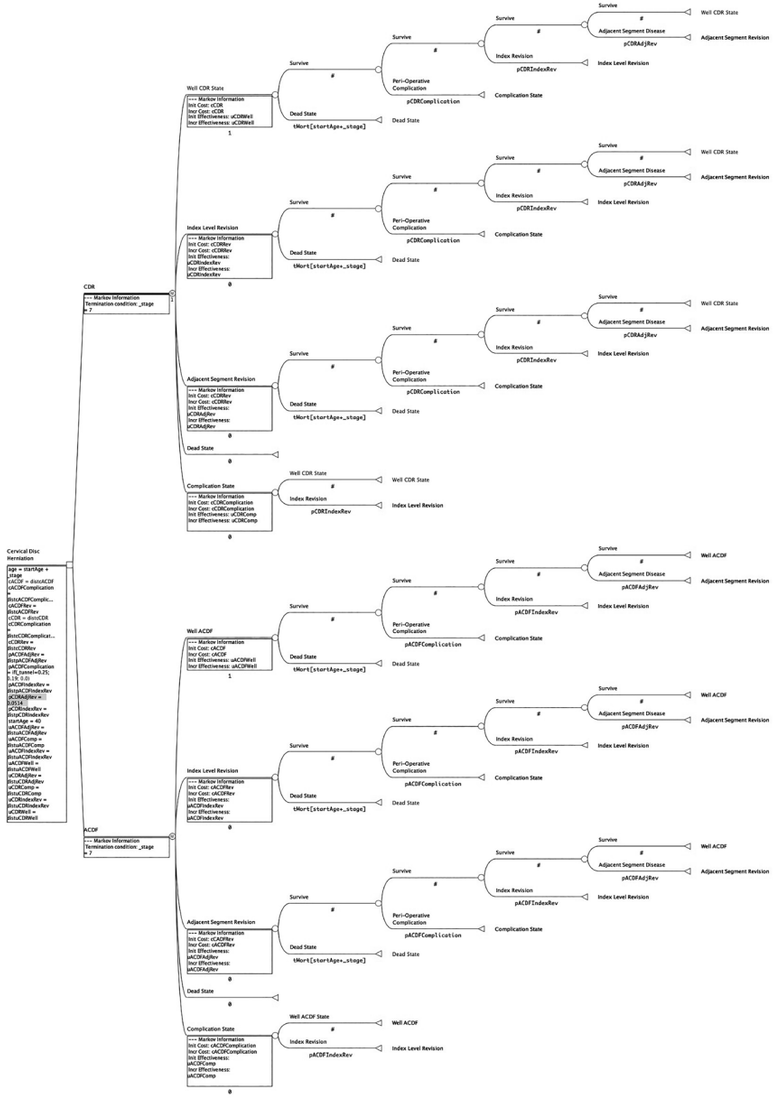
Presentation #54 (cont.)

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 option 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.



Presentation #54

Figure 2:Cost-Effectiveness Acceptability Curve Demonstrating that 56% of the Simulations Were Cost-Effective Below the $50,000 /WTP Threshhold

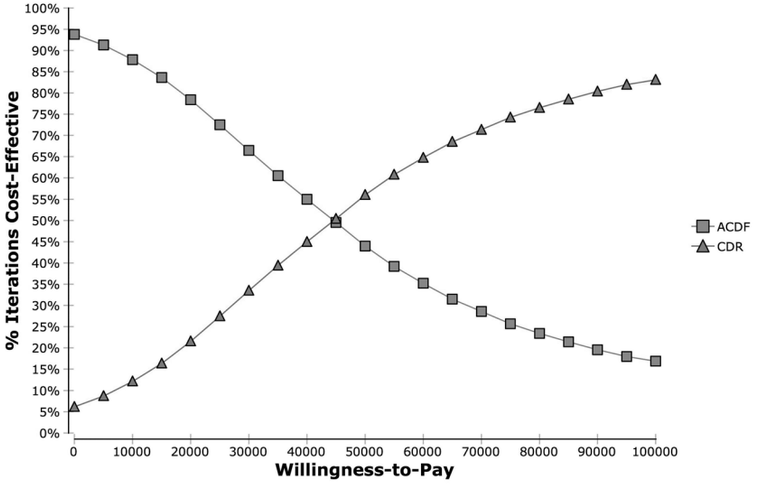
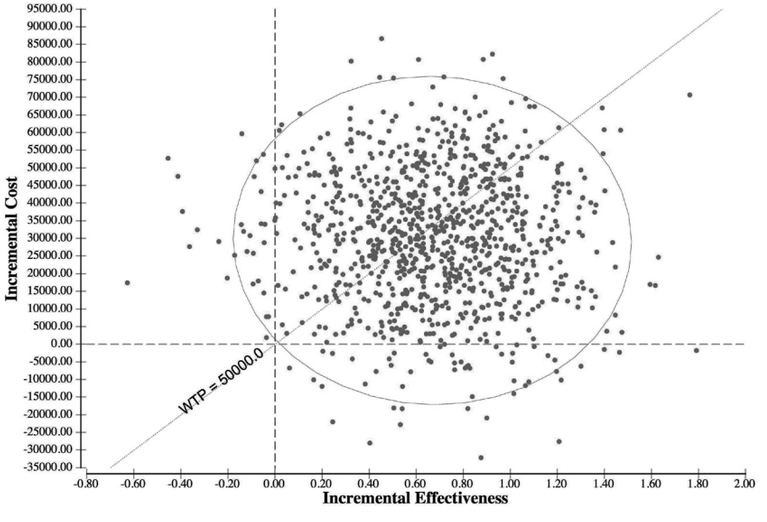


Figure 3: Incremental Cost-Effectiveness of CDR v. ACDF with Values to the Right of the $50,000/WTP Threshold Indicating Cost-Effectiveness of CDR



Presentation #55

Progressive Bone Formation after Cervical Replacement: Minimum of 5-Year Follow-up

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Background: Cervical Disc Replacement (CDR) can be complicated by postoperative ossification and unwanted ankylosis at the index level, which some authors have termed "heterotopic ossification". However, this terminology may be inaccurate as it assumes the postoperative bone formation is unnatural and a consequence of the CDR surgery. We advocate describing this phenomenon as one of progressive bone formation to reflect the fact that it has more to do with individual patient factors rather than the CDR surgery. The objective of our study was to examine the prevalence, clinical significance, ramifications, and possible etiology of postoperative bone formation at the index level after CDR with a minimum of 5 years of follow-up data.

Methods: A retrospective review was performed on 61 patients (76 levels) who underwent Bryan disc replacements by a single group within one institution between 12/2003 and 8/2008. All patients had at least 5 years of clinical follow-up. Postoperative bone formation at the index level was graded on lateral cervical spine radiographs using the McAfee classification. Patients were divided into two groups, those with and without postoperative bone formation. Clinical outcomes such as Japanese Orthopaedic Association (JOA) score for cervical spondylotic myelopathy (CSM) and Neck Disability Index (NDI) and Visual Analogue Scale (VAS) for neck pain and arm pain in cervical spondylotic radiculopathy (CSR) patients were collected pre- and post-operatively and then compared between groups. The radiographic parameters analyzed included: the degree of preoperative cervical spondylosis on cervical radiographs utilizing the Kellgren classification, segmental range of motion (ROM) on lateral flexion-extension radiographs, and the incidence of postoperative adjacent segment degeneration.

Results: The study patients had an average age of 43 years, with a mean follow-up of 94.2 months. The overall incidence of postoperative bone formation was 50% (38/76 levels). Clinical outcomes in CDR patients at final follow-up were significantly improved for CSM and CSR patients by all four patient-reported measures ($p < 0.001$). Despite decreased ROM ($p < 0.001$), patients with postoperative bone formation had no significant differences in any of the four measures compared to those without postoperative ossification. Notably, patients with more severe preoperative cervical spondylosis at the surgical level had higher rates of postoperative bone formation at final follow-up ($p = 0.036$). Similarly, more severe preoperative spondylosis also correlated with higher rates of adjacent segment degeneration (ASD) ($p = 0.010$). Patients with postoperative ossification had higher rates of ASD ($p = 0.007$), but there was no correlation between the severity of bone formation around the CDR and the incidence of ASD.

Conclusion: The overall incidence of postoperative bone formation after CDR was relatively high when patients are followed for greater than 5 years. However, this did not adversely affect patient reported outcomes even if it did decrease segmental ROM. Most notably, patients with more severe preoperative cervical spondylosis had higher rates of postoperative ossification. This suggests that postoperative ossification at the CDR segment is likely one of progressive bone formation in individuals already predisposed to forming bone rather than one of alleged heterotopic ossification as a consequence of the surgery, highlighting the importance of proper patient selection.

Presentation #56

Unintended Fusion in Cervical Artificial Disc Replacement: A Prospective Study on Heterotopic Ossification with 5 Years Follow-up

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Introduction: Anterior cervical discectomy and fusion (ACDF) is the gold standard for treatment of cervical radiculopathy. However, concerns about the decrease in motion and its potential to affect on the adjacent segments lead to the development of motion-preserving implants for artificial disc replacement (ADR), as an alternative to ACDF. By preserving segmental motion, ADR is expected to decrease the incidence of adjacent-level degeneration associated to fusion, leading to better clinical outcomes. Heterotopic ossification (HO) is a complication of ADR that may lead to fusion, thus failing to preserve motion. Its real incidence in the cervical spine segment is still under debate, with only a few studies reaching long-term follow-up. Our aim was to evaluate HO rates after cervical ADR over a 5-year period, and to analyse factors that could contribute for this complication.

Material and Methods: This study is a post-hoc from a multicentre prospective randomised study in which 151 patients were blindly randomised to receive ADR or ACDF, at a maximum of two cervical levels. The 81 patients that received ADR were treated postoperatively with NSAID for 10 days. Of those, 42 patients (57 prosthesis) who had good-quality radiological follow-up studies both at 2 years and at 5 years were included. 33 patients were women and 24 men, aged 35 to 59. Plain radiographs at 2 and 5 years after surgery where read by two experienced viewers, and graded in 5 levels according to a modified McAfee classification. Pre-operative degeneration on MRI, number and location of operated levels were assessed in order to establish factors that can influence the appearance and severity of HO.

Results: HO was found in 91,2% and 82,4% of prosthesis at 5 years and 2 years follow-up respectively. Severe HO (grade 3 or 4) was found in 66,7% and complete fusion (grade 4) in 24,6% at 5 years. 36 prosthesis (63,2%) did not increase the severity of HO between the 2- and 5-year follow-up. All the 5 that changed more than one grade (8,8%) over this period were female. Women had a statistically significant ($p < 0,005$) lower amount as well as lower grades of HO at all times. Age of the patients, place/amount of operated levels, or the severity of preoperative degeneration at adjacent levels on MRI did not influence the appearance of HO.

Conclusion: Cervical ADR is meant to move. Our results show an ossification rate of 91,2% and a fusion rate of 24,6% despite the fact that the patients where given prophylactic NSAID to prevent them. Although HO grade slightly increases with time, it occurs much more often early in follow-up. Female gender is clearly a protective factor from HO in cervical ADR. No difference in preoperative degeneration grade was found that could explain the difference in incidence between men and women. Further analysis is needed in order to establish if and how unintended fusion in cervical ADR affects clinical outcomes.

See Disclosure Index pages 39–89.

Presentation #57

Clinical Implications of Heterotopic Ossification after Cervical Disc Arthroplasty at 7 Years

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Introduction: Treatment with cervical disc arthroplasty (CDA) has been studied in multiple clinical trials meeting Level 1 evidence. Long-term data revealed that development of heterotopic ossification (HO) is possible, but the mechanism and clinical impact is unknown.

Materials and Methods: A total of 389 patients were treated with 1 or 2-level CDA for a prospective, randomized, FDA clinical trial across 24 sites in the US with 7-year follow-up. Patient characteristics including age, sex, BMI and type of work were collected preoperatively. Clinical and radiographic outcomes included HO, flexion/extension range of motion (ROM), NDI score, VAS neck pain score, and patient satisfaction. All radiographic evaluations were conducted by independent radiologists (MMI Inc., Houston, TX). HO was classified using the system adapted from McAfee and Mehren. HO grades 3 and 4 were classified as clinically relevant due to restricted ROM. Fisher's exact test ($P < 0.05$) was used to test significant differences across groups.

Results: Grade 0/1 HO was present in 4.6% of patients, grade 2 in 67.0%, grade 3 in 17.4%, and grade 4 in 11.0%. Clinically relevant HO was observed in 28.4% of 1-level patients. Between 5 and 7 years, 5.8% of patients had progression of HO 1 or 2 grades, with 94.2% showing no progression. Obese patients (preop BMI ≥ 30) had a higher prevalence of clinically relevant HO than non-obese patients (43.8% vs. 22.1%; $p = 0.035$), and males had a higher prevalence than females (37.3% vs. 20.7%; $p = 0.088$). Clinically relevant HO was present in 32.6% of 2-level patients. At the superior level, grade 0/1 was present in 4.5% of patients, grade 2 in 73.2%, grade 3 in 15.9%, and grade 4 in 6.4%. At the inferior level, grade 0/1 was present in 3.4% of patients, grade 2 in 65.8%, grade 3 in 26.2%, and grade 4 in 4.7%. From 5 to 7 years, 14% of patients showed HO progression of 1 or 2 grades, the remaining 86% of patients had no progression of HO. In 2-level CDA, clinically relevant HO was more prevalent in males vs. females (53.5% vs. 25.0%, $p < 0.001$), and a higher prevalence in obese patients (44.3% vs. 36.1%; $p = 0.36$). Patients with clinically relevant and non-clinically relevant HO had similar 7-year NDI and VAS neck pain scores. At 7 years, there were no cases of subsequent surgery because of HO, and patients with clinically relevant HO were equally satisfied with their procedure.

Conclusion: At 7-year follow-up, the majority of patients (69.2%) did not have clinically relevant HO. HO progression between 5 and 7 years was stable, 89.4% of patients had no further development of HO. Possible predictors for clinically relevant HO include preoperative obesity and male gender. Patients with clinically relevant HO maintained similar NDI and VAS neck pain scores to non-clinically relevant HO patients.

Presentation #59

Cervical Deformity Surgery does Not Result in Post-operative Dysphagia: A Prospective Cohort Study

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Introduction: The majority of current work describing the incidence of dysphagia after cervical surgery has focused on degenerative disease such as cervical spondylotic myelopathy or radiculopathy. The incidence of dysphagia in patients undergoing surgery for cervical deformity has not previously been described in the literature. We attempt to address this deficiency by describing the rate of persistent dysphagia following surgery for cervical deformity. We hypothesized that patients undergoing surgery for cervical deformity would not have significant post-operative dysphagia at intermediate-term follow up.

Methods: This was a prospective cohort study seeking to enroll operative cervical deformity (CD) patients. The inclusion criteria were one or more of the following: cervical kyphosis (CK) > 10°, cervical scoliosis (CS) > 10°, C2–7 SVA > 4cm and/or chin-brow vertical angle (CBVA) > 25°. Demographic, operative and radiographic variables were recorded. Intermediate (3 month) and long-term (1 year) follow up was obtained. Dysphagia was recorded using the Quality of Life in Swallowing Disorders (SWAL-QOL) survey. Paired t-tests (continuous variables), Paired t-test, independent t-tests and bivariate Pearson correlations were performed.

Results: 88 patients were included in the study. The average age was 61.52 ± 10.52 years. Three month (intermediate) follow up was available for all patients (100%), 45 (51.1%) patients had 1 year SWAL-QOL scores for analysis. The mean pre-op SWAL-QOL was 78.35. There was no difference between pre-op and intermediate SWAL-QOL scores (78.4 vs. 77.3, $p = 0.527$). SWAL-QOL scores improved in 54.5% of patients and worsened in 45.5% of patients.

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Presentation #59 (cont.)

Demographic Variables
Baseline SWAL-QOL was correlated with baseline NDI (r = -0.49), mJOA (r = 0.39) and EQ5D (r = -0.54). Increased Body Mass Index (BMI) was correlated worse baseline SWAL-QOL (r = -0.30). Patients who had had prior cervical surgery had a lower baseline SWAL-QOL score (74.3 vs. 82.0, P = 0.043). Age, gender, smoking and Charlson Comorbidity Index (CCI) showed no significant correlations at baseline. At 3 month follow up, a higher pre-operative CCI (r = -0.26) and a greater number of cervical procedures (r = -0.31) was correlated to worse SWAL-QOL score.

Radiographic Variables
There were no pre-operative variables that were correlated with the baseline total SWAL-QOL score or with 3-month total SWAL-QOL scores. Change in radiographic variables (i.e., deformity correction) was not correlated with change in total SWAL-QOL scores or 3-month total SWAL-QOL scores. Subgroup analysis of patients with pre-operative CK (CL < 0°) and those without CK. These groups had no difference in baseline, 3 month or change in SWAL-QOL scores. In the CK group, an increase in O-C2 angle was correlated with worse 3 month SWAL-QOL scores (r = -0.37).

Surgical Variables
Number of levels fused, upper instrumented vertebrae (UIV), osteotomy use, surgical approach and steroid use had no effect on 3 month SWAL-QOL scores.

Conclusion: While the incidence of early dysphagia in pts undergoing CD surgery is unknown, we show that patients undergoing surgery for CD do not have dysphagia that persists at intermediate, 3 month follow up. Surgical techniques used to correct CD do not appear to have a significant impact on SWAL-QOL scores. Patients with prior cervical surgery and a higher BMI had lower baseline SWAL-QOL.

Presentation #60

Pseudarthrosis in Patients Undergoing Multilevel Posterior Cervical or Cervical-Thoracic Fusions: Multi-Center Analysis

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Introduction: Pseudarthrosis after multilevel posterior cervical or cervical-thoracic fusions is a common complication. We investigated the effect of pseudarthrosis on cervical aligment. Futhermore, we report the effect of type of bone grafts on the rate of pseudarthrosis in patients undergoing multilevel posterior cervical or cervical-thoracic fusions.

Methods: We assembled a multicenter (4 sites) radiographic and clinical database of patients that had undergone 3 or more level posterior cervical or cervical-thoracic fusions for degenerative disease from January 2008 to May 2013 with at least 2 years of post-operative (post-op) follow-up. Patients were divided into two groups: group I (fusion ending in the cervical spine) and group II (fusion extending into the thoracic spine). All radiographic measurements were performed by an independent experienced clinical researcher. For the analysis, bone grafts were divided into four groups: local only; local and allografts; bone morphogenetic protein (BMP) only; and iliac crest only. Current smokers included those patients smoking at the time of or within 6 months of their surgery. Paired t-test was used to compare means. Analysis of variance (ANOVA) was used to investigate the effects of type of bone grafts on the rate of pseudarthrosis. Level of significance was set at $\alpha = 0.05$.

Results: Rate of pseudarthrosis in group I and group II were 21.2% and 10.96%, respectively. Mean age of patients with pseudarthrosis in group I and group II were 56(± 9) and 67 (± 4) years, respectively. Females had higher numbers of pseudarthrosis than males (group I: 67% vs. 33%; group II: 55% vs. 45%; $p < 0.05$). Overall, 53.3% of the patients with pseudarthrosis were current smokers. The rate of smoking in the solid fusion group was 21.9%. The odds ratio of pseudarthrosis for a smoker compared with a non-smoker was 4.071 (95% CI: 1.798–9.221). Mean number of spinal levels treated for patients with pseudarthrosis in group I and group II were 3.6(± 0.79) and 6.2(± 2.5), respectively. Mean T1 slope for patients with pseudarthrosis increased significantly (2 wk vs. 2 year post-op) in both groups ($p < 0.05$). Both groups with pseudarthrosis had significantly higher mean C2-C7 sagittal plumbline at 2 years follow-up ($p < 0.05$). Mean cervical lordosis decreased in both groups with pseudarthrosis (2 wk vs. 2 year post-op). The difference was not statistically significant ($p > 0.05$). Overall, ANOVA showed no significant effect of type of bone grafts on the rate of pseudarthrosis ($p > 0.05$).

Conclusion: We conclude that pseudarthrosis affects cervical alignment in patients undergoing multilevel posterior cervical or cervical-thoracic fusions. The study did not find any significant effect of type of bone grafts on the rate of pseudarthrosis. Prospective studies with additional patients and greater statistical power are needed to further understand the implications of pseudarthrosis on cervical alignment.

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Presentation #61

Not All Patients with Diabetes have the Same Risk: The Association of Perioperative Glycemic Control with Deep Postoperative Infection following ACDF in Patients with Diabetes

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Introduction: Diabetes mellitus has been associated with an increased risk for postoperative infection following spine surgery; however, among patients with diabetes, the level of perioperative glycemic control may affect the risk of postoperative infection. Patients with very tight perioperative glycemic control may have a lower risk of infection compared to patients with higher average glucoses in the perioperative period. The primary goal of the present study was to evaluate the association of perioperative glycemic control as demonstrated by hemoglobin a1c (HbA1c) in patients with diabetes with the incidence of deep postoperative infection following anterior cervical discectomy and fusion (ACDF) requiring operative irrigation and debridement. Our secondary objective was to calculate a threshold level of hemoglobin a1c above which the risk of postoperative infection after ACDF increases significantly in patients with diabetes.

Methods: A national administrative database was queried for patients who underwent primary ACDF. Patients with diabetes mellitus who had a perioperative HbA1c level checked within 3 months of surgery were identified; and were then stratified into fourteen mutually exclusive groups based on their hemoglobin a1c in 0.5 mg/dl increments from < 5.49 mg/dl to > 12 mg/dl. The incidence of deep infection requiring operative intervention within 1 year for each HbA1c group was then identified using CPT and ICD-9 codes. A receiver operating characteristic (ROC) analysis was performed to determine an optimal threshold value of the HbA1c above which the risk of postoperative infection was significantly increased.

Results: 3,341 patients who underwent ACDF with diabetes and a perioperative HbA1c recorded within 3 months of surgery in the database were included in the study. The rate of deep infection requiring irrigation and debridement within one year postoperatively stratified by HbA1c is pictured in Figure 1, which ranged from a low of 1.5% to a high of 6.4% and was significantly correlated with increasing HbA1c levels (P = 0.001). The results of ROC analysis determined that the inflection point of the ROC curve corresponded to an HbA1c level above 7.5 mg/dL (p = 0.022, AUC = 0.67, spec. = 68%, sens = 46%).

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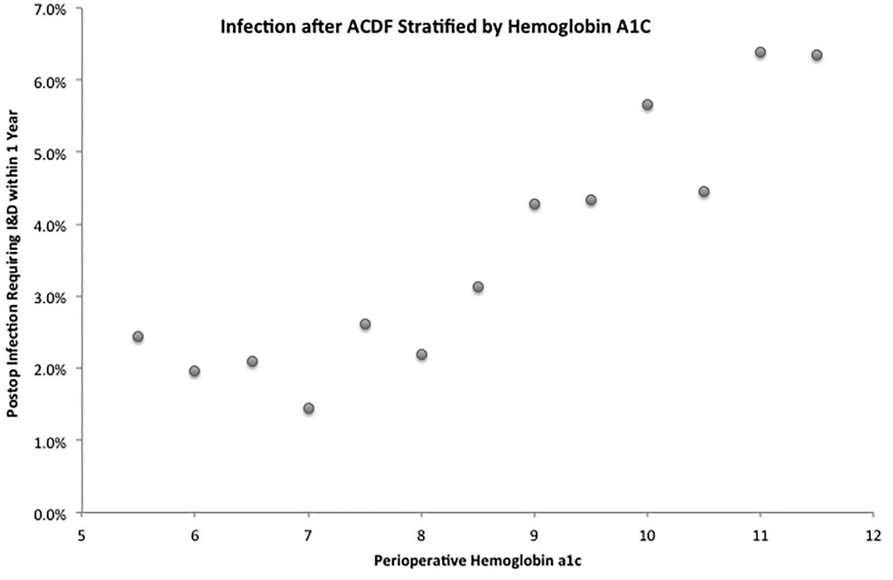
Presentation #61

Conclusions: The risk of deep postoperative infection requiring surgical intervention following ACDF in patients with diabetes mellitus increases as the perioperative HbA1c increases. ROC analysis determined that a perioperative HbA1c above 7.5 mg/dL could serve as a threshold for a significantly increased risk of deep postoperative infection following ACDF.



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Presentation #62

Laminoplasty and Wide Decompression were Risk Factors of C5 Palsy: Analysis of 303 Surgical Cases with Cervical Compression Myelopathy

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Introduction: C5 palsy is a potential complication after posterior cervical decompression. Before 2009, the incidence of C5 palsy was 9.5% (10 out of 105 patients) after double-door laminoplasty combined with laminectomy (DL) at our institute. Since 2009, we have performed laminectomy alone (LAM) of 2-3 mm wider than the spinal cord width which was measured on preoperative myelogram-CT. Incidence of C5 palsy was successfully reduced to 1.0% (2 out of 198 patients) after those changes. Purpose of this study is to elucidate the risk factors of C5 palsy by reviewing the surgical outcomes.

Materials and Methods: Out of 303 cervical myelopathic patients enrolled in this study, 105 patients underwent DL (cervical spondylotic myelopathy (CSM) 84 cases and ossification of the posterior longitudinal ligament (OPLL) 21 cases). The rest of 198 underwent LAM as wide as preoperatively planned (CSM 122 cases and OPLL 76 cases). We statistically analyzed risk factors of C5 palsy such as surgical procedures (DL or LAM), difference in width between surgical decompression and spinal cord (DW), dimension of C4/5 foramen measured at its narrowest point on axial CT, the amplitude of posterior spinal cord shift at C4/5 level (PSS) on sagittal MRI, post-operative C2-C7 angle on plain X rays, the number of consecutive levels decompressed, OPLL, T2 high intensity area at C3/4 level on MRI, age, gender, operation time and blood loss. Statistical analyses were performed using SPSS (version 22, SPSS, Inc.). Chi square test and one-way analysis of variance were used to compare the C5 palsy and no C5 palsy groups. Logistic regression analysis was used for risk factor analysis. First, the parameter significance was evaluated using univariate analysis. Factors with $p < 0.25$ in the univariate analysis were then induced in the multivariate analysis.

Results: There were significantly more patients with DL in C5 palsy group than no C5 palsy group (66.7% and 11.0%, p = 1.67E-02). Significantly more males were observed in patients with C5 palsy than those without (100% and 70.4%, p = 1.67E-02). DW (10.4 ± 4.5 and 5.3 ± 4.3, p = 5.16E-05), PSS (2.1 ± 1.1 and 1.0 ± 0.9, p = 7.38E-05), age (70.3 ± 6.9 and 62.1 ± 10.7, p = 9.80E-03), the numbers of surgically interfered laminae (3.4 ± 0.9 and 2.6 ± 1.0, p = 4.96E-03), operation time (181.1 ± 56.7 and 141.2 ± 40.4, p = 1.13E-03), and blood loss (94.0 ± 96.4 and 23.1 ± 54.7, p = 3.02E-05) were significantly greater in patients with C5 palsy than those without. Dimension of C4/5 foramen was significantly narrower in patients with C5 palsy than those without (p = 6.76E-04) (Table 1). Multivariate logistic regression analysis revealed that DL (OR, 17.2; 95% CI, 2.8 to 103.9, p = 1.99E-03), DW (OR, 1.2; 95% CI, 1.0004 to 1.4, p = 4.94E-02), dimension of C4/5 foramen (OR, 0.2; 95% CI, 0.08 to 0.6, p = 4.64E-03) and age (OR, 1.2; 95% CI, 1.1 to 1.4, p = 5.14E-03) were considered as the risk factors of C5 palsy (Table 2).

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Conclusion: Double-door laminoplasty, wide decompression, C4/5 foraminal stenosis and advanced age at surgery were considered as the risk factors of C5 palsy. Laminectomy of 2–3 mm wider than the spinal cord width dramatically reduced its incidence.

Table 1. Statistical analysis to compare the C5 palsy and no C5 palsy groups

Characteristic	C5 palsy	No C5 palsy	p-value
Number of cases	12	291	
demographic			
Age	70.3 ± 6.9	62.1 ± 10.7	9.80E-03
Sex, males	12 (100%)	205 (70.4%)	1.67E-02
diagnosis			
OPLL	5 (41.7%)	92 (31.6%)	0.47
operation			
Operation time (min)	181.1 ± 56.7	141.2 ± 40.4	1.13E-03
Blood loss (ml)	94.0 ± 96.4	23.1 ± 54.7	3.02E-05
DL	8 (66.7%)	32 (11.0%)	1.60E-05
Number of consecutive levels decompressed	3.4 ± 0.9	2.6 ± 1.0	4.96E-03
plain radiograph			
Postoperative C2-C7 angle (°)	-12.5 ± 12.7	-12.9 ± 12.0	0.91
MRI			
PSS (mm)	2.1 ± 1.1	1.0 ± 0.9	7.38E-05
T2 high intensity area at C3/4 level	2 (16.7%)	54 (18.6%)	0.61
CT			
DW (mm)	10.4 ± 4.5	5.3 ± 4.3	5.16E-05
Dimention of C4/5 foramen (mm)	2.0 ± 0.8	2.9 ± 1.0	6.76E-04

Abbreviations: DL = double-door laminoplasty combined with laminectomy; PSS = amplitude of posterior spinal cord shift at C4/5 level; DW = difference in width between surgical decompression and spinal cord.

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Presentation #62 (cont.)

Table 2. The results of Logistic regression analysis

Characteristic	OR	Univariate 95% CI	p-value	OR	Multivariate 95% CI	p-value
demographic						
Age	1.09	1.02 to 1.16	1.17E-02	1.19	1.05 to 1.35	5.14E-03
Sex, males			1.00			
diagnosis						
OPLL			0.47			
operation						
Operation time (min)	1.01	1.01 to 1.03	2.34E-03			
Blood loss (ml)	1.01	1.00 to 1.02	7.57E-04			
DL	16.19	4.61 to 56.79	1.40E-05	17.15	2.83 to 103.87	1.99E-03
Number of consecutive levels decompressed	2.39	1.27 to 4.50	7.08E-03			
plain radiograph						
Postoperative C2-C7 angle (°)	0.19	0.08 to 0.46	2.08E-04			
MRI						
PSS (mm)	2.65	1.55 to 4.52	3.48E-04			
T2 high intensity area at C3/4 level			0.87			
CT						
DW (mm)	1.21	1.09 to 1.34	3.37E-04	1.18	1.0004 to 1.40	4.94E-02
Dimention of C4/5 foramen (mm)	0.19	0.08 to 0.46	2.08E-04	0.22	0.08 to 0.63	4.64E-03

Abbreviations: OR = odds ratio; CI = confidence interval; DL = double-door laminoplasty combined with laminectomy; PSS = amplitude of posterior spinal cord shift at C4/5 level; DW = difference in width between surgical decompression and spinal cord.

Presentation #63

Reoperation Rates following Open Door Cervical Laminoplasty

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Introduction: Degenerative cervical myelopathy is a common cause of spinal cord dysfunction. Symptoms typically consist of upper and lower sensorimotor dysfunction. Surgical spinal cord decompression is effective in halting disease progression and allowing for neurological recovery. Instances of multilevel compression are commonly approached via a posterior approach with laminoplasty or laminectomy and fusion. Laminoplasty has been proven to be a safe and effective procedure that adequately decompresses the neural elements and allows for some motion preservation. The purpose of this study was to determine the reoperation rate after cervical laminoplasty and determine potential risk factors for reoperation.

Materials and Methods: We retrospectively reviewed our cohort who underwent open-door cervical laminoplasty between January 1, 2005 and October 31, 2012. Inclusion criteria included a minimum two-year follow-up or a reoperation. Follow up consisted of either a clinic visit or a telephone interview. Charts were reviewed with special attention to the age, sex, BMI, medical comorbidities including COPD and diabetes, workers compensation status, and duration of symptoms. Patient function was stratified according to the preoperative Nurick scale. Operative records were reviewed to determine the levels of laminoplasty performed, EBL, and if any concomitant procedures such as laminectomy, arthrodesis, and/or foraminotomies were performed. Postoperative notes were reviewed to determine if any complications requiring reoperations occurred as well as any C5 palsies. The reoperations were then divided into those occurring for acute postoperative complications such as infection, wound related issues, or malpositioned hardware versus those outside the acute post-operative period.

Results: Demographics are presented in Table 1 and Ranawat class in Table 2. 222 of 266 patients (83%) had a minimum two-year follow up with an average follow up of 4.97 years. Overall, 26 patients required 30 reoperations (13.5%). 15 patients required 16 reoperations (7.2%) in the acute postoperative period: 10 patients (4.5%) for infection requiring at least one irrigation and debridement, 3 (1.3%) patients for hardware related issues, and 3 (1.3%) patients for posterior cervical wound issues, one of which was a CSF fistula. 13 patients required 14 reoperations (6.3%) outside of the acute postoperative period: 6 (2.7%) for the development of a new radiculopathy, 3 (1.3%) for recurrent myelopathy, 2 (0.90%) for the development of neurological symptoms with a kyphotic deformity and 1 (0.45%) for a post-traumatic focal kyphotic deformity. 2 patients each reported an additional procedure being performed at an outside hospitals but the records were unable to be reviewed. Patients who had a concomitant laminectomy, either partial or complete, demonstrated a significantly ($p = 0.03$) higher reoperation rate compared to those that did not. This remained significant when comparing only the late reoperation cohort ($p<0.008$). No other statistically significant associations were found. We had an 18/222 (8.1%) C5 palsy rate.

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Presentation #63 (cont.)

Conclusion: Our cohort had a 13.5% reoperation rate with a 6% reoperation rate outside of the acute postoperative period related to the development of new neurological symptoms. Given the preservation of motion and less invasive nature of laminoplasty, these results support this procedure as a reasonable alternative to laminectomy and fusion.

Table 1. Demographics

Male/Female	132/90
Median Age (Years)	56.2 (30–86)
Median BMI	29.08 (18.29–59.06)
Median Duration of Symptoms (Months)	8.5 (1–288)
Median Follow-up (years)	4.97 (0–10)
Diabetes	21%
COPD	4%
Workers Compensation Status	9.9%

Table 2. Ranawat classification.

Ranawat Classification	Number of patients
Class I	38
Class II	74
Class III A	106
Class III B	4

Presentation #64

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

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Introduction: Obesity has often been associated with worse outcomes following spine surgery. Patients with greater BMIs may require more postoperative narcotics, increasing their risk for side effects and toxicity. Few studies have examined the effect of BMI classification on postoperative outcomes, narcotic consumption, complications, incidence and prevalence of revision surgery, costs or reimbursements following a 1- or 2-level ACDF. The purpose of this study is to compare surgical outcomes, postoperative narcotic consumption, complications, costs, and reimbursements across body mass index (BMI) stratifications for patients undergoing primary 1- or 2-level anterior cervical discectomy and fusion (ACDF).

Materials and Methods: A prospectively maintained surgical database of patients that underwent a primary 1- or 2-level ACDF for degenerative spinal pathology between 2007–2013 was reviewed. Patients were stratified in to one of four groups according to BMI: normal weight (<25kg/m2), overweight (25–30kg/m2), obese I (30–35kg/m2), or obese II-III (≥ 35kg/m2). Differences in patient demographics and preoperative characteristics were compared across the cohorts using independent sample t-tests and Chi-square analysis. The effect of BMI on peri- and postoperative outcomes analyzed using multivariate linear and logistic regression adjusted for demographic, comorbidity, and procedural characteristics. Two cohorts of 30 patients were matched for number of fusion levels, smoking, and Charlson Comorbidity Index (CCI) score to compare hospital costs and reimbursements. OME means were compared utilizing non-parametric analysis to adjust for distortions.

Results: A total of 315 patients were included in the analysis, of which 72 (22.9%) were normal weight, 117 (37.1%) were overweight, 72 (22.9%) were obese I, and 54 (17.1%) were obese II-III. No difference in age, gender, smoking status, operative level, or pre-operative VAS was found between cohorts (Table 1). However, greater BMI was associated with having an increased comorbidity burden ($p<0.001$). BMI was not found to be associated with mean operative time, estimated blood loss (EBL), length of hospital stay (LOS), in-hospital narcotic consumption, postoperative VAS scores at 6-weeks, 3-months, or 6-months, narcotic dependence at the 1st or 2nd postoperative visit, or complication and arthrodesis rates (Table 2). In the matched cohort analysis, the payments to charge ratios were 0.57 ± 0.36 and 0.70 ± 1.7 in the obese and non-obese cohorts, respectively, and no significant differences existed with regards to charges, reimbursement, or direct costs between cohorts ($p>0.05$).

See Disclosure Index pages 39–89.

Presentation #64 (cont.)

Conclusions: Patients with increased BMIs demonstrated comparable surgical outcomes, narcotic consumption, and hospital costs when compared to those with lower BMIs. While obese patients may present a technical challenge to spine surgeons, obesity was not associated with increased postoperative pain, narcotic consumption, complication rates, or hospital expenses. As such, the decision to perform a primary 1- or 2- level ACDF may not differ across BMI stratifications.

Table 1. Baseline characteristics.*

	Normal (N = 72)	Overweight (N = 117)	Obese I (N = 72)	Obese II-III (N = 54)	P-value
Age (Mean ± SD, years)	49.0 ± 11.3	48.9 ± 11.7	51.3 ± 11.0	52.5 ± 13.2	0.191
Sex (n)					0.079
Female	55.6% (40)	44.4% (52)	34.7% (25)	50.0% (27)	
Male	44.4% (32)	55.6% (65)	65.3% (47)	50.0% (27)	
Smoking status (n)					0.054
Smoker	73.6% (53)	71.8% (84)	81.9% (59)	88.9% (48)	
Non-smoker	26.4% (19)	28.2% (33)	18.1% (13)	11.1% (6)	
Comorbidity burden (CCI)	**2.9 ± 1.6**	**3.0 ± 1.8**	**3.5 ± 1.8**	**4.1 ± 2.3**	**< 0.001**
Operative levels (n)					0.078
1 level	58.3% (42)	61.5% (72)	66.7% (48)	44.4% (24)	
2 levels	41.7% (30)	38.5% (45)	33.3% (24)	55.6% (30)	
Preoperative VAS (Mean ± SD, min)	6.7 ± 1.8	6.3 ± 1.9	6.3 ± 1.9	6.6 ± 1.7	0.475

SD = Standard deviation; CCI = Charlson comorbidity index; VAS = Visual analogue scale
Boldface indicates statistical significance.

Presentation #64

Table 2. Outcomes.*

	Normal (N = 72)	Overweight (N = 117)	Obese I (N = 72)	Obese II-III (N = 54)	P-value†
Operative time (Mean ± SD, min)	64.2±19.8	62.8 ± 21.0	64.6 ± 19.2	72.5 ± 25.0	0.089
Estimated blood loss (mL)	60.5 ± 56.8	62.9 ± 55.3	64.0 ± 60.7	60.3 ± 51.5	0.841
Length of hospital stay (hours)	44.5 ± 60.1	39.7 ± 19.7	38.7 ± 16.7	45.0 ± 29.4	0.527
Narcotic utilization (OME)	41.4 ± 25.2	37.7 ± 26.7	43.0 ± 32.0	35.6 ± 25.3	0.440
Visual Analogue Scale (Mean ± SD)					
6-week VAS	3.5 ± 2.1	3.0 ± 2.0	3.6 ± 2.6	3.6 ± 2.0	0.099
3-month VAS	2.9 ± 2.8	2.7 ± 2.5	2.2 ± 2.6	3.2 ± 2.5	0.198
6-month VAS	2.4 ± 2.8	2.0 ± 2.6	1.7 ± 2.6	2.5 ± 2.4	0.617
Narcotic dependence (n)					
First postoperative visit	47.2% (34)	41.9% (49)	45.1% (32)	49.1% (26)	0.298
Second postoperative visit	30.6% (22)	35.0% (41)	26.8% (19)	34.0% (18)	0.605
Complications (n)∫	5.6% (4)	6.0% (7)	4.2% (3)	14.8% (8)	0.691
Pseudarthrosis (CT scan) (n)	2.8% (2)	5.1% (6)	2.8% (2)	1.9% (1)	0.719
Arthrodesis at 1 year (n)	97.2% (70)	94.9% (111)	97.2% (70)	96.3% (52)	0.675

SD = Standard deviation; VAS = Visual analogue scale.
Boldface indicates statistical significance.
†P-value is from multivariate logistic or linear regression adjusted for age, sex, smoking status, comorbidity burden, operative levels, and preoperative visual analogue scale.
‡Three patients required a multi-level revision procedure
∫Complications include durotomy (2), respiratory depression requiring reintubation (2), plate subsidence

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Presentation #65

Effect of Surgical Setting (Tertiary vs. Community Hospitals) on Hospital Reported Outcomes for Anterior Cervical Spine Procedures

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Introduction: As hospital compensation becomes dependent on pay-for-performance and bundled payment compensation models, hospitals seek to reduce costs and improve patient outcomes by decreasing patient length of stay (LOS), potentially avoidable utilizations (PAUs, 30 day all-cause readmissions/revisits), and in-hospital provider preventable conditions (PPCs, as defined by CMS, including postoperative respiratory failure, renal failure, decubitus ulcer, postoperative wound infection, and reoperation, among others). We sought to evaluate hospital-reported outcomes measures for elective ACDF at a tertiary hospital (TH) versus community hospitals (CH) within the same hospital system. The purpose was to determine if elective ACDFs performed at THs versus CHs have different LOS, PPCs, and PAUs.

Materials and Methods: 698 consecutive patients (January 2015–January 2016) undergoing an ACDF were retrospectively reviewed from a physician-driven, prospective database of a single medical system consisting of one TH (N = 97) and four CHs (N = 601). Inclusion criteria consisted of patients (> 18 years old) who underwent elective ACDF. Exclusion criteria included: trauma, tumor, and infection. Independent variables included: age, sex, ethnicity, insurance type, sub-specialty (orthopaedic spine surgery or neurosurgery), number of fusion levels, use of instrumentation plate, inpatient status, and discharge disposition. The primary outcome was the mean LOS. Secondary outcomes included rates of PPCs and PAUs.

Results: Table 1 shows the patient characteristics between THs and CHs. The CH patients were significantly older ($P = 0.003$) and were predominantly white. CHs had fewer patients with medicare/medicaid/medical assistance and more self-payers than the TH. THs had a higher proportion of orthopaedic surgeons performing ACDFs. CHs performed a greater number of fusion levels compared to the TH (mean, 2.23 ± 0.99 vs. 1.79 ± 0.93, $P < 0.001$). Significantly more patients were admitted postoperatively in the CHs vs. the TH (70.2% vs. 65.9%, $P < 0.001$). The TH discharged patients to home proportionally more than the CHs (92.8% vs. 70.2%, $P < 0.001$). Table 2 shows the univariate and multivariate linear regression results for predictors of LOS. After adjusting for age, sex, ethnicity, insurance type, specialty, surgical factors, inpatient status, discharge disposition, and PPCs, the TH was associated with a 0.51 days greater LOS ($P = 0.017$; 95% CI, 0.09–0.94) compared with the CHs. The most significant predictors of increased LOS were the presence PPCs and discharge to a facility (4.41 and 1.80 days longer LOS, respectively; $P < 0.001$). Medicare/Medicaid insurance significantly increased LOS by 0.37 days.

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Conclusion: In the multivariate analysis we found that tertiary vs. community setting, age, medicaid/medicare status, sub-specialty (neurosurgery vs. orthopaedics), and the presence of a PPC had significant correlation with a longer LOS. Surprisingly, the number of levels fused did not predict a longer LOS. The presence of a PPC had the most acute effect on prolonging LOS which highlights the importance in finding strategies to help mitigate it. This surgeon-driven data may help develop more effective protocols to decrease LOS while minimizing PAUs and PPCs. This could potentially improve patient care, reduce hospital costs, and improve surgeon compensation.

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Presentation #65 (cont.)

Table 1. Characteristics of Tertiary and Community Hospitals for Elective ACDF Procedures				
	Total (N = 698)	**Tertiary (N = 97)**	**Community (N = 601)**	**P value**
Mean age ± SD	54.9 ± 11.5	51.6 ± 11.1	55.4 ± 11.5	0.003*
Sex, n (%)				
Male	346 (49.6)	42 (43.3)	304 (50.6)	0.19
Female	352 (50.4)	55 (56.7)	297 (49.4)	
Ethnicity, n (%)				
White	583 (83.5)	65 (67.0)	518 (86.2)	<0.001*
Black / African American	90 (12.9)	25 (25.8)	65 (10.8)	
Other	25 (3.6)	7 (7.2)	18 (3.0)	
Insurance, n (%)				
Commercial	399 (57.2)	53 (54.6)	346 (57.6)	<0.001*
Medicare / Medicaid / Assistance	194 (27.8)	38 (39.2)	156 (26.0)	
Workers compensation	20 (2.9)	6 (6.2)	14 (2.3)	
Self	85 (12.2)	0 (0)	85 (14.1)	
Specialty, n (%)				
Orthopaedic Surgery	381 (54.6)	72 (74.2)	309 (51.4)	<0.001*
Neurosurgery	317 (45.4)	25 (25.8)	292 (48.6)	
ACDF Characteristics, n (%)				
Number of levels fused				
One	211 (30.2)	40 (41.2)	171 (28.5)	<0.001*
Two	238 (34.1)	45 (46.4)	193 (32.1)	
Three	174 (24.9)	8 (8.2)	166 (27.6)	
Four	71 (10.2)	2 (2.1)	69 (11.5)	
Five	2 (0.3)	0 (0)	2 (0.3)	
Six	2 (0.3)	2 (2.1)	0 (0)	
Mean Levels Fused ± SD		1.79 ± 0.93	2.23 ± 0.99	<0.001*
Instrumentation Plate	444 (63.6)	82 (84.5)	362 (60.2)	<0.001*
Inpatient	460 (65.9)	38 (65.9)	422 (70.2)	<0.001*
Discharge Disposition, n (%)				
Home or Self-Care	512 (73.4)	90 (92.8)	422 (70.2)	<0.001*
Facility	186 (26.6)	7 (7.2)	179 (29.8)	
PPC, n (%)	7 (1.0)	0 (0)	7 (1.2)	0.60
Revisit / Readmission, n (%)	13 (1.9)	2 (2.1)	11 (1.8)	0.70
Mean LOS in days ± SD	1.76 ± 1.99	1.59 ± 1.45	1.79 ± 2.07	0.37
PPC, provider preventable complications; LOS, length of stay. *Indicates a statistically significant value with P≤0.05.				

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Table 2. Univariate and Multivariate Analyses Between Various Clinical Predictors to Determine LOS for Elective ACDF Procedures						
	Univariate Analysis			Multivariate Analysis		
	β	***P***	**95% CI**	**β**	***P***	**95% CI**
Facility, ref. = community	-0.20	0.37	-0.63-0.23	0.51	0.017*	0.09-0.94
Age, per year	0.04	<0.001*	0.03-0.05	0.02	0.004*	0.01-0.03
Male, ref. = female	0.03	0.86	-0.27-0.32	0.03	0.84	-0.23-0.29
Ethnicity, ref. = white						
Black / African American	-0.60	0.43	-2.09-0.89	-0.30	0.65	-1.60-0.99
Other	0.17	0.45	-0.27-0.61	0.31	0.88	-0.37-0.43
Insurance, ref. = commercial						
Medicare / Medicaid / Assistance	0.89	<0.001*	0.56-1.23	0.37	0.026*	0.04-0.70
Workers compensation	-0.01	0.99	-0.88-0.87	0.22	0.59	-0.57-1.00
Self	0.85	<0.001*	0.40-1.31	0.0	0.99	-0.46-0.46
Neurosurgery, ref. = orthopaedic	-0.26	0.091	-0.55-0.04	0.53	0.001*	0.21-0.86
Number of levels fused, per level	0.29	<0.001*	0.14-0.43	0.09	0.20	-0.05-0.23
Instrumentation Plate, ref. = none	-0.61	<0.001*	-0.91-[-0.31]	0.24	0.23	-0.15-0.62
Inpatient, ref. = no	1.1	<0.001*	0.79-1.39	0.43	0.012*	0.10-0.76
Discharge to facility, ref. = home	1.74	<0.001*	1.43-2.05	1.80	<0.001*	1.40-2.20
PPC, ref. = no	5.44	<0.001*	4.00-6.87	4.41	<0.001*	3.10-5.71
PPC, provider preventable complications; LOS, length of stay. *Indicates a statistically significant value with P≤0.05.						

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Presentation #66

Predictive Models for Patient-Centered Efficacy and Discharge Destination after Elective Cervical Spine Surgery

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Introduction: Surgery is a valuable therapeutic option for degenerative cervical spine disease, however there is uncertainty as to which patients benefit. Here we introduce predictive models for clinically meaningful improvement in disability, as well as discharge destination, after cervical spine surgery (CSS).

Methods: 430 patients undergoing CSS were enrolled into a prospective registry. LOESS regression was performed to verify that a linear relationship between 12-month Neck Disability Index (NDI) and various explanatory variables was reasonable. The following variables were used to power a multiple linear regression model for NDI: demographics, diagnosis, number/location of diseased levels, baseline symptoms and PROs, employment/insurance status, comorbidities, a history of prior surgeries, and surgical approach. Possible interactions among variables such as diagnosis, age, baseline NDI, and employment status were also accounted for in the analysis. We then used Repeated Random Sub-Sampling (related to Monte Carlo cross-validation) to validate the predictive performance of our model. A separate model, based on logistic regression, was constructed to predict a clinically important improvement in NDI (at least 17.3) at one year. A third model was also developed and validated, using similar methods, with the aim of predicting post-surgery discharge destination (home versus facility).

Results: The mean NDI one year after surgery was 25.82, and the mean improvement was 16.33 points. 48% (205) of patients achieved the minimum clinically important difference (MCID) in NDI. Our predictive model for 12-month NDI has an R-squared of 0.69 (observed versus predicted NDI scores are plotted in Figure 1), and in validation, it achieved an R-squared of 0.43. The predictors, in descending order of influence, are: employment, baseline NDI, diagnosis, smoking, ethnicity, claudication, narcotic use, and symptom duration. Our model for achieving a MCID in NDI has an area under the curve greater than 0.80 for the development phase and an AUC of 0.65 for the validation phase. The predictors, in descending order of influence, are: baseline NDI, motor deficit, depression, ambulation, revision surgery, employment, diagnosis, smoking, and symptom duration. Finally, our predictive model for discharge destination has an area under the curve greater than 0.80 for the development phase and an AUC of 0.75 for the validation phase (ROC curve shown in Figure 2). The predictors, in descending order of influence, are: baseline EQ-5D, number of levels, myelopathy, depression, baseline NDI, and motor deficit.

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Conclusion: We present internally validated models that can help predict disability at one year, clinically meaningful improvement in disability, and discharge destination after elective CSS. Our NDI model explains roughly 70% of the variation in 12-month neck-related disability. The predictive accuracy of our associated model for achieving a MCID in NDI is a good starting point, but leaves room for improvement. Our model for discharge destination has strong predictive accuracy, and with external validation at other institutions, it can become a useful tool as spine care providers seek to better understand the post-operative trajectories of their patients.

Figure 1.

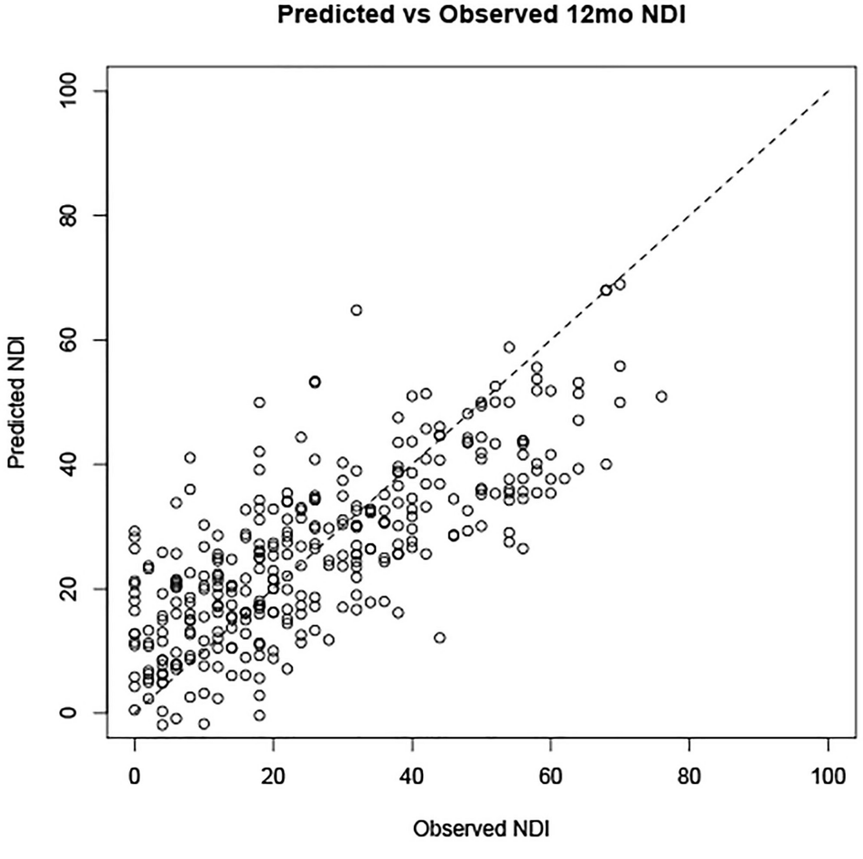

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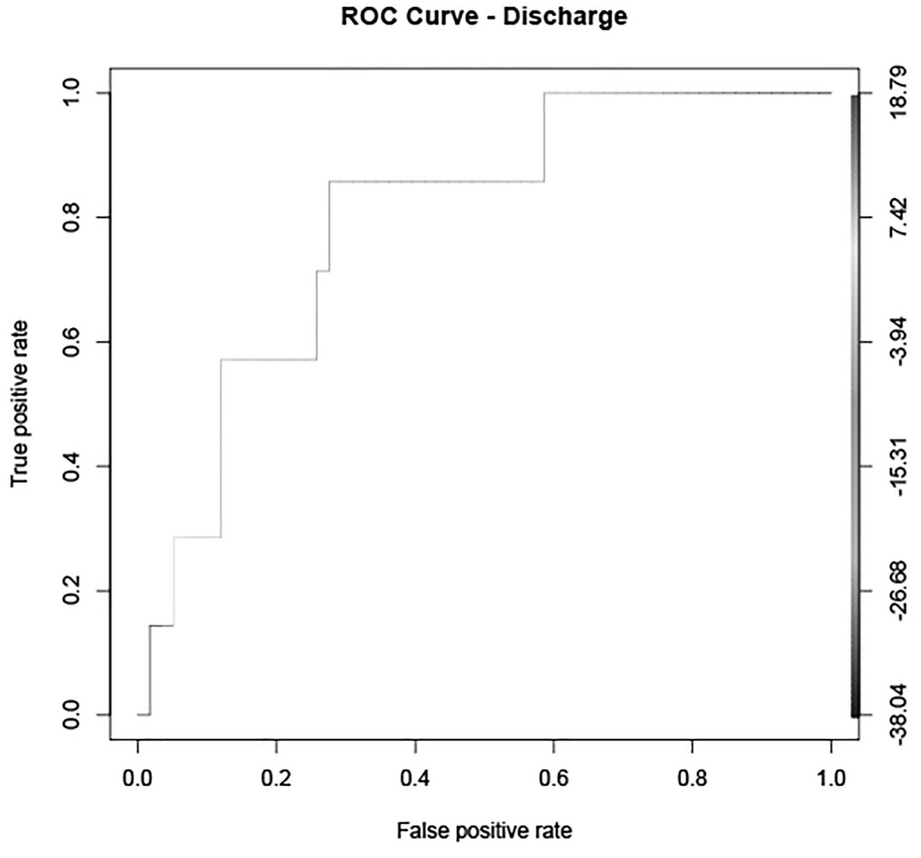
Figure 2.



Presentation #67

Reimbursement and Charges Related to a 90-Day Episode of Care for a One- or Two-Level Anterior Cervical Discectomy and Fusion

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Introduction: Bundled payments represent a single payment for services during an episode of care for a surgical procedure. Anterior cervical discectomy and fusion (ACDF) and associated 90-day costs have been suggested as a "bundle" amenable to such a payment structure; however, little data regarding costs related to this procedure and subsequent care are available.

Methods: The Medicare 5% national sample administrative database was used to catalog clinical and financial data associated with the day of surgery and the 90-day postoperative period for patients undergoing a one- to two-level ACDF procedure from 2005 to 2012. We simultaneously queried the database for total knee replacement as a means to compare the payments and verify the reliability of our analysis.

Results: A total of 4,506 patients underwent an ACDF procedure for cervical radiculopathy. Total 90-day reimbursement was $69,469,550 or $15,417/patient (+/-$947, median=$15,589). As a comparison, reimbursement for TKR patients amounted to $17,451/patient. Physician reimbursement for ACDF represented 20.42% of the total with the surgeon receiving 18.07% of total reimbursement. Revision surgery, readmission and emergency department reimbursement accounted for 0.71% of total reimbursement. Reimbursement for rehabilitation service, including physical therapy, skilled nursing facilities and home care represented 3.11% of total reimbursement. There was a statistically significant variation in reimbursement among geographic regions, being highest in the western United States ($p=0.015$) [Figure 1], and a trend towards increase in overall reimbursement over the years from 2005 to 2012 ($p=0.082$) [Figure 2].

Conclusions: This study is the first report we are aware of 90-day reimbursement/patient for one- to two-level ACDF procedures in a Medicare cohort. Payments had a statistically significant variation among geographic locations. Our study provides a reimbursement benchmark for one- to two-level ACDF procedures and understanding the payments relative to costs will help providers understand whether a bundled payment for the ACDF procedure is economically viable.

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Presentation #67 (cont.)

Figure 1. Breakdown of top DRG and CPT codes by region

Code	Midwest (Reimbursement/ patient)	South (Reimbursement/ patient)	West (Reimbursement/ Patient)	Northeast (Reimbursement/ Patient)
CPT-63075 (Physician code for discectomy)	$838 (+/- $66)	$828 (+/- $37)	$852 (+/- $61)	$869 (+/- $63)
CPT-22845 (Physician code for anterior instrumentation)	$555 (+/- $47)	$575 (+/- $21)	$559 (+/- $27)	$583 (+/- $43)
DRG 472/519 (Inpatient code for cervical spine fusion with a comorbid condition)	$2064 (+/- $459)	$2961 (+/- $423)	$4007 (+/- $682)	$1547 (+/- $153)
DRG 473/520 (Inpatient code for cervical spine fusion without a comorbid condition)	$6501 (+/- $655)	$6588 (+/- $679)	$7414 (+/- $766)	$7379 (+/- $759)

Figure 2. Variation in reimbursement per patient for the years 2005-2012

Year	Reimbursement/patient
2005	$13,310 (+/- $756)
2006	$14,244 (+/- $366)
2007	$13,749 (+/- $377)
2008	$15,248 (+/- $1240)
2009	$14,461 (+/- $1458)
2010	$15,399 (+/- $2142)
2011	$15,577 (+/- $883)
2012	$14,812 (+/- $1707)

• **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 #68

Is there Value in Retrospective 90-Day Bundle Payment Models for Cervical Spine Procedures?

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Introduction: The Centers for Medicaid and Medicare Services (CMS) Bundled Payments for Care Improvement (BPCI) initiative was implemented in 2015. At our private practice, we implemented a retrospective payment model 2 for a 90-day episode of care for cervical spine and other orthopedic procedures. Under these retrospective payment models, Medicare continues to make fee-for-service (FFS) payments but reconciles the total expenditures for the episode with a bundled payment amount as determined by CMS. A payment or recoupment amount is then made by Medicare reflecting the aggregate expenditures compared to the target price. The purpose of the study is to assess the value of the cervical spine CMS bundle at our private practice.

Methods: We utilized the data provided by CMS to compare the total expenditures of cervical spine diagnosis related groups (DRGs) of 471, 472, and 473. Medicare patients who underwent cervical spine surgery between January 2009-December 2012 were defined as non-BPCI (n = 88) and were compared to Medicare BPCI patients (n = 40) who had surgery between January 2015-December 2015. Post-acute events within the 90 day episode including admission to an IRF or SNF as well as home health (HH) and readmissions were analyzed. Expenditures were converted to 2016 dollars using Consumer Price Index (CPI). Normality of expenditures was assessed using the Manning & Mullahy method and expenditures were subsequently log transformed. Wilcoxon tests and a multivariate generalized estimated equation were used to determine differences between BPCI and non-BPCI patients as well as assess the independent effects of post-acute events.

Results: The median expenditure for non-BPCI patients was $16,566 (IQR $14,604–$19,951) compared to $18,510 (IQR $15,936-$23,371) for BPCI patients (p = .02). Compared to non-BPCI patients BPCI patients had a higher rate of SNF admissions (non-BPCI 6% vs 7.5% BPCI; p = .23), IRF admissions (non-BPCI 1% vs. 5% BPCI; p = .68), HH (non-BPCI 14% vs. 15% BPCI; p = .79) and readmissions (non-BPCI 9% vs. 12.5% BPCI; p = .54). At the multivariate level, the significantly higher expenditure for BPIC patients persisted and all post acute events were significant, independent drivers of increased cost. After controlling for post acute events, BPCI patients had a 10% increase in expenditures (p = .02). Admissions to an IRF or SNF increased cost 93% (p < .001) and 56% (p < .001), respectively. HH utilization increased expenditures 26% (p < .0001) and 90-day readmissions increased costs by 45% (p < .0001).

Conclusion: The objective of the BPCI initiative was to improve the value of health care, e.g. decreasing cost while improving outcomes. Our institution was only managing the post acute care expenditures and not the acute hospital expenditures. In spite of our best efforts to contain costs with clinical practice guidelines, patient navigators and a BPCI management team, the expenditures were significantly higher for BPCI patients. Furthermore, the outcomes defined as post acute events were not improved. The variability of surgical procedure complexity included in the 471, 472 and 473 DRGs, cervical spine bundles may not be appropriate. We have discontinued BPCI for cervical spine DRGs and are focusing our efforts on defining bundles by specific Current Procedural Terminology® codes.

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Presentation #69

The Use of a Novel iPad Application to Quantify Dysfunction in Cervical Myelopathy Patients

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Introduction: Cervical myelopathy is the leading cause of spinal cord dysfunction in the adult population. Despite the prevalence and importance of the condition there is a paucity of objective and quantitative clinical measures for analysis of the disease process. The most common diagnostic tools available to the physician are non-quantitative physical exam findings (pathologic reflexes, gait disturbance) and subjective scoring systems (mJOA, Nurick scales). The lack of an easily-performed, objective, and quantitative diagnostic tool has hindered the diagnosis of these patients. In an effort to better classify myelopathy, provide earlier diagnosis, and improve clinical outcome measurements we developed a novel iPad application to test fine motor skills. A decline in these fine motor skills is an early hallmark of cervical myelopathy. We wrote a novel code for the iPad application with clinical application in mind and thus were able to fine tune the instrument making use efficient for clinicians and patients.

Methods: We recruited 71 healthy control patients and 8 myelopathic patients aged of at least 18 years and no neurologic or physical condition (i.e. Parkinson's, dementia, blindness, rheumatoid arthritis) that precluded fine motor testing. Myelopathic subjects were diagnosed by a fellowship trained spine surgeon based on clinical and radiographic evaluation. Enrolled patients completed the modified Japanese Orthopaedic Association scale (mJOA) for cervical myelopathy and our novel Fine Motor Skills (FiMS) iPad application. The FiMS iPad application consists of 4 unique challenges (Figure 1). All the challenges focus on the use of fine motor dexterity testing and increase in difficulty as the challenges progress. Challenge 1 involves accurately tapping a moving target on the screen. Challenge 2 necessitates dragging a target on the screen to a goal. Challenge 3 involves moving a target through a maze without touching the maze walls. Challenge 4 is similar to Challenge 2 but requires the use of both hands to drag 2 separate targets to a goal. The scores are recorded independently for each challenge and the mean scores were used for data analysis. A student t-test was used to determine significance with a p-value set at < 0.01.

Results: The average mJOA score (scale 0–18) for the myelopathic cohort was 11.4 with a score less than 12 being classified as severe myelopathy. The 71 control patients had a mean mJOA score of 17.4 with a score greater than 17 being inconsistent with myelopathy. Regression analysis of the healthy controls (n = 71) showed that FiMS challenge scores decreased with age in all four challenges. When compared to age-matched healthy controls (n = 44) the myelopathic cohort had significantly lower FiMS scores for all challenges 1-4 (Table 1).

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Conclusion: The novel Fine Motor Skills (FiMS) iPad application produced significantly lower scores in a myelopathic cohort when compared to an age-matched control cohort. This is true for all 4 challenges in the FiMA iPad application. In summary, the FiMS iPad application is a novel, easily administered, objectively quantifiable test for analyzing cervical myelopathy.

Table 1. Fine Motor Skills (FiMS) iPad Application Results for Age-matched Controls vs. Myelopathics

	Healthy Controls n = 44		Myelopathic Patients n = 8		
	Average (SD)	95% CI	Average (SD)	95% CI	p-value
Age (years)	58.3 (7.8)	56 to 60.6	60.7 (10.0)	53.8 to 67.7	0.2252
mJOA score	17.2 (1.3)	16.8 to 17.6	11.4 (2.7)	9.5 to 13.2	***< 0.0001**
FMTIA Scores					
Challenge 1	23.9 (3.8)	22.8 to 25.0	13.0 (5.6)	9.2 to 16.9	***< 0.0001**
Challenge 2	16.4 (3.2)	15.5 to 17.4	9.8 (3.8)	7.1 to 12.4	***< 0.0001**
Challenge 3	3.3 (1.4)	2.9 to 3.7	1.3 (1.2)	0.4 to 2	***0.00016**
Challenge 4	6.3 (2.7)	5.6 to 7.1	1.4 (1.4)	0.4 to 2	***< 0.0001**

*indicates that the p-value reached clinical significance ($p < 0.01$ set value for significance)
CI, confidence interval; SD, standard deviation

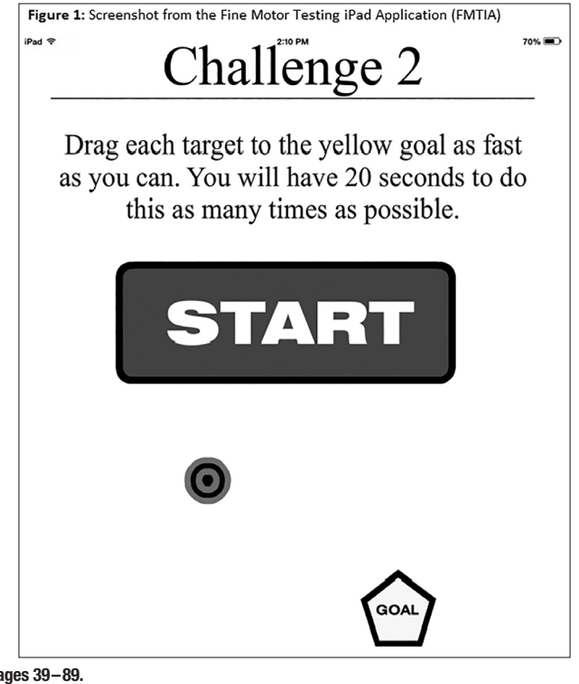

Figure 1: Screenshot from the Fine Motor Testing iPad Application (FMTIA)

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Presentation #70

Association between Paraspinal Muscle Morphology, Clinical Symptoms and Functional Status in Patients with Degenerative Cervical Myelopathy

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Introduction: Cervical muscle alterations have been reported in patients with chronic neck pain, but the assessment of cervical muscle morphology has been overlooked in patients with degenerative cervical myelopathy (DCM). The objective of this study was to assess the composition (e.g. fatty infiltration) and asymmetry of the multifidus (MF), semispinalis cervicis (SCer), semispinalis capitis (SCap) and splenius capitis (SPL) muscles in patients with DCM and evaluate their correlations with clinical signs, symptoms and functional scores.

Materials and Methods: Thirty-eight patients diagnosed with DCM and spinal cord compression at C4-C5 (n = 20) or C5-C6 (n = 18) (first level of compression) were selected from the AOSpine CSM database. Cervical muscle measurements of cross-sectional area (CSA) (Figure 1) and ratio of functional CSA (fat free area, FCSA) to total CSA (Figure 2) were obtained from T2-weighted axial MR images at the level above, same, and level below the most cranial level of spinal cord compression. Muscle fatty infiltration and asymmetry was assessed at every level and their associations with respect to clinical signs, symptoms and functional scores were investigated.

Results: There was a significant increase in fatty infiltration of the MF ($p = 0.001$) and SPL ($p < 0.001$) muscles at the level below the compression. A significant increase in MF CSA asymmetry was also observed at the level below the compression. Lower MF FCSA / CSA ratio was associated longer 30-meter walking test time. Lower SCer FCSA / CSA was associated with corticospinal distribution motor deficits and atrophy of the hands. Greater asymmetry in SCap CSA was associated with higher Neck Disability Index (NDI) scores while lower asymmetry in MF CSA was associated with a positive Hoffman sign and weakness.

Conclusion: A significant increase in muscle fatty infiltration and CSA asymmetry at the level below the compression was observed in patients with DCM. Our results also suggest an association between cervical muscle morphology and DCM clinical signs, symptoms and functional status. Clinicians should pay greater attention to cervical muscle morphology and composition in patients diagnosed with DCM and further evaluate whether such muscle parameters have an impact on prognosis and functional recovery.

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Figure 1.

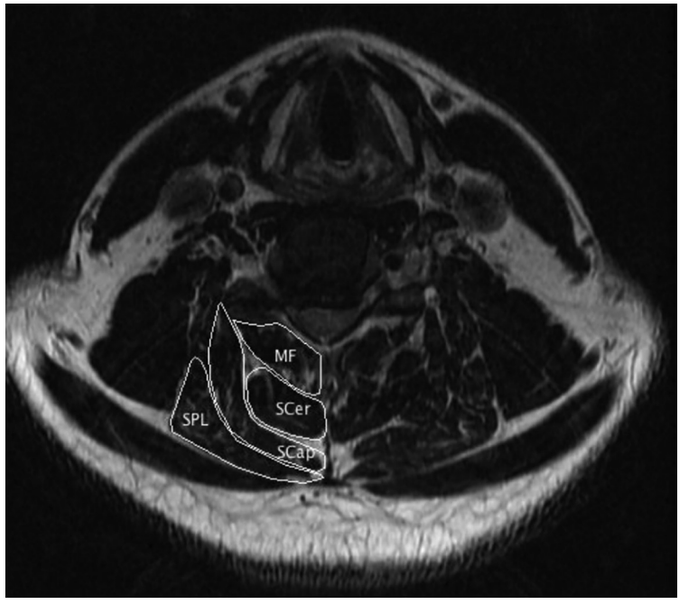
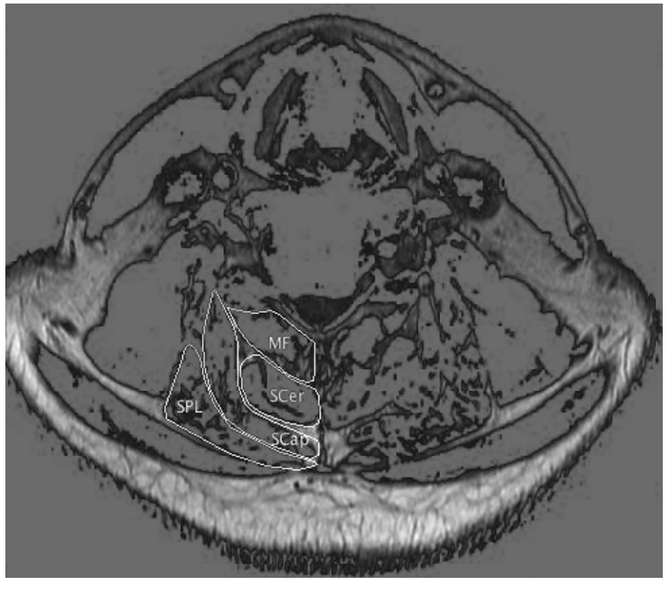


Figure 2.



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Presentation #71

MRI Analysis of the Combined AOSpine North America and International Studies: The Prevalence and Spectrum of Pathologies in a Global Cohort of Patients with Degenerative Cervical Myelopathy

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Introduction: Degenerative Cervical Myelopathy (DCM) encompasses a spectrum of age-related conditions of the cervical spine, including spondylosis, which result in progressive spinal cord injury through static and dynamic injury mechanisms. Unfortunately, little is known of the prevalence and constellation of anatomical pathology that presents in these patients and if there are differences between genders. Through detailed review of MRIs from prospective AOSpine multicenter studies, it is the purpose of the present research to report on the global prevalence of degenerative cervical pathologies of surgically treated DCM patients. Such information would be potentially helpful in uncovering etiological factors, provide insight into the natural history, and determine risk factors for DCM.

Methods: MRIs of 458 patients were reviewed for the type of pathology, source of stenosis, level of maximum cord compression, levels of spinal cord compression (SCC), and signal changes on T2WI and T1WI. Additionally, a cord occupying ratio (COR) within the canal at non-compressed sites was calculated and a COR $\geq$ 70% was used to identify congenital stenosis. The prevalence of these changes was separated into genders and the proportions were assessed using Chi-square analysis. A p-value of $\leq$0.05 was considered as statistically significant. Additionally, the proportion of degenerative changes present alongside other diagnoses was computed as well as the prevalence of pathologies per geographical region.

Results: Globally, spondylosis was the most frequent cause of SCC (89.7%) and was frequently accompanied by enlargement of the ligamentum flavum (LF) (59.8%), Figure 1. OPLL was accompanied by spondylosis in 91.7%. Single level disc pathology, OPLL and spondylolisthesis had a prevalence of ~10%. Associated abnormalities such as Klippel-Feil Syndrome and congenital stenosis were observed in 2.8% and 8.4%, respectively. Single level disc pathology was less common in North America, congenital stenosis less common in Europe, and OPLL more common and spondylolisthesis less common in Asia-Pacific. Females presented more commonly with single level disc pathology ($p = 0.013$) and were less likely to have their maximum site of cord compression at C3-4 ($p = 0.007$). Males more commonly presented with spondylosis ($p = 0.017$) and enlargement of LF ($p = 0.012$). Globally, the C5-6 region was the most frequent maximum compressed site (39.7%) and region for T2WI hyperintensity (38.9%). T2WI hyperintensity more commonly presented in males ($p < 0.001$).

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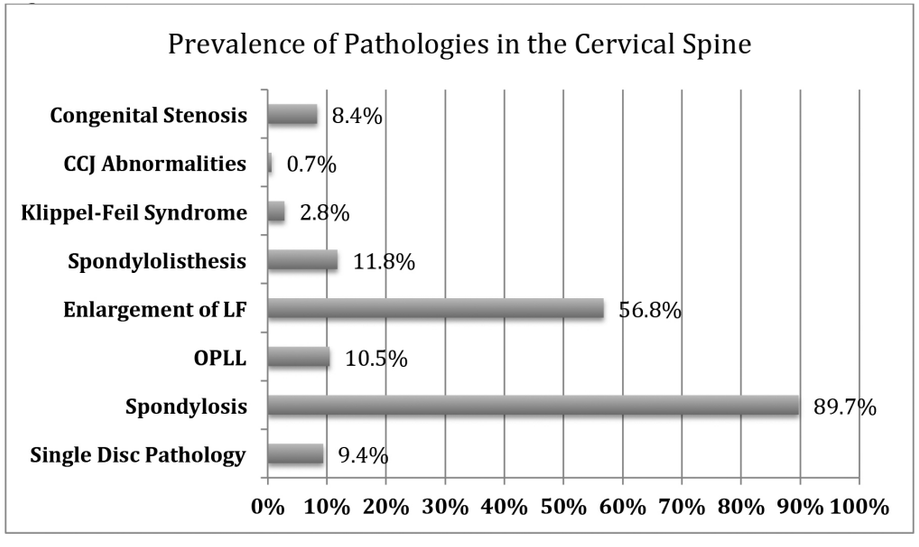
Conclusion: DCM presents as a constellation of pathologies that most commonly includes multilevel disc and bone pathologies, as well as enlargement of the LF. These findings support that pathological features, including OPLL, are highly interrelated with one another and rarely present in isolation. There appears to be a number of differences in the frequency and constellation of pathologies between genders. Overall, females presented with milder degenerative changes and correspondingly a lower frequency of T2WI hyperintensity of the spinal cord on MRI. There are also variances in the spectrum and prevalence of pathologies between geographical regions and these may be due to a multitude of causes that likely span beyond ethnic factors.

Figure 2.



See Disclosure Index pages 39–89.

Presentation #72

High-Resolution Magnetization Transfer (MT) MRI in Patients with Cervical Spondylotic Myelopathy

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Introduction: Cervical spondylotic myelopathy (CSM) is a progressive degenerative disease of the spine that has significant clinical morbidity with significant variation in symptoms. Advanced imaging with magnetic resonance imaging (MRI) has largely been accepted as a tool to evaluate CSM. However, there are limitations on quality and predictability of clinical deterioration, as such MRI now only serves to confirm the diagnosis. Magnetization transfer (MT) is a technique based on the application of off-resonance radio-frequency pulses and observing their effects on MR images. MT contrast has been established as a marker of myelin integrity through its ability to measure the exchange of freely moving protons to large macromolecules. We sought to compare the magnetization ratio (MTR) in healthy subjects to CSM patients.

Materials and Methods: Seven healthy controls and ten patients with clinical and MRI imaging manifestations of CSM were identified by three board-certified spine surgeons. The severity of CSM was assessed with the Nurick score. For imaging, transverse slices across the intervertebral discs of the cervical spine were acquired using a gradient echo sequence with and without an MT saturation pulse on a 3 Tesla Siemens Prisma scanner (TR = 300 ms, TE = 17 ms, flip angle = 30°, in-plane resolution = 0.47x0.47 mm2). Image processing was performed using the Spinal Cord Toolbox. The MT1 and MT0 images were coregistered, and MTR images were calculated. A T2 anatomical image of the cervical spine, which was in alignment with MT images, was normalized to a standard spinal cord template (Figure 1A), and the output warping fields were used to transform the MT images to standard space and transform a spinal cord mask from standard to native space. Using the transformed mask, the mean MTR was calculated at each intervertebral disc level (Figure 1B).

Results: The mean MTR across all of the intervertebral disc levels was 34.8 ± 3.5 (mean ± standard deviation) for the controls and 30.4 ± 6.5 for the CSM patients. The CSM patients tended to have a lower mean MTR than the controls, but the difference was not significant (independent samples t-test, $p = 0.110$)(Figure 2A). The mean MTR across all of the intervertebral disc levels was not significantly correlated to the Nurick score (Spearman's $\rho = -0.489$, $p = 0.151$)(Figure 2B). However, when focusing only at the intervertebral disc level with the lowest MTR for each subject, the mean MTR at this level was negatively correlated to the Nurick score (Spearman's $\rho = -0.725$, $p = 0.018$) (Figure 2C).

Conclusion: CSM patients tended to have decreased MTR indicating myelin degradation compared to our healthy subjects, and MTR was negatively correlated with the severity of CSM. MT MRI may have the potential to better detect structural changes in white matter than conventional T1 and T2 imaging techniques.

Presentation #72

Figure 1. A) Registration of MT to template. B) Example transverse MT, no MT, and computed MT ratio images.

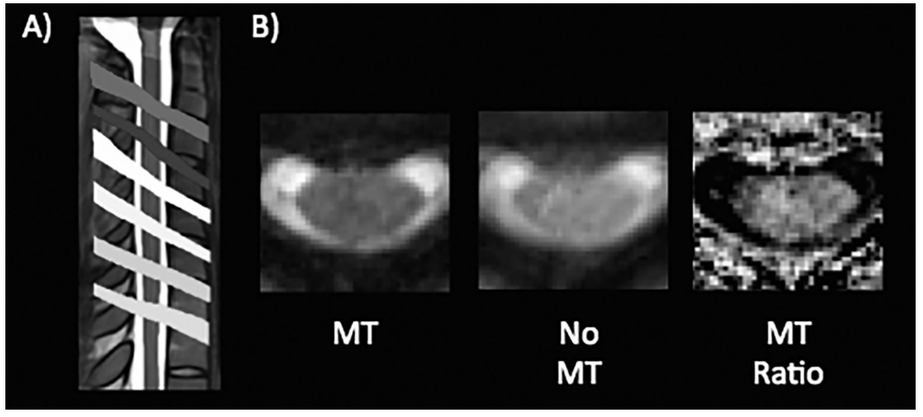
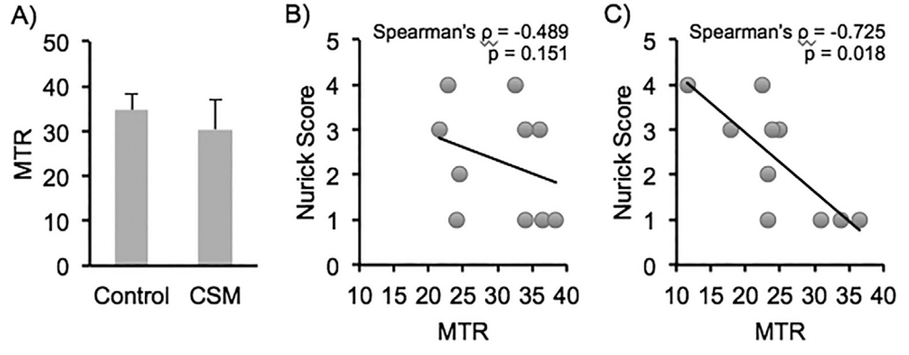


Figure 2. A) Mean MTR by cohort. B) Mean MTR vs. Nurick score. C) Lowest MTR vs. Nurick Score.



See Disclosure Index pages 39–89.

Presentation #73

The K-line Tilt, a Novel Radiographic Parameter of Cervical Sagittal Balance, is a Predictor of Postoperative Kyphotic Deformity after Laminoplasty for Cervical Myelopathy Caused by Ossification of the Posterior Longitudinal Ligament

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Introduction: Cervical laminoplasty (LAMP) is a standard surgical procedure for patients with cervical myelopathy caused by ossification of the posterior longitudinal ligament (C-OPLL). However, it is well known that LAMP is not suitable for patients with massive OPLL lesions or cervical kyphotic alignments. Moreover, one of the important complications following LAMP is postoperative kyphotic deformity, which prevents posterior spinal cord shift and leads to postoperative residual anterior compression of the spinal cord. While the K-line, which can evaluate OPLL size and cervical alignment in one parameter, is a good clinical tool for making decisions about surgical procedures, it cannot predict the postoperative kyphotic deformity following LAMP. Recently, it was reported that preoperative cervical sagittal imbalance is a predictive factor for postoperative kyphotic deformity following LAMP. We proposed the 'K-line tilt', a novel radiographic parameter of cervical sagittal balance, and hypothesized that it may influence the occurrence of postoperative kyphotic deformity following LAMP.

Materials and Methods: The study included a total of 38 consecutive patients (27 male, 11 female; mean age 65.4 years) who underwent LAMP for C-OPLL at our hospital from 2008 and completed at least 1 year of follow-up. We performed LAMP only for patients with slight OPLL lesions and without cervical kyphotic alignment. The average follow-up period was 3.1 years. We defined the K-line tilt as an angle between the K-line, which connects the midpoints of the spinal canal at C2 and C7, and the vertical line (Figure 1). Cervical lateral X-ray images taken in the neutral standing position were evaluated preoperatively and at the final follow-up visit. Radiographic measurements included the following: (1) K-line (2) K-line tilt, (3) CGH-C7 SVA, (4) CL (C2-7 lordotic angle) and (5) C7 slope. Clinical results were evaluated using the Japanese Orthopedic Association scoring system for cervical myelopathy (C-JOA score).

Results: The K-line tilt was strongly correlated with the CGH-C7 SVA preoperatively ($R = 0.842$) and postoperatively ($R = 0.845$). Preoperatively, all 38 patients had non-kyphotic cervical alignment and K-line (+); however, kyphotic deformity ($CL < -5°$) was observed in 5 patients and K-line (-) in 6 patients at the final follow-up. We compared preoperative factors between the kyphotic deformity group (5 cases) and the non-kyphotic deformity group (33 cases). Preoperative K-line tilt was significantly different ($P < 0.01$), but age, the CL and the C7 slope were similar between the two groups. The recovery rates of the C-JOA scores at the final follow-up in the kyphotic deformity group were worse than those in the non-kyphotic deformity group (14.1% vs. 46.6%: $P < 0.05$). K-line tilt was determined to be a preoperative risk factor using multivariate analysis ($P = 0.014$, $OR = 1.366$). The cutoff value by ROC analysis was a K-line tilt of 20°, which was associated with 80.0% sensitivity and 93.9% specificity, for predicting kyphotic deformity.

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Conclusion: K-line tilt is a predictive factor for postoperative kyphotic deformity after LAMP for C-OPLL patients, and LAMP is not suitable for patients with a K-line tilt ≥ 20°, even in cases with normal preoperative alignment and slight OPLL lesions.

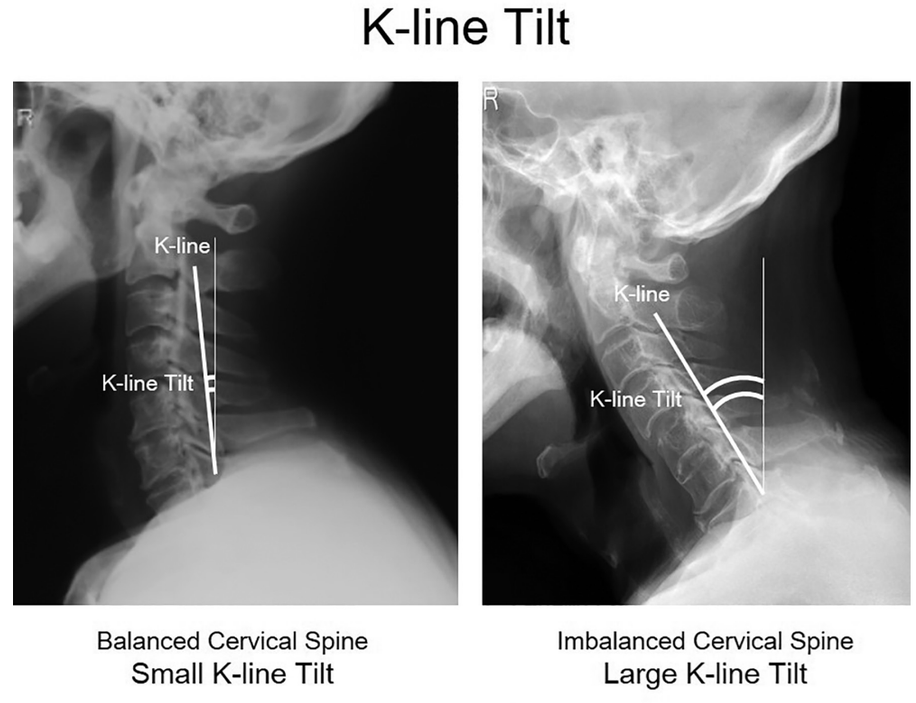

Figure 1

See Disclosure Index pages 39–89.

Presentation #74

The Difference in Clinical Outcomes between ACDF and Posterior Foraminotomy in Professional Athletes

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Introduction: Excellent clinical outcomes after operative management of cervical disc herniation (CDH) have been reported, however, there is has been no comparative study to guide a surgeon's choice of particular operative procedure in the professional athlete. Anterior cervical discectomy and fusion (ACDF), posterior foraminotomy (PF) have all been reported to have excellent clinical outcomes in the general population but the intense physical regimen of the professional athlete necessitates different outcome measures specific to his sport.

Materials and Methods: Professional athletes of the four major professional sports leagues – National Football League (NFL), Major League Baseball (MLB), National Hockey League (NHL) and National Basketball Association (NBA) – diagnosed with CDH and managed operatively were identified through team injury reports and archives on public record through a previously established protocol. Athletes were grouped into cohorts based on the type of operation (ACDF and PF). Outcome measures including games played, games started, seasons played and sport specific statistics were compared in each cohort before and after surgery. As used in previously established protocols, athlete performance score based on sport specific statistics was calculated and standardized for comparison across the sports.

Results: A total of 101 professional athletes met the inclusion criteria; 86 underwent ACDF, 13 underwent PF and 2 underwent TDA. The PF cohort had a significantly greater rate of return to play (92.3% vs. 70.9%, p = .03) and the shortest time to return after surgery (238 vs. 367 days, p = .0345) [Table 1]. However, the reoperation rate at the index level was significantly higher for PF patient compared to ACDF (46.2% versus 1.2%, respectively) (p = .0001). While there was an overall decrease in performance score after surgery, there was not significant difference between the surgical cohorts (p = .336). There was also no difference in long-term survival (p = 0.11) [Figure 1].

Conclusion: Anterior cervical discectomy and fusion, posterior foraminotomy both represent viable options for the operative management of CDH in the professional athlete. The role of total disc arthroplasty in elite athletes remains to be determined and may depend on the particular sport. Posterior foraminotomy provides athletes with significantly higher rate of return to play and quicker time to return compared to ACDF. However, athletes who undergo posterior foraminotomy must accept the significantly higher risk for reoperation at the index level.

Saturday, December 3, 2016, 10:12–10:18 am CSRS–2016

Presentation #74

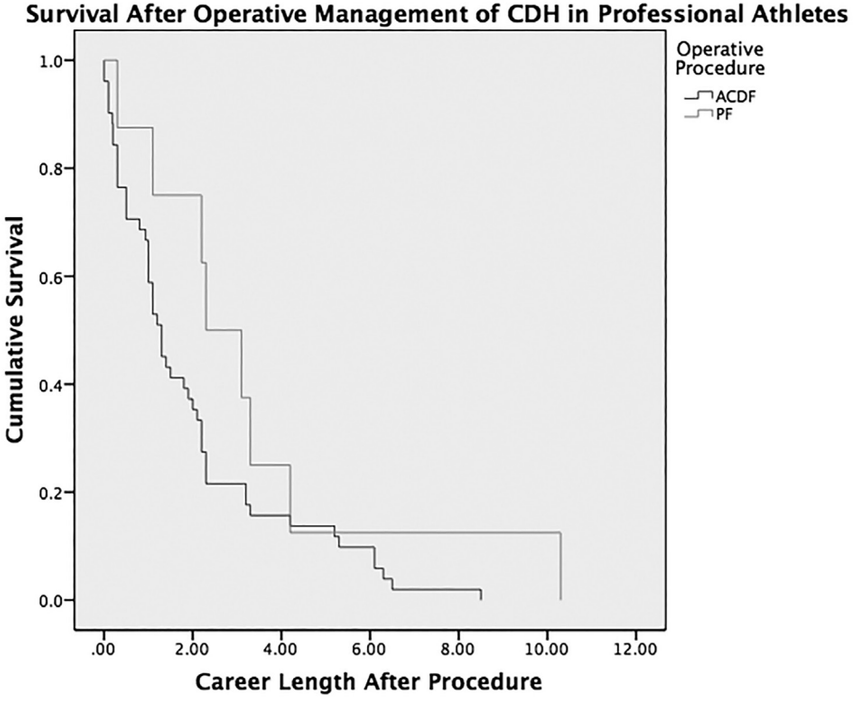
Table 1. Comparison of Operative Management Strategies for CDH in Elite Athletes

Characteristic	*ACDF*	*PF*	*TDA*	*P-Value*
Reoperative Rate	1.2%	46.2%	0.0%	**0.0001***
Return to Play	78.7%	92.3%	100.0%	**0.0313***
Return After Surgery (Days)	366.6	238.3	253.5	**0.0345***
Change In Performance	22.2%	27.9%	23.7%	0.336

TDA = Total Disc Arthroplasty

ACDF = Anterior cervical discectomy and fusion, PF = Posterior foraminotomy
TDA = Total Disc Arthroplasty

Figure 2. Kaplan-Meier survivorship curve demonstrating similar rates of survival after operative management of cervical disc herniations in professional athletes (Wilcoxon p = .11).



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Presentation #75

The Accuracy and Safety of Subaxial Cervical Pedicle Screw Insertion using Vertebral Lateral Notch-Referred Technique

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Instruction: Biomechanical studies revealed that pedicle screw instrumentation has superior stabilizing effect than other internal fixations in the reconstruction of subaxial cervical spine, particularly, in the surgery of cervical tumor resection, deformity correction and severe fracture and dislocation. However, high neurovascular risk precludes surgeons to conduct the pedicle screw manipulation in cervical spine. We here advocate a novel, easy-mastering and practical technique (as called notch-referred technique) for subaxial cervical PS insertion. In this study, the accuracy and safety of vertebral lateral notch-referred technique for subaxial cervical pedicle screw (PS) were evaluated clinically.

Materials and Methods: Eighty-six consecutive patients with cervical disorders underwent cervical PS instrumentation in two spine teams in a single spine center. Preoperative x-ray, CT and MRI of cervical spine were taken for surgery plan. The pedicle screw position was confirmed by postoperative CT scans. The penetration rate was analyzed and classified from ideal to unacceptable to assess the accuracy of this technique: grade 0 = screw centered in pedicle; grade I = perforation of pedicle wall less than one-fourth of the screw diameter; grade II = perforation more than one-fourth of the screw diameter but less than one-second; grade III = perforation more than one-second outside of the screw diameter. Neurovascular complication related with PS insertion was recorded to assess the safety of this technique. The accuracy of PS placement between two surgeons was analyzed to confirm the manipulative consistency.

Results: A total of 504 pedicle screws were inserted in subaxial cervical spine. Postoperative CT scan indicated the accuracy of PS insertion by using notch-referred technique was 90.9% (458/504) (grade0 + grade I). There were no vertebral artery injury or spinal cord injury related with cervical PS misplacement in this cohort except one slight nerve root compression. The patient relieved from the radiculopathy in the course of follow-up without screw removal. No revisional surgery was conducted due to the misplacements of pedicle screws. The inter-surgeon consistency of inserting cervical PS was excellent(Kappa value = 0.86).

Conclusion: The vertebral lateral notch is the reliable and consistent anatomic landmark. The accuracy and safety of subaxial cervical pedicle screw insertion by using notch-referred technique are high and satisfactory. Notch-referred subaxial cervical PS insertion is an easy-mastering, practical technique.

Presentation #76

Degenerative Cervical Spondylolisthesis: Does Adjacent Level Surgical Stabilization Result in Progressive Listhesis?

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Introduction: Degenerative cervical spondylolisthesis (DCS) occurs at a rate of 5.2%–11% in asymptomatic patients, increasing to up to 20% in symptomatic patients. Patients with cervical spondylotic myelopathy (CSM) often present with multi-level disease and may have a spondylolisthetic level within or adjacent to the levels of pathology. It remains unclear what happens to an unfused DCS segment when it is not included in a surgical construct. The primary aim of this investigation was to test the hypothesis that unfused DCS segments do not develop worsening instability requiring surgical intervention.

Materials and Methods: Twenty-four consecutive patients who presented with CSM, had radiographs revealing DCS at one or more levels, and underwent surgical intervention were retrospectively reviewed. All patients did not have clinical symptoms or radiographic pathology present at their DCS level and had surgery performed at adjacent levels. Demographic variables including age, sex, smoking, body mass index, number of levels fused, and location of levels fused, were documented. Radiographic measurements were obtained on pre-operative radiographs and final follow-up radiographs to assess the degree of instability, cervical lordosis, sagittal vertebral axis, and T1 slope at the affected level. Clinical and radiographic evaluation at final follow up was reviewed for signs of progression of disease and reoperation rates. Subgroup analysis was performed to assess for variables that might predict progression of unfused segments and reoperation rates.

Results: The cohort consisted of 13 males and 11 females. The average age at presentation was 61.3 years (range 27–83.6 years). Mean follow-up was 21.4 months. DCS was present at C2-3 in three cases (12.5%), C3-4 nine cases (37.5%), C4-5 seven cases (29.2%), C5-6 two cases (8.3%), C6-7 no cases (0%), C7-T1 three cases (12.5%). Surgical procedures performed were as follows: anterior cervical discectomy and fusion (18; 75.0%), posterior cervical fusion (5; 20.8%), posterior cervical laminoplasty (1; 4.2%). The average pre-operative slip was 2.7mm ± 0.6mm. At final follow-up, six (25%) demonstrated progression (> 0.5mm) of their slip, 18 (75%) remained stable (± 0.5mm) or improved. The average slip at final follow-up was 2.9mm ± 1mm, which was not statistically significant (p = 0.561). Three patients (12.5%) with DCS developed symptomatic progressive instability with myelopathy or radiculopathy requiring further surgery. Multivariate analysis (Table 1) revealed age greater than 65 and female sex were associated with progression of listhesis. Radiographic parameters including level of listhesis, number of adjacent levels fused, cSVA, cervical lordosis, and T1 slope were not associated with progression. No demographic or radiographic variables were associated with reoperation.

See Disclosure Index pages 39–89.

Presentation #76 (cont.)

Conclusions: The pathomechanics of DCS remain poorly understood and the necessity of including a spondylolisthetic level in a surgical construct remains in question. Despite the presence of increased stress at the DCS level due to adjacent surgical intervention, the majority of patients had the same or smaller slips at final follow-up and the majority of patients did not require further surgical intervention. Older age and female sex were associated with progression but did not increase the risk of reoperation. This study offers valuable information regarding the durability of a listhetic level adjacent to a surgical construct; however, further investigation with long-term follow-up is warranted.

Table 1. Association of Patient Characteristics with Increased Spondylolisthesis at Final Follow-up.

Risk factor	Beta*	p
Age		
18–44 years	ref	ref
45–54 years	+0.1	0.857
55–64 years	+0.3	0.506
65+ years	**+1.3**	**0.030**
Female sex	**-0.9**	**0.014**
Number of surgical levels		
1	ref	ref
2	+0.1	0.793
3	+0.6	0.294
4	-0.7	0.545
Procedure type		
ACDF	ref	ref
Post. Lami/fusion	+0.6	0.544
Post. Laminoplasty	-1.0	0.318
Level		
C2/3	ref	ref
C3/4	-0.1	0.936
C4/5	+0.3	0.595
C5/6	+0.2	0.781
C7/T1	+2.7	0.066

*Unstandardized beta values reported in this table represent the change in the difference between final spondylolisthesis and preop spondylolisthesis in millimeters. For example, a beta coefficient of +1.3 for age > 65 indicates that for patients with age > 65, they have an additional 1.3 mm of spondylolisthesis progression compared to patients with age < 45.

Presentation #77

Should Long Segment Cervical Fusions Be Routinely Carried into the Thoracic Spine? Multi-Center Analysis

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Introduction: While recommendations for caudal "end level" in posterior cervical reconstruction remain highly variable, the benefits of routine extension of posterior cervical fusions into the thoracic spine remain unclear. We compared clinical and radiographic outcomes in patients in whom posterior fusions ended in the cervical spine versus those in whom the fusion was extended into the thoracic spine. Our hypothesis was that extension of posterior cervical fusions into the upper thoracic spine improves clinical outcomes while decreasing kyphosis.

Methods: We assembled a multicenter (4 sites) radiographic and clinical database of patients that had undergone 3 or more level posterior cervical fusions for degenerative disease from January 2008 to May 2013 with at least 2 years of post-operative (post-op) follow-ups. Patients were divided into two groups: group I (fusion ending in the cervical spine) and group II (fusion extending into the thoracic spine). All radiographic measurements were performed by an independent experienced clinical researcher. Two-sample t-test with unequal variances was used to assess for differences between the two groups ($\alpha = 0.05$).

Results: Group I and Group II had 104 and 73 patients, respectively. The demographics of the two groups were similar. Minimum and maximum number of spinal levels treated for group I and group II were 3 & 4 and 3 & 9, respectively. Mean estimated blood loss (EBL) for group II was significantly higher than group I ($p < 0.05$). Mean operative time (OR) and length of hospital stay (LOS) were comparatively higher for group II than group I but were not statistically significant ($p > 0.05$). Mean cervical lordosis at 2 years post-op improved in both groups. There was no significant statistical difference in change in mean cervical lordosis (2 wk vs. 2 year post-op) between the two groups ($p > 0.05$). Similary, there were no significant statistical differences in change in mean C2-C7 sagittal plumbline and T1 slope (2 wk vs. 2 year post-op) between the two groups($p > 0.05$). Rate of pseudarthrosis was higher in group I (21.2%) than group II (10.96%). This differnce was statistically significant ($p < 0.05$). There were significant improvements in mean clinical outcomes (i.e. visual analog scale and oswestry disability index) at 2 years follow ups in both groups but there were no statistically significant differences between the two groups ($p > 0.05$).

Conclusion: Our analyses indicate that both groups had similar clinical and radiographic outcomes. Lower pseudarthrosis rate but higher EBL, OR and LOS in group II suggest that extension of posterior cervical fusions into the thoracic spine still remains debatable. Prospective studies with additional patients and greater statistical power are needed to elucidate optimal means of posterior stabilization in patients with degenerative cervical disease.

See Disclosure Index pages 39–89.

Presentation #78

Should Asymptomatic Levels with MRI Abnormalities be Included in an ACDF Construct? A Long-Term MRI Analysis

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Introduction: ACDFs are generally limited to the levels that are causing neurologic symptoms. But there are situations where asymptomatic levels may be considered for inclusion in an anterior construct, such as if there is severe radiographic degeneration adjacent to symptomatic levels. We evaluated whether the presence of asymptomatic preoperative MRI abnormalities was predictive of reoperation for symptomatic adjacent segment degeneration (ASD) after ACDF.

Methods: We reviewed patients at our institution who underwent an ACDF between 2000 and 2010 and had MRIs both preoperatively and postoperatively at least 3 years after the index surgery to evaluate new neurologic symptoms. We intended to exclude patients who had inadequate treatment, residual disease, or early recurrence after the index ACDF. MRIs were scored for ASD severity using published criteria. Patients were stratified according to the ASD severity score. Logistic and Cox regression analyses were used to evaluate the association between preoperative MRI abnormalities and reoperation for ASD after adjusting for covariates.

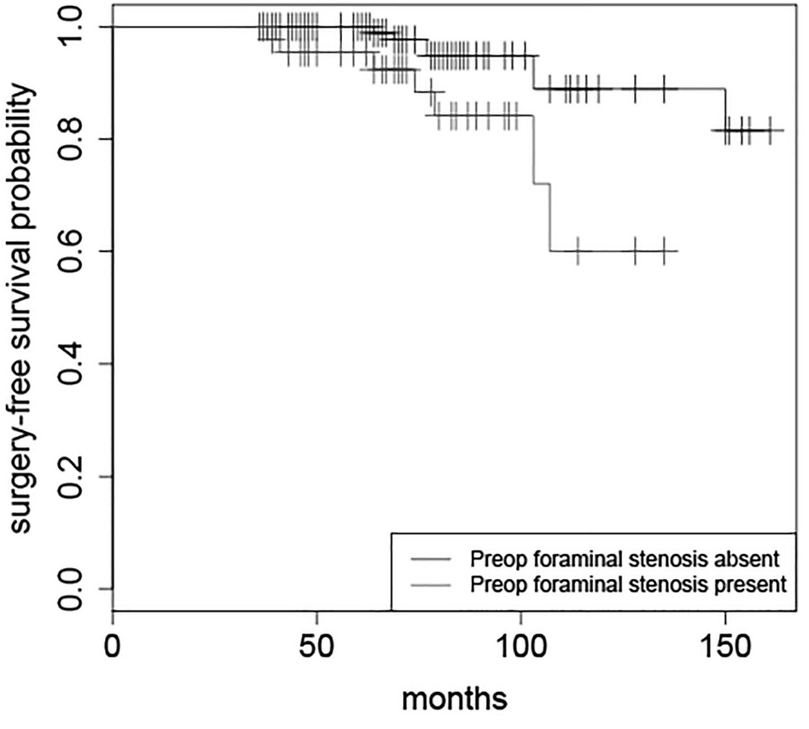
Results: Of 2,246 patients who underwent an ACDF during the study period, 96 (4%) had MRI evaluation at least 3 years postoperatively for new symptoms. Mean follow-up was 78 months. Of the 195 adjacent segments evaluated, 14 (7%) underwent subsequent fusion procedures. The 10-year surgery-free survival estimate was 82.7% (73.4–93.2%). After adjusting for covariates, preoperative MRI abnormalities were predictive of reoperation only for the group with the highest severity score [HR 4.5 (1.0–19.8)] and those with foraminal stenosis [HR 4.2 (1.4–12.7)] (Figure). However, the prevalence of reoperation for ASD in these groups was only 16% and 15%, respectively.

Conclusions: The prevalence of reoperation for ASD is low for patients who present with new symptoms several years after the index ACDF. Our findings do not support including asymptomatic levels in an anterior fusion construct, even if severe MRI abnormalities are present.

Saturday, December 3, 2016, 10:40–10:46 am CSRS–2016

Presentation #78

Figure1. Patients with preoperative foraminal stenosis had a lower surgery-free survival than patients without preoperative foraminal stenosis (log-rank $p < 0.01$). After adjusting for age, the presence of preoperative foraminal stenosis remained a risk factor for adjacent segment surgery on Cox proportional hazard analysis [HR 4.2 (95% CI 1.4–12.7), $p = 0.01$].



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Presentation #79

Thoracolumbar Reciprocal Changes following Cervical Reconstruction Surgery for Cervical Kyphosis

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Introduction: There is a complex interaction among each spinal segment. Reciprocal change in the cervical spine has been noted following thoracolumbar deformity surgery. However, little is known about the effect of cervical deformity surgery on thoracolumbar alignment. This study identifies changes in thoracolumbar alignment following cervical reconstruction surgery for cervical kyphotic deformity.

Materials and Methods: We conducted a retrospective multi-center study of adult patients undergoing cervical reconstruction surgery. 78 patients were identified after excluding those with coronal deformity > 30°or prior thoracolumbar fusion. Sagittal radiographic parameters were measured before and after surgery. Preoperative cervical sagittal alignment was categorized as imbalanced (CSI, C2-C7SVA ≥ 40 mm, N = 56) or balanced (CSB, C2-C7SVA < 40 mm, N = 16). Preoperative thoracolumbar sagittal balance was categorized as C7P (C7SVA ≥ 0, N = 41) or C7N (C7SVA < 0, N = 31). Using paired t-test, the effect of cervical reconstruction on thoracolumbar alignment was analyzed for the entire cohort and each subgroup. A p value < 0.05 was considered as statistically significant.

Saturday, December 3, 2016, 11:01 – 11:03 am CSRS – 2016

Presentation #79

Results: In the entire cohort, cervical reconstruction surgery caused significant changes in TK, LL, and T1 slope from 33.5° to 37.0° (P = 0.002), -51.0° to -48.5° (P = 0.0135), and 20.8° to 30.5° (P < 0.0001), respectively. The C7 plumb line shifted significantly anteriorly (mean C7SVA from -6.7mm to 17.3mm, P = 0.0003). C2-C7SVA and cervical kyphosis improved from 61.6mm to 36.5mm (P < 0.0001) and from 27.2° to -1.2° (P < 0.0001), respectively. The CSI group had significant reciprocal change in several thoracolumbar parameters such as TK; from 36.2 to39.2 (P = 0.00125), LL; from-52.1 to -48.4 (P = 0.0063), LL(4-S); from -30.8 to -27.9 (P = 0.0148), C7SVA; from -25.3 to 9.7 (P = 0.0002), and T1slope; from 23.0 to 31.0 (P = 0.0013). However, only the T1 slope changed significantly from 17.2 to 26.4 P = 0.0142 in the CSB group. The C7N group experienced significant changes in TK; from 29.9 to 33.9 (P = 0.0005), TK(8-12); from 10.4 to 12.4 (P = 0.0421), LL; from -56.6 to -51.2 (P = 0.0028), T1 slope; from 15.5 to 27.3 (P < 0.0001), and PI-LL from-1.3 to 5.7 (P = 0.0003). On the other hand, there were no significant thoracolumbar and PI-LL changes in the C7P-group. In terms of cervical sagittal parameters, such as, C2-C7SVA was decreased less than 40mm in both C7P-group and C7N-group, indicating cervical reconstruction surgery improved cervical sagittal imbalance. COG-SVA, which is the indicator of head position, was decreased from129.6mm to 78.9mm (P = 0.0052) in C7P-group, on the contrary, COG-SVA was increased from 32.1mm to 40.0mm (P = 0.0361) in C7N-group. Also, The C7N-group experienced significant changes in C7SVA; from -51.2 to -3.47 (P < 0.0001), however, there was no significant in C7P-group; from 45.2 to 44.0.

Conclusion: This is the first report of thoraco-lumbar reciprocal change following cervical reconstruction surgery. The reciprocal change was dependent on preoperative cervical and thoracolumbar sagittal balance. Cervical reconstruction surgery can restore both cervical sagittal alignment and global spinal harmony.

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Presentation #80

Preoperative Global Sagittal Imbalance is a Predictor of Postoperative Neck Pain following Laminoplasty in Patients with Cervical Spondylotic Myelopathy: Based on the Prospective Analysis of 165 Patients

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Introduction: Cervical laminoplasty is an established procedure in the treatment of cervical spondylotic myelopathy (CSM). Although favorite outcome have been reported, postoperative neck pain and persistent extremity pain are known to be a problem. While some reports indicated the influence of regional cervical alignment on surgical outcomes, few reports investigated the correlation between postoperative neck/extremity pain and global sagittal balance. The purpose of this study was to investigate an influence of global sagittal balance to clinical outcomes after cervical laminoplasty.

Materials and Methods: A hundred and sixty-five patients with cervical spondylotic myelopathy were prospectively enrolled. Whole-spine radiographs were obtained preoperatively in the standing position. Patients were stratified into three groups [group 0; sagittal vertical modifier (SVA) < 4cm, group + : SVA 4 to 9.5cm, group ++ : SVA > 9.5cm) by C7-SVA according to Scoliosis Research Society (SRS)-Schwab Adult Spinal Deformity (ASD) Modifier. We also evaluated clinical outcomes on the Japanese Orthopaedic Society (JOA) score, neck pain and extremity pain (upper/lower) on the visual analogue scale (VAS) before and one year after laminoplasty.

Results: After excluding 65 cases for a paucity of adequate radiographic examination, or an insufficiency of follow-up duration (>12months), a hundred patients (60 males and 40 females with an average age of 63.1 years) were evaluated. The mean preoperative C7-SVA was 5.2 ± 6.7 cm (Group 0, N = 45; group +, N = 27; group ++, N = 28). The mean preoperative VAS for lower extremity pain were 2.2 ± 2.7 in group 0, 4.4 ± 3.8 in group +, and 4.0 ± 3.8 in group ++. The mean pre- and post- operative JOA score were 11.7 ± 2.4 and 14.7 ± 2.3 ($p < 0.001$) in group 0, 10.9 ± 3.0 and 14.1 ± 2.0 ($p < 0.001$) in group +, and 10.2 ± 2.5 and 13.2 ± 2.9 ($p < 0.001$) in group ++. With respect to neck pain, the mean pre- and post- operative VAS were 3.7 ± 2.9 and 3.7 ± 2.5 in group 0, 3.4 ± 3.4 and 4.1 ± 2.7 in group +, and 3.3 ± 3.3 and 5.0 ± 2.7 ($p < 0.01$) in group ++.

Conclusions: Patients with mild or severe global sagittal imbalance (group +, ++) revealed higher VAS in lower extremity preoperatively than patients with non pathologic sagittal balance (group 0). The mean JOA score in each groups improved significantly at one year following surgery. In this study, a postoperative deterioration of neck pain was seen in group ++. While cervical laminoplasty is still effective for CSM patients with global sagittal imbalance, surgeons should keep in mind the possibility of a postoperative deterioration of physical complaints in treatment patients with severe global sagittal imbalance.

Presentation #81

Adult Spinal Deformity Patients with Proximal Junctional Kyphosis Adjust with Cervical Malalignment at Similar Rates but Distinct Characteristics Relative to those Unaffected

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Introduction: Post-operative proximal junctional kyphosis (PJK) has been analyzed for associations with increased regional deformity, but cervical alignment is rarely considered in these patients. Specifically, the impact of PJK and the onset of cervical deformity is understudied, notably in the context of increasing PJK angle and global sagittal deformity worsening. This study aims to analyze cervical malalignment onset as a result of PJK following adult spinal deformity (ASD) corrective surgery.

Materials and Methods: Retrospective review of a prospective, multi-center ASD patient registry. Inclusion criteria: primary ASD patients (≥5 levels fused, UIV at T7 or above, 1 year minimum follow-up) without baseline cervical deformity (CD). CD was defined as meeting ≥2 of the following criteria on baseline radiographs: TS-CL < 20°, cSVA < 4cm, C2-C7 CL > 10°. PJK presence (< 10° change in UIV and UIV + 2 kyphosis) and angle were identified at 1 year post-operative. SRS-Schwab classification modifier (PI-LL, SVA, PT) grades were also assigned at baseline and 1year f/u. ANOVA and t-tests compared radiographic parameters across and within PJK groups.

Results: Of 193 patients showing baseline radiographic cervical alignment, PJK developed in 69 (35.8%) patients, with 34 (17.6%) instances occurring at/above T7. PJK patients had significantly greater CL and TS-CL 6w-1year change ($p < 0.018$), and also displayed higher 1 year T1 Slope, CL, cSVA, and C2-T3 angle ($p < 0.05$). At 1 year post-op, the concomitant CD rate was 23.5%. PJK angle (range: 10°–48°) was stratified: 10°–20° (55.9%), 20°–30° (23.5%), >30° (20.6%). The highest angle group corresponded to significantly increased T1 Slope, CL, cSVA, and C2-T3 angle ($p < 0.05$ all) in PJK patients. Global malalignment (SVA) also increased at 1 year with increasing PJK angle ($p = 0.040$). The prevalence of higher PI-LL and SVA modifier grades at baseline was significantly higher in PJK patients ($p < 0.001$) though not at 1 year follow-up. PJK patients with high (+/++) 1 year SVA modifiers displayed higher T1 Slope and TS-CL at 1 year; PJK patients with higher (+/++) 1 year PI-LL modifiers also showed higher T1-CL and C0 Slope ($p < 0.05$, all). PJK patients with high PT modifier grades did not significantly differ in cervical alignment.

Conclusions: ASD patients adjust for PJK with cervical malalignment onset with increased C2-T3 angle and CL onset at 1year. Global sagittal deformity and increasing PJK angle were both related to increased cervical deformity. Considerations for the cervical spine in PJK patients should be taken into account.

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Presentation #82

The Difference of Spinal Sagittal Alignment and Health-Related QoL Between Males and Females with Cervical Deformity

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Introduction: There are some reports that adult spinal deformity, especially in lumbosacral lesion, is frequently observed in females. However, there are also some reports recently that the factors which HRQOL deteriorate are not only lumbar spine and pelvic malalignment but also cervical deformity (CD). There are some reports that cervical deformity is observed more in males. However, there are few studies that investigate the difference of mechanism of spinal deformity between males and females. The purpose of this study were to clarify separately in gender the spinal sagittal alignment and HRQOL in health screening volunteers aged over 50 with CD.

Methods: This cohort study included 656 volunteers aged 50 to 89 years (263 males and 393 females, mean age 73). The definition of CD was C2-7 sagittal vertical axis (SVA) over 40°. The volunteers were divided into 4 groups (CDM: males with CD, NCDM; males without CD, CDF; females with CD, NCDF: females without CD). Whole spine X-rays were taken in standing position for all volunteers. Pelvic tilt (PT), Lumbar lordosis (LL), pelvic incidence minus LL (PI-LL), Thoracic kyphosis (TK), T1 slope (T1S), cervical lordosis (CL), T1S-CL, C2-7 sagittal vertical axis (SVA), C7 SVA were measured using software (Surgimap SPINE). HRQOL was evaluated by EQ-5D.

Results: The numbers of each group were 82 in Group CDM, 181 in Group NCDM, 36 in CDF, 357 in Group NCDF. The average parameters in each groups (CDM, NCDM, CDF, and NCDF) was PT (15, 14, 26, and 21 degrees), PI-LL (7, 5, 16, and 10 degrees), C2-7 SVA (49, 24, 46, and 20mm), C7 SVA (61, 40, 75, and 47mm), EQ-5D (0.82, 0.88, 0.78, and 0.81), respectively. In females, PT was significantly greater in Group CDF compared to Group NCDF ($P < 0.05$). However, there were no significant difference in pelvic parameters between group CDM and NCDM in males. In comparison between CDM and CDF, there were no significant difference in cervical parameters, but only PT in CDF was significantly higher than that in CDM ($P < 0.01$). Moreover, CDM had significantly deteriorated EQ-5D compared to NCDM ($P < 0.05$).

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Conclusions: Different mechanism of sagittal spinal deformity was observed between males and females in the present study. Group CDF had deteriorated PT and PI-LL compared to group NCDF. However those in group CDM were not significantly different compared to those of group NCDM. Group CDF had already deterioration of spinopelvic alignment, although it was kept well in group CDM. This means that the deterioration of spinal sagittal alignment in male originate from cervical spine. Moreover, EQ-5D in group CDM was significantly deteriorated than that in group NCDM, while deterioration of lumbopelvic parameters had less influenced in males ($P < 0.05$). This result suggested that CD was associated with HRQOL.

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Presentation #83

Analysis of Successful vs. Failed Radiographic Outcomes following Cervical Deformity Surgery

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Introduction: Recent studies have demonstrated correlation between cervical sagittal alignment and patient reported outcomes. Few studies have explored cervical deformity correction prospectively and the factors that result in successful vs. failed cervical alignment corrections remain unclear. The purpose of this study was to evaluate pre-operative alignment and surgical factors associated with sub-optimal early post-operative radiographic outcomes following surgery for cervical deformity.

Methods: Adult cervical deformity (CD) patients were consecutively enrolled in a multi-center database. Inclusion criteria were cervical kyphosis > 10°, cSVA > 4cm, or CBVA > 25°. Patients were categorized into failed outcomes group if cSVA > 4cm or T1Slope-Cervical Lordosis (TS-CL) > 20° at 6 months post operatively. Demographic, surgical and pre-operative radiographic measures were compared between failed and successful deformity corrections. Multivariate analysis using binary logistic regression was performed to evaluate for associations between radiographic parameters and failed outcomes with respect to cSVA and TS-CL separately.

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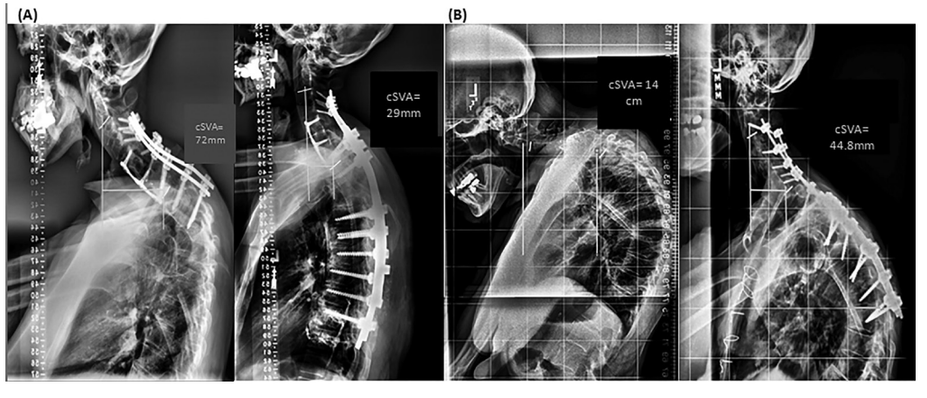
Results: 71 CD patients (mean age 62 yrs, 56% female, 41% revisions, minimum 6 mos. follow up) were included. 45 had primary deformities within the cervical spine and 26 at the CT junction. Overall 33 (46.4%) had failed radiographic outcomes by cSVA and 46 (64.7%) by TS-CL. Failure to restore cSVA was associated with worse preop C2-pelvic tilt angle (CPT: 64.4 vs 47.8°, $p = .01$), presence of any "+" Schwab modifier ($p = .007$), revision surgery ($p = .05$) and failure to address the secondary, thoracolumbar driver of the deformity ($p = .02$). Patients with failed corrections of cSVA had worse postoperative C2Slope (35.0 vs 23.8°, $p = .004$), TS-CL (35.2 vs 24.9°, $p = .01$), and CPT (47.9 vs 28.2°, $p < .001$). Failure to correct TS-CL was associated with worse preoperative cervical kyphosis (10.4 vs -2.1°, $p = .03$), and CPT (52.6 vs 39.1°, $p = .04$). Patients with failed corrections of TS-CL had worse postoperative C2Slope (30.2 vs 13.3°, $p < .001$), cervical lordosis (-3.6 vs -15.1°, $p = .01$), and CPT (37.7 vs 24.0°, $p < .001$). Multivariate analysis revealed occurrence of post-operative DJK (kyphosis > 10° at LIV to LIV-2 from pre- to post-op) as the only significant parameter associated with sub-optimal outcomes with respect to cSVA (OR- 0.06, CI- 0.01-0.4, $p = .004$, Figure 1) and TS-CL (OR-0.15, CI-0.02-0.97, $p = .05$).

Conclusions: Surgery to correct CD can be challenging. Factors that were associated with failure to correct the cSVA included revision surgery, worse preop CPT, concurrent thoracolumbar deformity, and failure to correct secondary, thoracolumbar deformity drivers. Failure to correct the TS-CL mismatch was associated with worse preoperative cervical kyphosis and CPT. Occurrence of early post-operative DJK significantly affects post-operative radiographic outcomes.

Figure 1. Figure (A) shows pre- and early post-operative radiograph of a patient with cervical deformity who underwent a fusion from C2-T9 with adequate restoration of cervical alignment. Figure (B) shows pre- and early post-operative radiographs of a patient with cervical deformity who underwent fusion from C2-T7 with sub-optimal correction and development of distal junctional kyphosis.



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Presentation #84

Laminoplasty Decreases Postoperative Axial Neck Pain Scores in Myelopathic Patients: A Comparsion with Laminectomy and Fusion

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Introduction: Postoperative new or worsening axial neck pain is commonly cited as a major disadvantage of laminoplasty. However, there remains a paucity of corroborative data from large series. In this study, we examined axial pain and other clinical outcomes after laminoplasty (LP) in a large cohort of myelopathic patients and compared them to a cohort undergoing laminectomy and fusion (LF).

Materials and Methods: Following IRB approval, we reviewed the medical records, radiographs, and prospective clinical outcomes database of 85 patients undergoing LP and 52 patients undergoing LF for cervical myelopathy with minimum 1-year radiographic follow-up and average clinical follow-up of 18.5 months. Primary outcomes included Visual Analogue Scale neck pain score (VAS, average and worst), neck disability index (NDI) score, patient-reported pain location, and SF-36 Mental / Physical Component Scores. Secondary outcomes included Modified Japanese Orthopaedic Association (mJOA) scores and radiographic parameters (C2-7 Cobb and T1 Slope).

Results: Preoperatively, there were no significant differences between the groups with respect to age, mJOA, SF-36, VAS neck pain, NDI, Miyazaki spondylosis score, AP spinal cord dimension, and T1 slope. However the LP patients had greater preoperative lordosis (C2-7 Cobb: LP $12.69^{o} \pm 10.40$; LF $3.96^{o} \pm 13.39$, $p < 0.0001$). VAS-worst (Figure 1a) significantly improved for LP (-1.7 ± 0.55, $p = 0.03$) and trended to improvement for LF (-1.0 ± 0.59, $p = 0.09$). VAS-average (Figure 1b) significantly improved in both groups (LP -1.4 ± 0.51, $p = 0.008$; LF -1.04 ± 0.52, $p = 0.05$). NDI (Figure 2) significantly improved for the LP group (-6.79 ± 2.25, $p = 0.0032$) but not for LF (-4.01 ± 3.05, $p = 0.19$). mJOA scores significantly improved in both groups (LP $+2.89 \pm 0.27$, $p < 0.0001$; LF $+2.45 \pm 0.33$, $p < 0.0001$). SF-36 MCS and PCS scores did not significantly change in either group. There was a small but statistically significant loss of lordosis in the LP group (-2.92 degrees, $p = 0.0181$); no significant change was noted in the LF group (-1.25 degrees, $p = 0.53$).

Conclusion: In one of the largest case-control series of patients undergoing laminoplasty for cervical myelopathy, LP led to significant improvement in axial neck pain similar to that seen with LF. Neck pain improved rather than worsened after both operations. Similar significant improvements in mJOA occurred in both groups, but NDI improved significantly only for LP. In the appropriately selected patient, LP can be performed to treat myelopathy despite the presence of axial neck pain with an expectation that it may actually improve rather than worsen.

Presentation #85

The Pa-mJOA: A Patient-Derived, Self-Reported Outcome Instrument for Measuring Myelopathy–Comparison with the mJOA

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Introduction: Although the mJOA is widely used in the assessment of cervical myelopathy, one downside is that it is not a patient-derived outcome. If available, a patient-derived mJOA (Pa-mJOA) might more accurately access the burden of myelopathy by removing physician biases. Furthermore, a Pa-mJOA could facilitate research because the data would be immediately available instead of requiring the researcher to complete the instrument retrospectively. The JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ) is a patient-derived instrument to assess myelopathy, but it is long and has not correlated well with the mJOA. The purpose of this study is to evaluate a patient derived, self reported version of the mJOA (the Pa-mJOA) that a patient can complete along with other patient-derived outcome measures.

Materials and Methods: The Pa-mJOA was created by slightly modifying / expanding upon the verbiage of the mJOA to make it possible for a patient to understand and complete the instrument while not changing the core structure of the questionnaire (TABLE 1). 100 consecutive consenting patients (both pre and postoperative) with cervical myelopathy presenting to a spine clinic completed the survey over a 4-month period. After the patient completed the Pa-mJOA, the mJOA was scored by a physician blinded to the Pa-mJOA result. The results of the Pa-mJOA were compared to that of the mJOA, and statistical analysis performed.

Results: Mean Pa-mJOA score (14.68) was almost identical to mean mJOA score (14.66) ($p = 0.89$). The overall kappa coefficient for Pa-mJOA was 0.66, which suggests substantial agreement with the mJOA. The Cronbach's alpha was 0.62 for the Pa-mJOA and 0.65 for the mJOA, suggesting very similar internal consistency for both instruments in measuring myelopathy. There were no significant differences in Pa-mJOA and mJOA scores for those with mild and moderate myelopathy (Table 2). There was a statistically significant difference in those with severe myelopathy, but the number of severe patients in this study was small ($n = 13$), and the difference was 1.1, which falls below the MCID of 3 quoted in the literature for severe myelopathy. When asked how the survey should be administered, 67% of patients preferred (strongly to slightly) to fill out the Pa-mJOA themselves rather than having the physician complete it for them, suggesting low patient burden for completing the survey. Only 17% strongly preferred the physician to complete it.

Conclusions: The Pa-mJOA provided very similar scores to the mJOA in assessing myelopathy. The Pa-mJOA shows promise as a patient-derived outcome that can readily be completed by the patient with results similar to those obtained using the mJOA. Comprising the same 5 questions as the mJOA but reworded for ease of patient comprehension, the Pa-mJOA also demonstrated low patient burden in completing the survey. Further validation is necessary, especially to determine its responsiveness to changes in myelopathy, as well as in those with more severe myelopathy.

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Presentation #85 (cont.)

Table 1.

The Modified Japanese Orthopaedic Association Scale (mJOA)	Modified Japanese Orthopaedic Assessment for Patient Self-Administration (Pa-mJOA)
Motor Dysfunction	**Motor Dysfunction**
Motor dysfunction score of the upper extremity	**Upper Extremities (arms and hands)**
	Choose the statement that best fits: I am…
0 - Inability to move hands	0 - Unable to move my hands
1 - Inability to eat with a spoon, but able to move hands	1 - Unable to eat with a spoon but am able to move my hands
2 - Inability to button shirt, but able to eat with a spoon	2 - Unable to button my shirt but able to eat with a spoon
3 - Able to button shirt with great difficulty	3 - Able to button my shirt with great difficulty
4 - Able to button shirt with slight difficulty	4 - Able to button my shirt with slight difficulty
5- No dysfunction	5 - Not having any trouble using my hands.
Motor dysfunction score of the lower extremity	**Lower Extremities (legs)**
	Choose the statement that best fits: I am…
0 - Complete loss of motor and sensory function	0 - Completely unable to move legs at all and have no feeling in legs
1 - Sensory preservation without ability to move legs	1 - Having feeling in legs but not able to move them at all
2 - Able to move legs, but unable to walk	2 - Able to move my legs but am unable to walk
3 - Able to walk on flat floor with a walking aid	3 - Able to walk on flat floor with a walking aid (cane or crutch)
4 - Able to walk up and/or down stairs with hand rail	4 - Able to walk up-&/or downstairs w/aid of a handrail
5 - Moderate-to-significant lack of stability, but able to walk up and/or down stairs without hand rail	5 - Able to walk up-&/or downstairs without handrail but I notice moderate-to-significant lack of stability/feeling of imbalance when I walk
6 - Mild lack of stability but walks with smooth reciprocation unaided	6 - Able to walk unaided (no crutches, canes, walker) with smooth reciprocation (ie, legs move smoothly) but I still notice mild lack of stability/feeling of imbalance when walking
7 - No dysfunction	7 - Able to walk without any problems of imbalance or instability
Sensory dysfunction score of the upper extremities	**Sensory dysfunction**
	Upper Extremities (arms and hands)
	Choose the statement that best fits: I have…
0 - Complete loss of hand sensation	0 - Complete loss of feeling in hands
1 - Severe sensory loss or pain	1 - Severe loss of feeling, or have pain in my hands
2 - Mild sensory loss	2 - Mild loss of feeling in hands
3 - No sensory loss	3 - No loss of feeling in hands
Sphincter dysfunction score	**Sphincter dysfunction**
	Choose the statement that best fits: I…
0 - Inability to micturate voluntarily	0 - Am completely unable to control urination
1 - Marked difficulty with micturition	1 - Have marked difficulty controlling urination
2 - Mild-to-moderate difficulty with micturition	2 - Have mild to moderate difficulty controlling urination
3 - Normal micturition	3 - No difficulty controlling urination

Table 2.

	mJOA Mean ± SE [95% CI]	Pa-mJOA Mean ± SE [95% CI]	Difference Mean ± SE [95% CI]	P value
All Patients n = 100	14.66 ± 2.61 [7,18.0]	14.68 ± 2.47 [8,18.0]	-0.02 ± 1.49 [-5.0,4.0]	0.89
Severe n = 13 (mJOA score < 12)	10.1 ± 0.4 [9.3 ,10.8]	11.2 ± 0.4 [10.4 ,11.9]	-1.1 ± 0.4 [-1.9,-.3]	0.0082
Moderate n = 30 (mJOA score 12-14)	13.0 ± 0.1 [12.7,13.3]	13.3 ± 0.2 [12.8 ,13.8]	-0.2 ± 0.2 [-0.7,0.3]	0.34
Mild n = 57 (mJOA score > 14)	16.6 + 0.1 [16.3,16.9]	16.2 ± 0.2 [15.8,16.7]	0.3 ± 0.2 [-0.04,0.7]	0.082

Presentation #86

Accuracy of Post-Operative Recall of Baseline Neurological Function by Patients Undergoing Surgical Decompression for Cervical Spondylotic Myelopathy

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Introduction: Patient satisfaction over decompressive surgery for cervical spondylotic myelopathy (CSM) is affected by their perceived change in neurological function. The Japanese Orthopaedic Association (JOA) scale is one of the primary measurement tools for neurological function in these patients. Instead of comparing pre- and post-operative JOA scores, this perceived change is really determined by comparing their self-recalled pre-operative status against how they feel at the follow-up visit. In this study we aim to examine the accuracy of patient recall of their baseline neurological function when compared with their pre-operative scores.

Material and Methods: CSM Patients who underwent decompressive surgery at a single institution between 2008 and 2010 were identified and those with at least three JOA scores (baseline, recall, and current) were included. The Wilcoxon signed-rank test was used to evaluate the mean difference between recall and baseline. A generalized estimating equation regression model was built to identify predictors for recall error. Included predictors were baseline JOA, JOA improvement rate, gender, age, follow-up time, and the type of procedure. Bivariate analysis was first performed to evaluate the impact of each single predictor. A backward algorithm was then used to determine their significance, and the quasi-likelihood information criterion was applied in cases of colinearity. The SAS software (version 9.4) was used for statistical analysis.

Results: 77 patients were included in the final analysis. The gender ratio was 6:4. Mean age was 59 (range: 29–77) years. Follow-up was available at 3,12 and 24 months. Overall, there was no significant difference between baseline and recall JOA scores regardless of follow-up time. Lower baseline JOA, higher improvement rate, and the female sex were determined as significant predictors for greater recall error by the final multivariate analysis model.

Conclusion: Post-operative patient satisfaction is associated with the self-perceived neurological improvement, and it is important to see if patients could accurately recall their pre-operative functional status. Patient recall of their baseline neurological function was accurate regardless of the length of follow-up time. For patients in a certain visit, higher recall accuracy was associated with lower baseline JOA, higher improvement rate, and the female sex.

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Presentation #87

What are the Research Priorities for Patients with Degenerative Cervical Myelopathy?

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Introduction: Cervical Spondylotic Myelopathy [CSM] is a common cause of spinal dysfunction and despite optimal therapy, many live with significant disabilities. Misalignment of patient and clinician objectives is felt to contribute to research wastage. In North America, in 2010, 85% of biomedical research was felt to have yielded no actual or potential clinical benefit. Our objective therefore was to assess the research priorities of patients with degenerative cervical myelopathy to meet the needs of our patients.

Design: Cross-sectional online patient survey.

Subjects: Patients with self-reported CSM.

Methods: CSM patients, registered with the non-profit organisation myelopathy.org, were invited to complete an online survey, to rank the 7 functional domains of spinal cord injury in order of priority. First choice domains were weighted with 7 points and the least preferred option with 1. Average scores were calculated. Patient demographics and current disability (mJOA) was also noted.

Results: 106 patients (M = 31, F = 75), average age 55 ± 11 years completed the survey. Priorities in rank order were elimination of pain (5.6), recovery of walking (5.3), arm / hand (5.2), upper body strength / balance (3.4), bladder / bowel function (3.3), normal sensation (3.2) and sexual function (2.2). Age, sex and prior surgery did not influence priorities. Patients with severe myelopathy (mJOA < 12) prioritised recovery of hand function over pain.

Conclusions: Alleviation of pain, and improvements in mobility and hand function emerge as key priorities for patients and should be a focus for researchers and outcome measures in clinical trials for CSM.

Presentation #88

The Impact of Cervical Sagittal Alignment on Axial Neck Pain and Health-Related QOL after Laminoplasty: A Prospective Comparative Study between Cervical OPLL and CSM

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Introduction: Many studies have focused on postoperative axial neck pain after laminoplasty. However, there exist only a few reports that investigated the correlation among axial neck pain, patient-based QOL outcome measure; JOACMEQ (Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire), and cervical sagittal alignment. The purpose of this study is to prospectively investigate the correlation among axial neck pain, JOACMEQ, and cervical sagittal alignment after laminoplasty for cervical myelopathy on the hypothesis that cervical sagittal malalignment has negative effects on axial neck pain and JOACMEQ.

Materials and Methods: Consecutive fifty-seven patients who treated by open-door laminoplasty for cervical myelopathy were included (mean age: 63.7 years, 15 females and 42 males), and divided into two groups by the diagnosis (CSM group: 35 patients, OPLL group: 22 patients). JOA score, JOACMEQ, 10-second test, and VAS for axial neck pain (VAS) were assessed at the time points of before surgery and postoperative 12 months (POM12). Radiographic parameters were measured by C2 sagittal vertical axis (C2 SVA), C2-C7 lordosis, T1 sagittal slope, and cervical sagittal range of motion on flexion and extension (ROM). The Spearman's rank-correlation coefficient was used for the statistical analysis, and the significance was set by $R > 0.4$ and $P < 0.05$.

Results: The value of C2 SVA in both groups have slightly shifted to anterior from the respective pre-op. value (CSM: + 19.7 ± 10.9 mm, OPLL: + 22.1 ± 13.4 mm) to the value at POM12 (CSM: + 23.2 ± 16.1 mm, OPLL: + 28.7 ± 15.4 mm). The postoperative VAS in OPLL group showed strong negative correlations with C2 SVA and T1 sagittal slope (Table 1). And, the strong negative correlations were found between the VAS and cervical spine function in both preoperative CSM and OPLL group (CSM; $R = -0.45$, $P = 0.01$, OPLL; $R = -0.61$, $P < 0.01$) and between the VAS and cervical spine function in postoperative OPLL group ($R = -0.51$, $p = 0.05$) (Table 2).

Conclusion: This study demonstrated that significant negative correlation was found between the VAS and the subdomain of cervical spine function in JOACMEQ in preoperative CSM, OPLL and postoperative OPLL groups. However, radiographic cervical sagittal parameters were not significantly correlated with the VAS. Because the global sagittal alignments were not investigated in this study, the compensation by thoracic / lumber spine and lower extremities might affect the results. Further studies are underway including the relationship between axial neck pain and global sagittal alignment.

See Disclosure Index pages 39–89.

Presentation #88 (cont.)

Table 1: Correlation between the VAS for axial neck pain and radiographic parameters

CSM		C2SVA	C2-C7 lordosis	T1 sagittal slope	ROM
VAS (Pre-OP)	R	0.01	- 0.18	- 0.07	- 0.23
	P	0.83	0.43	0.87	0.15
VAS (POM12)	R	- 0.10	- 0.11	- 0.17	0.04
	P	0.69	0.59	0.46	0.54
OPLL		**C2SVA**	**C2-C7 lordosis**	**T1 sagittal slope**	**ROM**
VAS (Pre-OP)	R	0.25	0.08	0.16	- 0.13
	P	0.22	0.77	0.49	0.36
VAS (POM12)	R	**- 0.33**	- 0.20	**- 0.43**	- 0.03
	P	**0.16**	0.59	**0.11**	0.84

Table 2: Correlation between each subscale of JOACMEQ and the C2 SVA or the VAS for axial neck pain

Preoperative parameters		Cervical Spine Function	Upper Extremity Function	Lower Extremity Function	Bladder Function	QOL
C2 SVA: CSM	R	- 0.14	- 0.07	- 0.07	- 0.24	- 0.11
	P	0.22	0.65	0.31	0.27	0.23
C2 SVA: OPLL	R	- 0.26	< 0.01	0.01	0.29	- 0.21
	P	0.33	0.73	0.85	0.31	0.52
VAS: CSM	R	**- 0.45**	- 0.07	- 0.06	0.04	- 0.31
	P	**0.01**	0.75	0.87	0.91	0.11
VAS: OPLL	R	**- 0.61**	- 0.22	- 0.15	- 0.04	- 0.03
	P	**< 0.01**	0.37	0.52	0.79	0.97
Postoperative parameters		**Cervical Spine Function**	**Upper Extremity Function**	**Lower Extremity Function**	**Bladder Function**	**QOL**
C2 SVA: CSM	R	- 0.34	- 0.22	- 0.34	- 0.34	- 0.34
	P	0.09	0.86	0.07	0.27	0.12
C2 SVA: OPLL	R	0.13	0.22	< 0.01	0.23	0.03
	P	0.40	0.54	0.90	0.48	0.92
VAS: CSM	R	- 0.25	- 0.26	- 0.00	0.09	- 0.19
	P	0.44	0.08	0.93	0.46	0.30
VAS: OPLL	R	**- 0.51**	**- 0.53**	- 0.36	**- 0.46**	- 0.22
	P	**0.05**	**0.03**	0.06	**0.04**	0.12

Presentation #89

Complications and Readmission after Cervical Spine Surgery in Elderly Patients: An Analysis of 1,586 Patients

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Introduction: There is a paucity of literature describing risk factors for adverse outcomes after geriatric cervical spinal surgery. How safe is cervical spine surgery in elderly patients? Does patient selection, type of surgery, length of surgery, and other elderly patient comorbidities affect complication and readmission rates after surgery?

Methods: A retrospective cohort study was performed using data from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. Patients over the age of 65 who underwent cervical spinal surgery from 2005–2013 were identified using ICD-9 diagnosis codes and CPT codes. Outcome data was classified as either a major complication, minor complication, readmission, or mortality. Major complications included sepsis, pulmonary embolism, deep surgical site infection, organ or surgical site infection, unplanned intubation, CVA, MI, cardiac arrest, ventilator use > 48 hours, septic shock, acute renal failure, peripheral nerve injury, coma, or graft/prosthesis/flap failure. Minor complications included blood transfusion, UTI, DVT, superficial SSI, pneumonia, renal insufficiency, and wound dehiscence. Multivariate logistic regression models were used to determine factors which placed the patients at risk to develop adverse outcomes in the initial 30 postoperative days.

Results: 1,586 patients over the age of 65 who underwent cervical spine surgery were identified. Overall, 150 (9.46%) patients experienced at least one complication or death in the intial 30 postoperative days. 62 (3.91%) patients experienced a major complication. 120 (7.57%) patients experienced a minor complication. 71 (5.99%) patients were readmitted to the hospital within 30 days. 13 (0.82%) deaths recorded in the initial 30 postoperative days. Patients who were over the age of 75 were at higher risk of developing a complication than patients aged 65–70, or 70–75 (age > 75, OR: 1.72 [1.09–2.71]. Increased operative times were also strongly associated with perioperative complications (operative time > 180 mins, OR: 3.49 [2.16–5.64]). Patients who had a baseline functional status of partially or totally dependent were also at higher risk for developing complications (Partially/Totally dependent, OR: 3.28 [1.83–5.88]). Other factors associated with increased complication rates were emergency cases and patients with and ASA classification of 3 or greater (Emergency, OR: 4.56 [1.66–12.54], ASA 3/4/5, OR: 1.77 [1.10–2.83]. Patients with preoperative pulmonary or nutritional/endocrine comorbidities were also at increased risk for developing a postoperative complication in the initial 30 postoperative days (Pulmonary, OR: 1.86 [1.19–2.92], Nutrition/Endocrine, OR: 2.07 [1.04–4.14]. Patients who developed at least one postoperative complication were at increased risk of readmission to the hospital within 30 days (Post-Op Complication, OR: 10.03 [5.07–19.84]).

See Disclosure Index pages 39–89.

Presentation #89 (cont.)

Conclusions: Elderly patients undergoing cervical spinal surgery have a complication rate of 9.46% and readmission rate of 5.99% in the initial 30 postoperative days. Risk factors for complications include age greater than 75, longer operative time, decreased baseline functional status, emergency cases, and higher ASA Classification. Patients with preoperative pulmonary or endocrine comorbidities were also at higher risk of postoperative complications. Higher readmission rates are associated with patients who experienced at least one postoperative complication. These risk factors should be considered when planning cervical spinal surgery in elderly patients.

Presentation #90

Opioid Use Trends Following Cervical Spine Surgery

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Introduction: The United States is in the midst of an opioid epidemic. The purpose of this study purpose was to evaluate peri-operative opioid use following cervical spine surgery comparing pre-operative opioid users (OU) and non-opioid users (NOU).

Materials and Methods: The Humana Inc. dataset was reviewed from 2007–2015 for patients undergoing anterior or posterior cervical spine fusion surgery. Patients were identified using ICD-9/CPT codes and prescription opioid use was measured by monthly prescription fill rates. An OU user was defined as opioid prescription within 3 months prior to surgery. Rates of opioid use were evaluated pre-operatively for OU and trended for one year post-operatively for both OU and NOU.

Results: In total, 14.801 procedures were evaluated, consisting of 12,921 patients with an anterior cervical (87.3%), and 12.7% with a posterior cervical fusion. Overall, 51.4% of patients were pre-operative OU. 47.7% of all NOU filled opioid prescriptions during their first post-operative month with less than 7.8% filling prescription by 3-months for all NOU and re-fill rates ranged from 5.7–6.6% from 6–12 months post-operatively. OU, however, had fill rates in the first month of 82.0%, and a 6–12 month fill rate between 44.9% and 46.9%. NOU filled significantly less opioid prescriptions than OU at all time points ($p < 0.001$). The fill rates did not differ significantly between anterior and posterior fusion surgery.

Conclusion: Approximately half of cervical spine fusion patients use opioids prior to surgery. Post-operative opioid use fell dramatically during the first 3 months in NOU, but nearly half of the pre-op opioid users will remain on narcotics at 1 year post-op in those using opioids before surgery. This data will serve as an important baseline to encourage discontinuation of opioids prior to spinal surgery.

See Disclosure Index pages 39–89.

Presentation #90 (cont.)

Figure 1a. Percentage of OU and NOU filling opioid prescriptions following Cervical Spine Surgery plotted by monthly intervals. Average pre-operative monthly prescription refill rate was calculated based upon average number of OU refilling prescriptions each month over the three months prior to the index surgery.

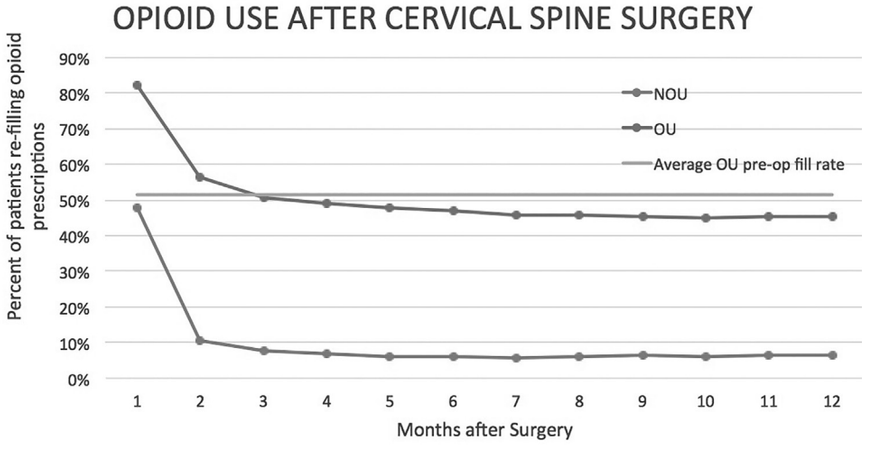

Table 1. Number of patients filling opioid prescriptions following Cervical Spine Surgery

∫	Non-Opioid Users		Opioid users		
	Patients	**Percent**	**Patients**	**Percent**	**P value**
Total patients	4267	100.00%	7607	100.00%	
Number of months post-operatively					
1 month	2034	47.67%	6240	82.03%	<0.001
2 months	448	10.50%	4274	56.19%	<0.001
3 months	332	7.78%	3843	50.52%	<0.001
4 months	299	7.01%	3735	49.10%	<0.001
5 months	254	5.95%	3649	47.97%	<0.001
6 months	260	6.09%	3565	46.86%	<0.001
7 months	243	5.69%	3492	45.91%	<0.001
8 months	253	5.93%	3481	45.76%	<0.001
9 months	274	6.42%	3435	45.16%	<0.001
10 months	265	6.21%	3412	44.85%	<0.001
11 months	281	6.59%	3439	45.21%	<0.001
12 months	270	6.33%	3450	45.35%	<0.001

Presentation #91

Adjacent-Level Degeneration after Bryan Cervical Disc Arthroplasty Compared with Anterior Discectomy and Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a reliable and proven procedure for the treatment of radiculopathy and/or myelopathy. Despite a successful track record for treating cervical disease, several potential limitations specific to ACDF including adjacent segment degeneration/disease, loss of viscoelastic disc properties, perioperative immobilization, bone graft site morbidity, pseudarthrosis, and plating complications have been identified. In an effort to improve upon the treatment of cervical disorders and avoid potential negative effects of a fusion, total disc arthroplasty (TDA) was developed. One of the original driving forces and theoretical basis for TDA was prevention of adjacent level degeneration. The purpose of this study is to compare adjacent level degeneration in both of these treatment groups using patients that were enrolled in a randomized controlled study. We also wish to assess the reliability of our measurements utilizing a method not previously described in the literature.

Materials and Methods: A total of 79 patients were enrolled and followed prospectively at two centers involved in a multicenter, FDA IDE trial for the BRYAN Cervical Disc arthroplasty. Neutral lateral radiographs were obtained preoperatively and postoperatively, and at 1, 2, 4, and out to 7 year follow-up after surgery. Inclusion criteria for analysis required images of sufficient clarity and ability to visualize the adjacent level above the study level. All original plain film images were digitized and the surgical level hidden for blinding purposes. The cephalad, adjacent level above the blinded procedure level was analyzed for all patients and time points by measuring the anteroposterior (AP) distance and the vertical disc height at the midpoint of the AP distance. A ratio was then created using disc height/AP distance in order to effectively compare images. Repeated measures ANOVA was used for data analysis.

Results: A total of 70 patients (Bryan Cervical Disc N = 34 and ACDF N = 36) met inclusion criteria and were included in this study. Changes over time were assessed for each group and between groups. Both the fusion and arthroplasty group showed a decrease in disc height over time that was significant ($p = 0.001$) regardless of study group, indicative of adjacent level degeneration. Overall change in disc height between groups however, was not significantly different at any time point. Using our measurement technique, the overall inter-reviewer reliability was good (ICC [95% CI] = 0.77 [0.55,0.85] and intra-reviewer reliability was excellent (0.93 [0.91,0.94] and 0.85 [0.81,0.87]).

Conclusion: According to our data analysis, adjacent level degeneration occurs in a similar fashion in both the ACDF and TDA group. Our measurement technique is reliable and to the best of our knowledge not previously reported in the literature. There continue to remain inconsistencies in the literature regarding ACDF and TDA outcomes. It is important that we continue to follow these patients in order to obtain long-term follow-up data. Hopefully over time, such data will better clarify whether TDA can improve upon any of the shortcomings associated with ACDF, and specifically adjacent level disease.

See Disclosure Index pages 39–89.

Presentation #92

Incidence, Epidemiology, and Treatment Trends for Spinal Epidural Abscesses Involving the Cervical Spine - A Single Institution 10 Year Retrospective Analysis

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Introduction: Spinal epidural abscesses (SEA) affecting the cervical spine are exceedingly rare and little is reported in the literature pertaining to their incidence, epidemiology, and treatment trends. The purpose of this study was to determine the etiology and epidemiology of bacterial SEA involving the cervical spine and their treatment trends.

Methods: The medical center's data warehouse was queried for patients with ICD-9 diagnosis code for intraspinal abscess (324.1) over a 10-year period from September 24, 2001 to September 24, 2011. Patients with cytopathologic or radiographic evidence of bacterial SEA in the cervical or cervicothoracic spinal levels were included. Patients were excluded if they were under the age of 18. Patient demographics, vertebral levels, signs and symptoms, risk factors, microorganisms, pre/post-treatment clinical status, and treatment (medical vs. surgical) were recorded. Clinical status was recorded according to the following stages: stage 1 = pain at level of affected spine; stage 2 = nerve root pain radiating from involved spinal area; stage 3 = motor weakness, sensory deficit or bladder/bowel dysfunction; and stage 4 = paralysis. Patients were diagnosed with a bacterial SEA involving the cervical spine (C1-C7) by either CT, MRI, or intraoperatively and had all listed outcome measures to be included in the study.

Results: A total of 43 patients were diagnosed with a SEA involving the cervical spine and included in the study. Males made up 60% of the study population (n = 26), and the average age was 55.1 ± 12.1 years (range 28–79). Locations of the SEA involving the cervical spine included 36 that were cervical (C1-C7) and 7 that were cervicothoracic (C1-T12). The average number of levels involved was 3.9 ± 2.7 (range 1–15). Patients presented in Stage 1 (33%), Stage 2 (12%), Stage 3 (37%) and Stage 4 (19%). Presenting signs and symptoms included elevated erythrocyte sedimentation rate (60%), elevated white blood cell count (81%), and fever (49%). Risk factors included tobacco use (56%), concurrent non-spinal infection (37%), and diabetes mellitus (35%). The most common grown organisms were methicillin-resistant Staphylococcus aureus (44%) and methicillin-susceptible Staphylococcus aureus (23%). Fifteen patients were treated with antibiotics only (35%), and 28 were treated with both surgery and antibiotics (65%).

Conclusion: Spinal epidural abscesses involving the cervical spine are challenging to treat and manage. The majority of patients presented with motor weakness/sensory deficit or neck pain. Tobacco use, non-spinal infections, and diabetes mellitus were found to be the biggest risk factors for spinal epidural abscesses of the cervical spine. Outcomes for the significant portion of patients treated non-operatively were poor.

Presentation #93

The Posterior Use of BMP-2 in Cervical Deformity Surgery Does not Result in Increased Peri-Operative Complications: A Prospective Multicenter Study

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Introduction: Although the use of recombinant human bone morphogenetic protein-2 (BMP-2) is contraindicated in anterior cervical procedures, retrospective series have shown that it can be safely using in posterior cervical procedures. However, the rate of complications following BMP use in the posterior cervical spine has not been studied in a prospective series of adult cervical deformity (ACD) patients.

Methods: This was a prospective cohort study seeking to enroll operative cervical deformity (CD) patients. The inclusion criteria were one or more of the following: cervical kyphosis (CK) > 10°, cervical scoliosis (CS) > 10°, C2-7 SVA > 4cm and/or chin-brow vertical angle (CBVA) > 25°. Demographic, operative and radiographic variables were recorded. Intermediate (3 month) and 6 month follow up was obtained. Patients were divided into two groups: those who received BMP-2 (BMP) and those who received no BMP-2 (NoBMP). Patient demographic data, operative details, and radiographic parameters were compared. Patients with neurologic complications were identified. Statistical analysis was performed with an independent t-test for continuous variables or Chi-square test for categorical variables. In the BMP group, the relationship between BMP use (total, dose per level) and complications was also evaluated using linear regression.

See Disclosure Index pages 39–89.

Presentation #93 (cont.)

Results: A total of 100 patients were included. Average age was 61.5 yrs with 40.8% males and 59.2% females. Average follow up was 7.6 months. There were 47 patients in the BMP group and 53 in the NoBMP group. An average of 13.6mg of BMP was used per person with 1.5mg per level. BMP was used posteriorly only. Compared to the NoBMP group, patients in the BMP group were older ($p = 0.03$) and had longer prior fusions (6.0 vs. 2.5 levels, $p < 0.01$). There was no difference between the BMP and NoBMP groups with regards to: revision vs. primary surgery, Charlson Comorbidity Index (CCI), estimated blood loss (EBL), operation time, fusion levels, surgical approach, posterior osteotomy and anterior corpectomy. Radiographically, there was no difference between the two groups in maintenance of the radiographic parameters at 6-month follow up. There was no difference between groups with regards to complication incidence, total complications per person, major complications per person or any specific complication (e.g., neurologic complications, wound complications, etc.) Furthermore, a linear regression in the BMP group showed no predictive relationship between the total dose of BMP and incidence of total, minor or each specific complication ($p > 0.05$). Also linear regression did not reveal predictive relationship between the total dose of BMP and fusion levels, the incidence of major or operative complications ($r2 = 0.09, 0.08, 0.06$) despite statistical significance.

Conclusion: The posterior use of BMP was not directly associated with an increased incidence of complications in this prospective cohort of operative Adult Cervical Deformity patients. BMP use was associated with older patients and with longer fusions.

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E-Poster Abstracts

Cell Replacement Therapy Improves Breathing after Cervical Spinal Cord Injury

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Introduction: Approximately half of all human spinal cord injury (SCI) affects cervical spinal cord regions, resulting in debilitating and often chronic respiratory compromise. Unfortunately, the consequent breathing impairment is the leading cause of mortality amongst cervical SCI (cSCI) patients. With the lack of optimal treatment strategy available, the development of treatment strategies to improve breathing in cSCI patients is of paramount importance. Hence, this proposal aims to examine the effect of transplanting induced human pluripotent stem cells to promote remodeling of the respiratory neural network and improve breathing following traumatic cSCI.

Methods: To test the above aim, 2 weeks post-cSCI, neural precursor cells (NPCs) derived from induced human pluripotent stem cells (hiPSCs - NPCs) expressing green - fluorescent protein (GFP) were transplanted into the cervical spinal cord. 10 weeks after injury, whole cell patch clamp recordings and immunohistochemistry with a neuronal marker were used to confirm the phenotype of the transplanted cells. Phrenic motor neurons (PhMNs) located in the cervical spinal cord (C3 - C6 rodents) innervate the diaphragm, which is the main inspiratory muscle. The PhMNs in turn receive descending commands from neurons within the rostral ventral respiratory group (rVRG) in the medulla. To assess if grafted cells make direct functional connections onto PhMNs, the transynaptic tracer, pseudorabies virus (PRV) - 263 (red), was injected into the diaphragm of cSCI mice transplanted with hiPSC - NPCs - GFP at 10 weeks post - injury. Resulting number of RFP^+ / GFP^+ interneurons in the cervical enlargement allowed for the identification of transplanted neurons synaptically connected to PhMNs. To identify if new rVRG input onto PhMNs are made through grafted stem cells, HSV - synaptophysin - cerulean was injected into rVRG and PRV - 263 into the diaphragm prior to termination of the experiment. Assessment of the number of RFP^+ / GFP^+ / $Cyan^+$, RFP^+ / GFP^+ / $Cyan^-$ and RFP^+ / GFP^- / $Cyan^+$ within the cervical spinal cord allowed us to identify the ratio of neurons derived from the grafted stem cells that relay excitatory connections from the rVRG to PhMNs. Finally, we assessed spinal respiratory functional recovery using respiratory related diaphragmatic electromyographic (EMGs) recordings of inspiratory burst frequency; peak amplitude and burst duration from all groups.

Results: Transplantation of hiPSC - NPCs - GFP into the injured cervical spinal cord resulted in significant survival of these cells within the spinal cord. Patch clamp electrophysiological assessment and immunohistochemistry confirmed that a significant portion of the precursor cells differentiated into neurons. Furthermore, transplanted cells were integrated with the host tissue, forming specific functional synaptic connections onto PhMNs. Moreover, we also detected transplanted cells that were functionally connected to both PhMNs and premotor neurons within with brainstem. Importantly, with this approach we were able to restore respiratory function in mice that had undergone cSCI indicated by increased inspiratory peak amplitude and burst duration.

Discussion: This is the first report indicating successful functional remodeling of the injured cervical spinal cord and improved breathing following cSCI using intraspinal cell replacement treatment. The use of hiPSCs - NPCs represents a cell source that circumvents ethical and moral concerns while allowing for autologous transplantation of NPCs derived from hiPSCs. This targeted cell replacement into the respiratory network represents a significant advancement in the field of cSCI and respiratory recovery.

See Disclosure Index pages 39–89.

Pharmacological Modulation of Distal Spinal Locomotor Circuitry Improves Motor Function after Cervical Spinal Cord Injury

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Introduction: Cervical spinal cord injury (SCI), the most common type of SCI, results in substantial motor impairment. Currently, no effective treatment options exist to restore motor function. Interestingly, we have discovered that the distal neural network responsible for locomotion within the lumbar region undergoes degeneration during the chronic phase of cervical SCI (cSCI). Based on this novel finding, here we hypothesize that early and selective stimulation of the lumbar glutamatergic neurons may prevent degeneration of the locomotor central pattern generator (CPG) and enhance locomotor recovery after cSCI.

Methods: Adult transgenic mice expressing cre recombinase under the Vglut2 promoter *(Vglut2::cre)* were used in this study. We specifically expressed a G protein-coupled receptor (hM3Dq) to the lumbar glutamatergic cells by injecting a cre dependent adenovirus expressing the hM3Dq in the lumbar spinal cord of an uninjured and two cSCI groups of *Vglut2::cre* mice. The hM3Dq receptor can be selectively activated by the pharmacologically inert, orally bioavailable drug clozapine-N-oxide (CNO). hM3Dq activation leads to depolarization, and enhanced neuronal excitability resulting in burst-like firing and subsequent neuronal activation. Following cSCI induction we immediately administered CNO intraperitonealy to artificially replace the supraspinal input on the glutamatergic lumbar neurons. CNO was administered daily for 3 weeks. Control cSCI mice with hM3Dq expression received saline. Mice in all groups underwent detailed locomotor assessment using gait and kinematic analysis.

Results: Mice that underwent remote and selective stimulation of the lumbar glutamatergic neurons demonstrated higher locomotor ability compared to controls. Specifically, chemogenetic stimulation attenuated the loss of speed, cadence and stride length during overground locomotion compared to controls. Moreover, abatement of locomotor deficits was associated with preservation of interneurons and motoneurons within the lumbar locomotor neural network compared to controls. Thus, stimulation therapy emerged as an effective treatment option for preventing the degeneration of the distal locomotor network and improving locomotor recovery after sSCI.

Discussion: Here, we report a novel pharmaco-genetic approach capable of selectively and remotely modulating the lumbar circuits immediately after cSCI. Importantly, we showed that this exogenous replacement of the supraspinal input onto lumbar glutamatergic cells preserves the anatomical and functional integrity of the locomotor neural network and improves locomotor recovery. In summary, our novel and exciting work suggests the selective neuromodulation of the locomotor CPG early after cSCI as a promising treatment strategy to restore walking in cSCI patients.

Influence of Riluzole on Osteogenic Differentiation of Human Bone Marrow Stromal Cells and Osteoblasts

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Introduction: Preliminary studies suggest that Riluzole, a sodium channel-blocking medication, may be neuroprotective in patients with an acute spinal cord injury (SCI), however its effect on bone formation has never been studied. The purpose of this study is to determine the effects of riluzole on osteogenic differentiation of human mesenchymal stromal cells (MSCs) and human primary osteoblasts (OBs).

Methods: Human bone marrow aspirate and human femoral heads were used to obtain MSCs and OBs. For cell viability testing MSCs and OBs were seeded in 96-well plates at 7,500 cells/cm2. After 24 h, the cells were treated with osteogenic medium containing different concentrations of riluzole (50 ng/mL; 150 ng/mL; 450 ng/mL). Control groups of MSCs and OBs were cultured without riluzole. After two and seven days, cell viability was determined.

For quantification of Alkaline Phosphatase (ALP) activity, MSCs and OBs were plated in 24-well plates (10,000 cells/cm2) and cultured for 2 days in basal medium. Then they were treated with standard osteogenic differentiation medium. Control groups without riluzole, and experimental groups that were exposed to different concentrations of riluzole (50 ng/mL; 150 ng/mL; 450 ng/mL) were cultured. After 7, 14, 21 and 28 days ALP activity was measured. For gene expression analysis total RNA was extracted from controls and cells treated with 50 ng/mL or 450 ng/mL riluzole at days 7, 21 and 28 to determine the expression of osteogenic genes (type I collagen, alkaline phosphatase, osteocalcin, RUNX2 and Sox9). Quantitative real-time PCR was performed. The experiments were performed in duplicate (PCR) or triplicate (ALP activity) for 3 MSC donors and 3 OB donors.

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Results: Riluzole affected neither the cell viability of human MSCs nor osteoblasts after up to seven days. There was also no influence of riluzole on the proliferation of the MSCs or OBs. In contrast, ALP activity was increased by 30% in MSCs after 14 days of culture in medium containing 150 ng/mL of riluzole ($p = 0.035$ vs. control); after 21 days of culture, ALP activity was up-regulated 2.5 times and 1.9 times in MSCs upon supplementation of 150 ng/mL ($p < 0.001$ vs. control) and 450 ng/mL ($p = 0.010$ vs. control) of riluzole, respectively. In osteoblasts, 2-2.5 times increased ALP activity was observed after 14 days of culture in presence of 150 ng/mL ($p < 0.001$ vs. control) or 450 ng/mL ($p = 0.011$ vs. control) of riluzole, while similar up-regulation was also noticed after 21 days of culture with 150 ng/mL ($p < 0.036$ vs. control) or 450 ng/mL ($p = 0.044$ vs. control) of riluzole. The gene expression levels of osteogenic genes were not affected by treatment of osteoblasts with riluzole; however, longer exposure to high doses (450 ng/mL) of riluzole resulted in a significant down-regulation of collagen 1, RUNX2 and SOX9 gene expression in MSCs ($p < 0.05$ vs. control).

Discussion: Low dose riluzole has no effect on the viability or function of either MSCs or OBs; however, longer treatment with high doses of riluzole might compromise the osteogenic function of the MSCs.

Peptide Amphiphile Nanoslurry in Spinal Arthrodesis: An Improved Carrier for BMP-2

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Introduction: Advances in biologics and bone graft substitutes have improved spine fusion rates; however, there still exists a need for a product that elicits high fusion rates with minimal adverse effects. Recombinant human bone morphogenetic protein-2 (rhBMP-2) applied onto absorbable collagen sponges (ACS) promotes fusion rates of > 90% in humans. However, the supraphysiologic dose required when rhBMP-2 is utilized with this carrier can lead to serious complications. For this reason, improving carrier technology has become a priority in order to reduce the exogenous BMP necessary to achieve fusion. Changes in carrier form (for example lyophilizing collagen) may change its properties and influence carrier effectiveness, thereby improving the carrier.

In previous work, we evaluated nanofiber scaffolds composed of peptide amphiphiles (PA), which localize BMP-2, thereby reducing the requisite dose of exogenous growth factor needed for successful fusion. The purpose of the current study was to optimize collagen as a carrier – utilizing a lyophilized form – along with PA technology to decrease the amount of BMP necessary to achieve fusion. We hypothesized that assembling PA with lyophilized collagen in a collagen slurry vehicle (nanoslurry) would enhance the bioactivity of a carboxyl rich (E3) PA nanogel, yielding a malleable paste that could be used to fill bone defects and potentially reduce the exogenous growth-factor necessary to achieve arthrodesis.

Methods: Female Sprague-Dawley rats and New Zealand white rabbits underwent L4-L5 posterolateral spine fusion (PLF) procedures with placement of collagen slurry +/- E3PA or ACS alone. Scaffolds were preloaded with saline or rhBMP-2 (100ng per rat or 60µg per rabbit). Bone regeneration and spine fusion were assessed using radiographs, manual palpation-based fusion scoring, microCT imaging (rats), and histology (rats). Fusion scores were determined by blinded manual palpation from 3 scorers using an established scoring system: 0 = no bridging bone, 1 = unilateral bridging, and 2 = bilateral bridging. Spines with an average score of ≥ 1.0 were considered successfully fused.

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Results: Preloading E3PA-collagen slurry with 100ng rhBMP-2 in rats elicited a significantly higher mean fusion score relative to equivalently pre-loaded ACS ($p < 0.001$) or control slurry ($p < 0.001$; Figure 1). Successful fusion was seen in 100% of animals treated with E3PA-collagen slurry +100ng rhBMP-2. This was significantly higher than fusion rates of equivalently pre-loaded ACS (0%) and control slurry (8%). Similarly, fusion rates in rabbits treated with E3PA-collagen slurry +60µg rhBMP-2 (100%) were significantly higher than equivalently pre-loaded ACS (50%) ($p < 0.05$).

Conclusions: Multiple groups have established 10µg rhBMP-2 applied on ACS as a 100% fusion positive control in the rodent model. Our data suggests that E3PA-collagen slurry – a combination of lyophilized collagen particles and PA technologies – can effectively reduce the requirement for rhBMP-2 by a factor of 100 relative to ACS, the current FDA-approved carrier. Additionally, E3PA also served as an improved rhBMP-2 carrier in the rabbit posterolateral spine fusion model.

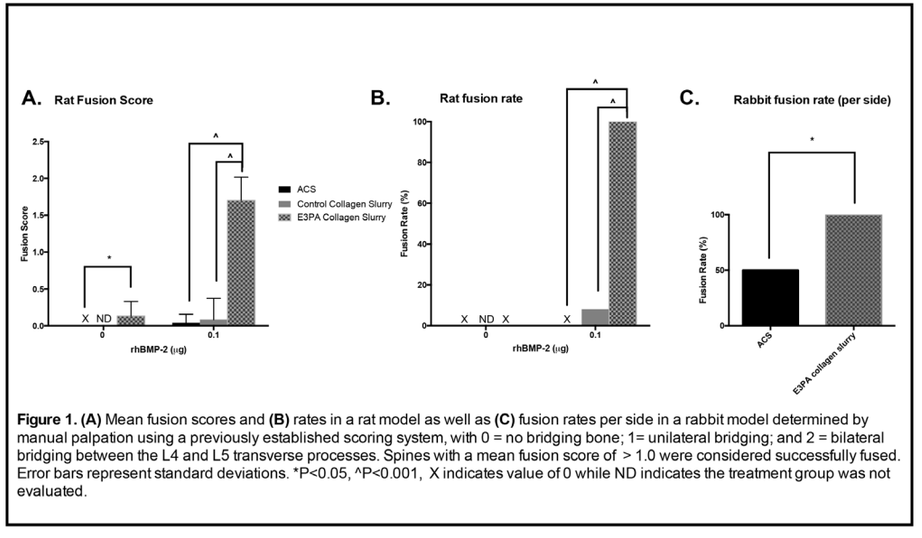

Figure 1. (A) Mean fusion scores and **(B)** rates in a rat model as well as **(C)** fusion rates per side in a rabbit model determined by manual palpation using a previously established scoring system, with 0 = no bridging bone; 1= unilateral bridging; and 2 = bilateral bridging between the L4 and L5 transverse processes. Spines with a mean fusion score of > 1.0 were considered successfully fused. Error bars represent standard deviations. *P<0.05, ^P<0.001, X indicates value of 0 while ND indicates the treatment group was not evaluated.

Intervertebral Disc Regeneration using Tissue-Engineered Construct Derived from Adipose Mesenchymal Stem Cells in a Rat Model of Disc Transplantation

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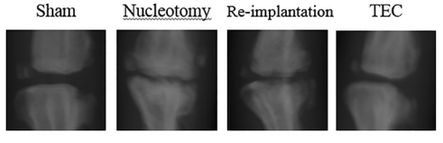
Introduction: Intervertebral disc (IVD) degeneration plays key roles in low back pain and spinal sagittal malalignment which back great impact not only on patient's QOL and social economy. Therefore, IVD regeneration is drawing increasing attention. We developed a scaffold-free tissue engineered construct (TEC) as a novel cell therapy and reported its regenerative capacity for articular cartilage and meniscus. The purpose of this study is to investigate the regenerative potential of a TEC derived from adipose mesenchymal stem cells (ADSCs) in a rat model of IVD transplantation.

Materials and Methods: ADSCs were isolated from adipose tissue of GFP transgenic rats. For the in vitro analysis, their capacity to differentiate into adipocytes, chondrocytes and osteocytes (tri-linage differentiation) was assessed, and their phenotype was characterized using flow cytometry. TECs were developed by culturing ADSCs at a high density and followed by suspension culture. For in vivo analysis of the rat tail model, a total of forty-two SD rats were classified into four groups; sham group (n = 10), nucleotomy group (n = 10), nucleus pulposus re-implantation group (n = 11), and TEC-implanted group (n = 11). After six weeks after operation, disc height index (DHI) was assessed by x-ray and endplate degeneration score was by micro-CT (Grades, 3: No degeneration, 2: Endplate irregularity with intact growth plate, 1: Growth plate disruption, 0: Severe degeneration). Histology was evaluated by H&E and Safranin O staining. The viability of the implanted cells were investigated by GFP immunostaining.

Results: Tri-lineage differentiation of ADSCs were confirmed by Alizarin red staining (ostenogenisis), Safranin O staining (chondrogenesis) and Oil red O staining (adipogenesis). Flow cytometry analysis showed ADSCs were positive for CD90 and CD29 and negative for CD45 and CD34 and confirmed to meet the requirements of mesenchymal stem cell. DHI was 0.0±0.0 in nucleotomy group, 0.9±1.8 in nucleus pulposus re-implantation group, 2.8±2.4 in TEC-implanted group and 8.6±2.0 in Sham group. TEC group demonstrated significantly higher DHI compared to nucleotomy and nucleus pulposus re-implantation groups (Figure 1). Endplate degeneration score by micro-CT was 0.0±0.0 in nucleotomy group, 0.6±1.1 in nucleus pulposus re-implantation group, 1.4±0.9 in TEC-implanted group and 3.0±0.0 in Sham group, respectively. The score in the TEC group was significantly higher than nucleotomy group (Figure 2). Histological assessments showed that the laminar structure of annulus fibrosus, bony endplates and disc height were preserved than the nucleotomy and nucleous pulposus re-implantation groups. However, GFP positive cells were not detected in the disc space.

Discussion and Conclusions: TEC implantation to IVD preserved the disc height, the annulus fibrosus and endplate structure. The regenerative effects seemed to be exerted by the trophic effects of the TEC. The application of TEC into the degenerated disc can be an alternative therapy for various disease associated with structural and functional failure of IVD.

Fig. 1 **Radiograph**



Disc height index

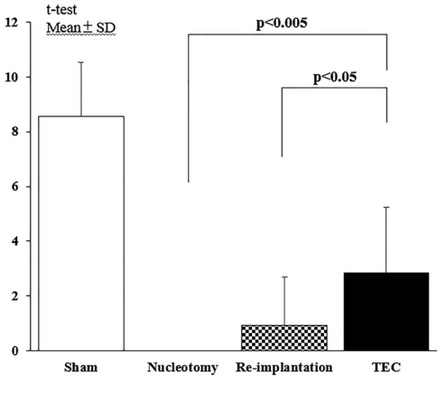
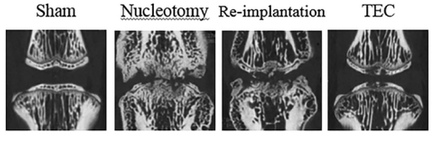
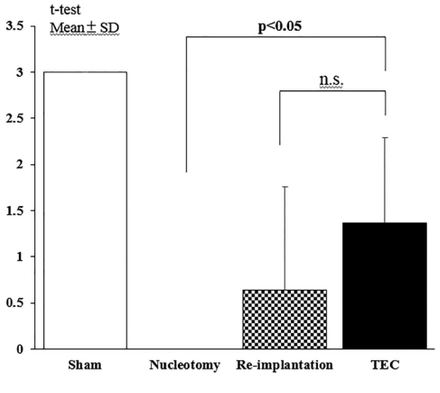


Fig. 2 **μCT**



Endplate degeneration score



Effect of Hyperglycemia on Apoptosis, Matrix Degrading and Fibrotic Enzymes and Inflammatory Cytokines of Annulus Fibrosus Cells in Genetically Engineered Diabetic Rats

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Introduction: Diabetes mellitus (DM) is a risk factor for development of intervertebral disc degeneration (IDD). Otsuka-Long-Evans-Tokushima fatty (OLETF) rats are genetically engineered diabetic rats that are characterized by mild obesity and late-onset hyperglycemia (after 4–5 months of age), similar to human type 2 DM. Long-Evans Tokushima Otsuka (LETO) rats are the non-diabetic genetic controls for OLETF rats. One hundred percent penetrance of DM is observed in male OLETF rats by 6 months of age compared with age-matched control LETO rats. The advantage of genetically-engineered animal studies is that all variables can be controlled to isolate the variable of interest. The purpose of current study was to investigate the effect of DM on apoptosis, expression of matrix degrading and fibrotic enzymes and inflammatory cytokines of annulus fibrosus (AF) cells using age-matched OLETF and LETO rats.

Materials and Methods: AF tissues (L1-6) were obtained from 6-month old OLETF and LETO rats (10 each). We performed TUNEL assay for apoptosis of AF cells and calculated the apoptotic index (%). We also performed Western blot and RT-PCR to investigate expression of matrix metalloproteinase (MMP)-1, -2, -3, and -13 (matrix degrading enzymes), tissue inhibitor of metalloproteinases (TIMP)-1 and -2 (fibrotic enzymes), Fas (apoptosis-related protein) and inflammatory cytokines (interleukin [IL]-1 and -6 and tumor necrosis factor-alphas [TNF-α]) of AF cells. Results were evaluated by semiquantitative analysis of densitometry. Histologic analysis of AF tissues was performed in hematoxylin-eosin and Masson trichrome stained sections.

Results: At 6 months of age, OLETF rats showed higher body weight (565 g vs. 448 g, $p<0.05$) and 2-hour postprandial glucose level (225 mg/dl vs. 119 mg/dl, $p<0.01$) than LETO rats. The apoptotic index of AF cells and the degree of Fas expression were higher in the OLETF rats compared to LETO rats (22.9% vs. 15%, $p<0.05$; 2.4 times, $p<0.01$). The degree of expression of MMP-1, -2, -3 and -13 was higher in the OLETF rats than LETO rats (1.4 times, $p<0.05$; 5 times, $p<0.01$; 1.3 times, $p<0.05$; 1.5 times, $p<0.05$). The degree of expression of TIMP-1 and -2 was higher in the OLETF rats than LETO rats (1.9 times, $p<0.01$; 1.4 times, $p<0.05$). The degree of expression of IL-1 and -6 and TNF-α was higher in the OLETF rats than LETO rats (1.3 times, $p<0.05$; 3.9 times, $p<0.01$; 1.4 times, $p<0.05$). Histological analysis showed more severe loss of lamellar pattern (fragmentation and disorganization) and fibrosis in AF tissues of OLETF rats compared to LETO rats.

Conclusion: Hyperglycemia is associated with increased apoptosis and expression of matrix degrading and fibrotic enzymes and inflammatory cytokines in AF cells. These changes result in more severe loss of lamellar pattern and fibrosis in AF tissues, leading to rapid IDD. To our knowledge, this is the first study to demonstrate biochemical mechanism underlying association of DM and AF degeneration.

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Combinatory Therapy of Induced Pluripotent Stem Cell-Derived Neural Stem Cells with Chondroitinase ABC Pre-Treatment Promotes Functional Repair in Chronic Cervical Spinal Cord Injury

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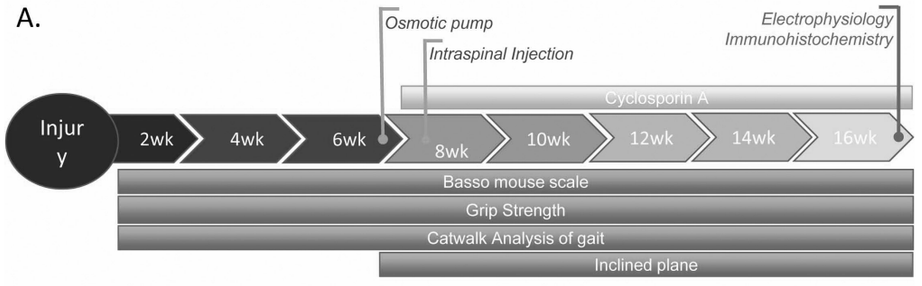
Introduction: Aspects of chronic spinal cord injury (SCI) environment such as formation of glial scars and Chondroitin sulfate proteoglycans (CSPGs) act as barrier to repair and regeneration. To address this environment Chondroitinase ABC (ChABC) is used to breakdown CSPGs and facilitate a permissive 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 eight weeks after transplantation, we performed histological and electrophysiological analysis.

Results: The administration of ChABC reduces elements of the glial scar nd 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 synaptic connections via glutamate and acetylcholine receptors in patch clump analysis.

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.

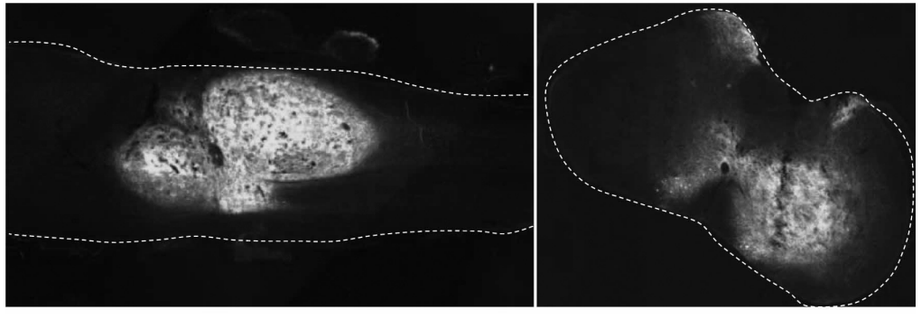
Figure 1. Schematic representation of experimental design.



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.



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Effect of RNA Interference (RNAi)-Mediated Suppression of FAS and P75 Genes on Viability of Rat Notochordal Cells

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Introduction: RNA interference (RNAi) enables inhibition of specific genes by sequence-specific gene silencing by double-stranded RNA (dsRNA). It involves post-transcriptional gene silencing via a process by which dsRNA inhibits gene expression through degradation of a specific, targeted mRNA. Small interfering RNA (siRNA), a type of RNAi, is a hybrid consisting of a sense and antisense strand homologous in sequence to the suppressed gene. Therefore, synthetic siRNA can trigger an RNAi response in mammalian cells and induce inhibition of specific gene expression. Fas and p75 death receptors are reported to cause apoptosis of intervertebral disc cells, which results on disc degeneration. Anti-apoptotic agents, such as caspase inhibitors and growth factors, attenuate apoptosis of disc cells. However, these agents block apoptosis after its initiation or at a late stage. Therefore, activation of early apoptotic signals may cause detrimental effects on disc cell metabolism and activity. These limitations suggest that siRNA technology can be used to target the early stage of apoptosis and by acting prior to caspase activation. We performed the current study to investigate the effect of siRNA on Fas and p75 gene expressions, apoptosis, and proliferation in rat disc cells treated with serum deprivation.

Materials/Methods: Disc cells were isolated from nucleus pulposus tissues of 4-week old rats, cultured, and placed in either 10% (normal control) or 0% (apoptosis-promoting condition) fetal bovine serum (FBS) for 48 hours. The expression of Fas and p75 and viability (apoptosis and proliferation) of the cells were determined. To suppress Fas and p75 expressions, siRNA against Fas (Fas siRNA) and p75 (p75 siRNA) was synthesized and transfected into the cells using oligonucleotides. The suppression of Fas and p75 expressions was investigated by RT-PCR and densitometry. The effect of Fas siRNA and p75 siRNA on apoptosis and proliferation of the cells was determined. Negative siRNA and MOCK (transfection agent alone) were used as control.

Results: Serum deprivation increased apoptosis by 40.3% and decreased proliferation by 45.3% in rat disc cells (both, $p < 0.001$), and upregulated Fas and p75 expressions. Fas siRNA and p75 siRNA suppressed Fas and p75 expressions in 0% FBS. The rate of suppression by Fas siRNA and p75 siRNA was 68.5% and 72.5% at the mRNA level (both, $p < 0.001$). Suppression of Fas and p75 expressions by siRNA inhibited apoptosis by 9.3% and 7% (both, $p < 0.05$) and increased proliferation by 21% and 14% (both, $p < 0.05$) in 0% FBS.

Conclusions: RNAi-mediated suppression of Fas and p75 genes results in significant inhibition of apoptosis and increased proliferation of rat disc cells under serum deprivation. This dual positive effect of RNAi might be a powerful therapeutic approach for disc degeneration by suppression of harmful gene expression. RNAi can also be used in gene function studies for the process of disc degeneration.

Preoperative Factors Affecting Postoperative Axial Neck Pain following Cervical Laminoplasty

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Introduction: Postoperative axial neck pain following cervical laminoplasty is a well-known complication. Although past reports have indicated the involvement of multiple clinical factors, particularly radiographic factors, few reports have investigated the involvement of both physical or mental outcome scores and imaging evaluations. The purpose of this study is to clarify preoperative factors affecting postoperative neck pain.

Methods: We retrospectively evaluated the outcomes of 103 patients who underwent cervical laminoplasty for cervical compression myelopathy. The primary outcomes were numerical rating scale (NRS, 0–10) for neck and scapular pain, Japanese Orthopaedic Association (JOA) score, and Short Form 36 Health Survey [physical and mental summary scores (PCS and MCS, respectively)].

Postoperative axial pain was defined as NRS ≥ 5. Cervical alignment (C2–7 Cobb angle), range of motion, C7 slope, and spondylolisthesis were evaluated as imaging parameters. MRI evaluation included the presence or absence of intramedullary signal changes as well as the maximum spinal cord compression. Statistical analyses used were the Mann–Whitney U test, chi-square test, and multivariate logistic regression model. P-values < 0.05 were considered statistically significant.

Results: There were 67 men and 36 women, with a mean age of 65 years (32–89 years). The mean follow-up period was 24 months (12–60 months). The surgical levels included C7 in 89% of the patients. Twenty-five patients (23%) had postoperative axial pain (NRS ≥ 5) and were compared with 78 patients without postoperative axial pain (NRS < 4). The proportion of female and the average score of preoperative neck pain were higher in the postoperative axial pain group. Furthermore, preoperative PCS and MCS were significantly worse in the postoperative neck pain group. None of the imaging parameters were statistically different between the two groups. Of the preoperative factors, multivariate logistic regression analysis revealed that PCS (OR: 5.8) and MCS (OR: 3.6) were risk factors for postoperative neck pain.

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Conclusions: The patients with postoperative axial neck pain showed poorer outcomes both pre- and postoperatively. To the best of our knowledge, this is the first report of physical and mental factors on postoperative axial neck pain, with a clear definition of neck pain in terms of the pain distribution and intensity. As our procedure was not a muscle-preserving one, the postoperative neck pain could be higher. Nevertheless, preoperative physical and mental factors were significantly worse in the postoperative axial neck pain group, even after adjusting for the preoperative neck pain scores. Although postoperative factors can also modify the degree of axial neck pain, preoperative physical and mental problems can be predictive for postoperative complaints of axial neck pain.

Table 1. Comparison between patients with (NRS ≥5) and without (NRS <5) postop axial pain groups

			No Pain N=78		Axial Pain N=25		
			Average	SD	Aveage	SD	p value
Age			63.9	11.8	65.8	10.7	0.48
Sex*	M/F		55/23		12/13		0.04
Follow-up			24.1	8.7	25	11.9	0.72
CSM/OPLL*			41/37		18/7		0.11
Involvement of C7*			70/8		21/4		0.83
Neck Pain		pre	1.4	2.4	3.6	2.5	0.00
		post	1.0	1.4	6.3	1.3	0.00
SF-36	PCS	pre	23.4	19.3	16.0	15.4	0.09
		post	35.2	17.5	20.5	16.4	0.00
	MCS	pre	50.9	11.5	42.7	8.5	0.00
		post	52.8	9.6	43.3	9.1	0.00
JOA score		pre	10.4	2.5	10.0	2.7	0.53
		post	13.7	2.3	12.5	2.1	0.03
		Recovery rate	49.2	30.8	32.1	29.0	0.03
Radiographic							
	C2/7 Cobb	pre	9.3	9.8	9.8	7.9	0.81
		post	9.5	11.8	7.6	11.3	0.48
	ROM	pre	39.7	15.2	37.1	16.0	0.60
		post	25.7	12.3	23.7	12.1	0.47
	C7 slope	pre	26.2	8.9	26.6	8.7	0.81
		post	26.4	9.6	24.8	9.3	0.46
	Slip (y/n)*	pre	66/10		22/3		1.00
MRI							
	MSCC	pre	45.8	18.0	40.9	12.8	0.26
	T2 high(y/n)*	pre	68/10		20/5		0.51

** Number of patients*

Analysis of Early Distal Junctional Kyphosis (DJK) after Cervical Deformity Correction

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Introduction: Proximal junctional kyphosis is prevalent following thoracolumbar deformity correction. Few studies have prospectively assessed the prevalence, risk factors and effect of distal junctional kyphosis after cervical deformity correction. The purpose of this study was to assess risk factors and effects of development of distal junctional kyphosis following surgical correction of cervical and cervico-thoracic deformities.

Methods: A prospective database of operative cervical deformity patients (CD) was analyzed for development DJK at 6 month follow-up interval. Inclusion criteria were cervical kyphosis (CK) >10°, cervical scoliosis (CS) >10°, C2-7 SVA>4cm or chin-brow vertical angle >25°. DJK was defined as a change in kyphosis >10° in LIV to LIV-2 from pre- to post-op. Patients with the above criteria were excluded as having DJK if their pre-operative LIV to LIV-2 value was <0°. Patients with DJK were compared to those without DJK with respect to demographic, surgical, radiographic parameters and patient reported outcome measures (NDI, mJOA, NSR neck and arm pain).

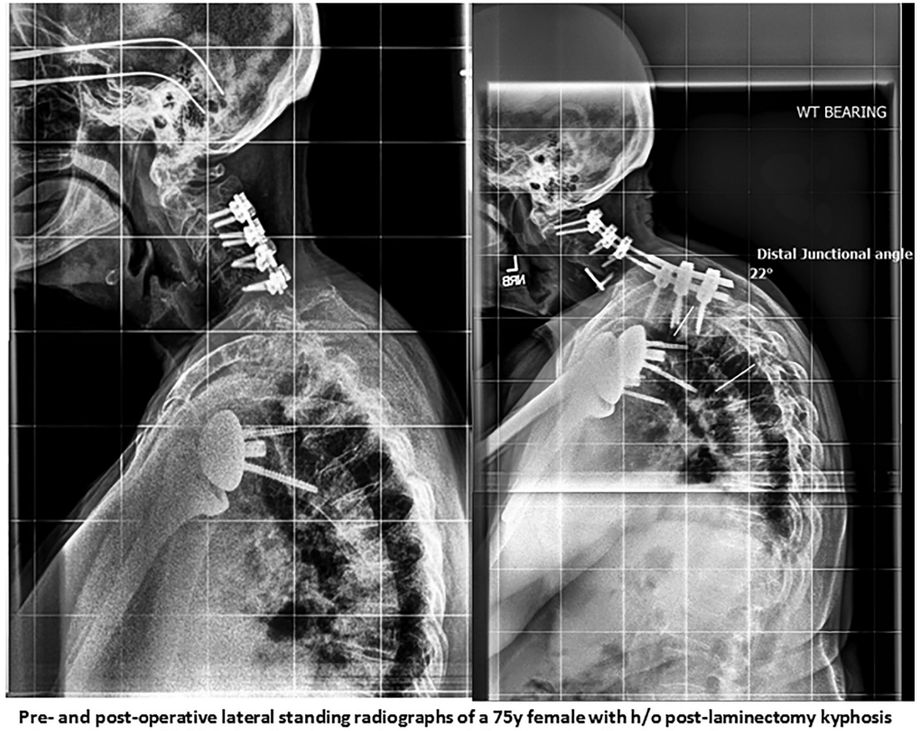
Results: 67 CD patients (mean age 62 yrs, 56% female, 41% revisions and minimum follow up 6 months) were included. DJK occurred in 16 (24%) patients (11 within 3 months and 5 between 3 and 6 months, Figure 1); 2/16 (12.5%) required revision. 75% of the patients with DJK had the LIV at or above T7. The most common failure mechanisms were ligamentous (75%), fracture (19%) and screw pull-out (6%). DJK patients had more posterior levels fused (8.6 vs. 6.1, p=0.02), a higher mean total posterior osteotomy grade (5.9 vs. 3.3, p=0.03) and higher use of transition rods (57% vs. 43%, p=0.01). 78% of DJK patients did not have the secondary, thoracolumbar driver of deformity corrected vs. 35% in noDJK (p=0.04). DJK patients had more preoperative thoracic kyphosis (52.6° vs. 40.8°, p=0.04) and less PI-LL mismatch (-8.2° vs. 5.8°, p=0.05). Postoperatively, DKJ patients had worse C2-C7 SVA (53.5 vs. 33.1mm, p<.001) and T1Slope-Cervical lordosis (34° vs. 21°, p=.01).

See Disclosure Index pages 39–89.

Multivariate-analysis using binary logistic regression revealed use of transition rods as the only parameter affecting occurrence of DJK (OR- 0.3, CI- 0.05- 0.8, $p = 0.03$). None of the baseline and post-operative pROM were significantly different between the DJK and noDJK groups ($p > 0.05$).

Conclusions: Distal junctional kyphosis is prevalent following cervical deformity correction. DJK patients had longer posterior fusions, larger total posterior osteotomy grades and more preoperative thoracic kyphosis. Fewer DJK patients had thoracic and lumbar drivers of their deformities corrected. Postoperatively DJK patients had worse cervical alignment.

Figure 1.



Pre- and post-operative lateral standing radiographs of a 75y female with h/o post-laminectomy kyphosis who underwent C2-T1 fusion showing development of distal junctional kyphosis at 6m post-op

Cervical Spine Surgery Malpractice Litigation

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Background: Complications related to cervical spine surgery often lead to litigation. Few studies have evaluated the association between complications and medical malpractice proceedings, outcomes, and awards.

Methods: The medicolegal research service VerdictSearch (ALM Media Properties, LLC, New York, NY), a comprehensive database that includes cases from February 1988 to May 2015, was searched for "cervical spine." Patient age, sex, type of surgical complication, delay in diagnosis, and the medical specialty of provider were recorded. Complications were sorted into catastrophic and non-catastrophic categories. Catastrophic complications were defined as paralysis, anoxic/hypoxic brain injury, and death; non-catastrophic complication included all other complications. Chi-squared and t-tests were utilized to evaluate the effect of these variables on case outcomes and total indemnity.

Results: 84 relevant cases were available for review with 32.1% (27/84) involving catastrophic complications. Overall, 61.9% (52/84) resulted in a defendant ruling, 21.4% (18/84) resulted in a plaintiff ruling, and 16.7% (14/84) resulted in settlement. The awards granted for the plaintiff rulings ranged from \$162,000 to \$13,300,000 (mean \$2,353,015±\$3,356,961) while the award for settlements ranged from \$900,000 to \$9,000,000 (mean \$3,740,200±\$2,641,981). Cases involving a delay in diagnosis were significantly more likely to result in a defendant loss compared to no delay (70% vs. 30%; $p = 0.0268$), and plaintiff awards were significantly larger when there was a delay in diagnosis (mean \$6,837,000 vs. \$1,792,517; $p = 0.0204$). Cases involving catastrophic complications were more likely to go to court than settle out of court (63% vs. 37%; $p = 0.0006$). In cases resulting in settlement, there was no statistical difference between awards granted for catastrophic complications and non-catastrophic complications (mean \$3,961,280 vs. \$3,187,500; $p = 0.3198$). In cases that resulted in settlement, male patients were awarded significantly less than females (mean \$3,246,900 vs. \$6,700,000; $p = 0.0432$). Settlement cases involving orthopedists were associated with larger monetary awards when compared to other specialties (mean \$5,653,200 vs. \$2,975,000; $p = 0.0430$). Patient age was not statistically associated with case outcome or award granted.

Conclusions: This study examined 84 legal cases following cervical spine surgery complications. Cervical spine surgery cases involving a delay in diagnosis and catastrophic complications are a predictor of plaintiff verdicts and are linked to large sums awarded to the plaintiff.

See Disclosure Index pages 39–89.

TABLE 1 Case Characteristics for 84 Cervical Spine Surgery Malpractice Suits

Variable	No. Cases
Avg. Age (± STDEV)	50.6 yrs (± 15.9)
Age not provided	4 cases
Sex	
Females	34 (40.5%)
Males	50 (59.5%)
State	
California	19
Georgia	5
New York	19
Ohio	7
Texas	8
Other states	26
(CT=1) (FL=3) (IL=1) (MA=3) (MD=4) (MI=4) (MO=1) (NJ=2) (NC=1) (PA=2) (SC=1) (VA=2) (WV=1)	
Procedure*	
Decompression	12
Discectomy	18
Foraminotomy	6
Fusion	38
Laminectomy	14
Other surgical procedure	15
Procedure not listed	6
Complication**	
Death	4
Spinal Cord Injury	24
Anoxic/hypoxic brain	1
Nerve root injury	9
Malpositioned instrumentation	3
Incorrect site surgery	1
Other medical or anesthetic complications	61
Delay in Diagnosis	
Yes	10
No	74
Delay in Treatment	
Yes	8
No	76
Profession Sued	
Orthopaedic Surgery	38
Neurosurgery	40
Non-Surgical	6

28.5% of patients underwent multiple procedures
**23.8% of cases listed more than one complication*

Table 2 Case outcomes for delay in diagnosis and catastropic complications

	Defense Verdict	Plaintiff Verdict & Settlement	Court Case	Settlement
Delay in diagnosis	3 (30.0%)	7 (70.0%)*	5 (50.0%)	5 (50.0%)**
No delay in dx	49 (66.2%)	25 (33.8%)	65 (87.8%)	9 (12.2%)
Catastrophic	14 (51.9%)	13 (48.1%)	17 (62.9%)	10 (37.1%)***
Non-catastrophic	38 (66.7%)	19 (33.3%)	53 (92.9%)	4 (7.1%)

p=0.027 statistically significant
**p=0.002 statistically significant*
***p=0.0005 statistically significant*

Complications and Mortality following 1 to 2 Level Anterior Cervical Fusion for Cervical Spondylosis in Patients Above 80 Years of Age

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Introduction: Cervical spondylosis is frequently observed in the elderly and is the most common cause of myelopathy in older adults. With increasing life expectancies, a greater proportion of patients are being treated with spine surgery at a later age. Limited information is available regarding outcomes following anterior cervical fusion surgery in patients 80 years of age or older. The objective of this study was to determine the complication and mortality rates in patients 80 years of age and older who were treated with anterior cervical fusion surgery and to compare these rates against those of other elderly patients.

Materials and Methods: Medicare data from the PearlDiver Database (2005–2012) was retrospectively queried for patients who underwent primary 1–2 level anterior cervical spine fusion surgeries for cervical spondylosis. After excluding patients with prior spine metastasis, bone cancer, spine trauma, or spine infection, this cohort was divided into two study groups: patients 65–79 (51,808) and ≥80 years old (5,515) were selected. A cohort of 5,515 matched control patients was selected from the 65–79 year old and 90-day complication rates and 90-day and 1-year mortality rates were compared between cohorts.

Results: The proportion of patients experiencing at least one major medical complication was relatively increased by 53.4% in patients ≥80 years (OR 1.63). Patients 80 years of age or older were more likely to experience dysphagia (OR 2.16), re-intubation (OR 2.34), and aspiration pneumonitis (OR 3.17). Both ninety-day (OR: 4.34) and one-year (OR 3.68) mortality were significantly higher in the ≥80 year cohort.

Conclusions: Patients 80 years of age or older are more likely to experience a major medical complication or mortality following anterior cervical fusion for cervical spondylosis than patients 65–79 years old. Dysphagia, aspiration pneumonitis, and reintubation rates are also significantly higher in patients 80 years of age or older.

See Disclosure Index pages 39–89.

Intraoperative Neuromonitoring for Anterior Cervical Spine Surgery: What is the Evidence?

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Introduction: Neurological injuries are known complications of spine surgery. While intraoperative neuromonitoring (ION) has been shown to decrease the risk of neurological injury in deformity surgery, its utility in anterior cervical spine surgery (ACSS) remains controversial. Proponents of ION for ACSS claim that it improves patient safety and functional outcome while opponents refute this claim by citing increased cost and the lack of correlation between ION abnormalities and postoperative neurological deficits especially with anterior cervical discectomy and fusions (ACDFs). The goal of this meta-analysis was to 1). Assess the risk of neurological injury following ACSS with and without ION and 2). Evaluate differences in the sensitivity and specificity of ION for ACSS.

Materials and Methods: A systematic search of multiple medical reference databases was conducted for studies on ION use for ACSS. Studies that involved cranial surgery, posterior cervical spinal surgery, or non-spinal surgery were excluded. Meta-analysis was performed using the random-effects model for heterogeneity.

Results: The search yielded 10 studies totaling 26,357 patients. The weighted risk of neurological injury following ACSS was 0.64% (0.23–1.25). The weighted risk of neurological injury was 0.20% (0.05–0.47) for ACDFs compared to 1.02% (0.10–2.88) for corpectomies. For ACDFs, there was no difference in the risk of neurological injury with or without ION (OR: 0.726, CI: 0.287–1.833, $p = 0.498$). The pooled sensitivities and specificities of ION for ACSS are 71% (CI: 48%–87%) and 98% (CI: 92%–100%), respectively. Unimodal ION has a higher specificity than multimodal ION (unimodal: 99% (CI: 97%–100%), multimodal: 92% (CI: 81%–96%), $p = 0.0218$). There was no statistically significant difference in sensitivities between unimodal and multimodal (68% vs. 88%, respectively, $p = 0.949$).

Conclusions: The risk of neurological injury following ACSS is low although procedures involving a corpectomy may carry a higher risk. For ACDF alone, there is no difference in the risk of neurological injury with or without ION use. Unimodal ION has a higher specificity than multimodal ION and may minimize "subclinical" intraoperative alerts in ACSS. Future studies should examine the utility of ION with corpectomy versus ACDF alone since such comparative studies do not exist.

The Change of Cervical Spine Alignment along with Aging in Asymptomatic Population

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Introduction: Previous studies demonstrated the influence of lumbar and thoracic spine on cervical spine alignment, but few has reported the cervical spine alignment change along with aging in asymptomatic population.

Methods: Asymptomatic population were divided into four groups according to different age (Group A: ≤ 20 years; Group B:21–40years; Group C:41–60years; Group D: ≥ 61years). Each group was composed of 25 subjects. The following parameters were measured: C0-1 Cobb angle, C1-2 Cobb angle, C2-7 Cobb angle, C1-7 SVA, C2-7 SVA, center of gravity-C7 SVA(CG-C7 SVA), TIA, NT, cervical tilt, cranial tilt, T1 slope(TS), TS-CL. ANOVA statistical method was used to analyze the differences among four groups, then linear regression analysis was performed to analyze correlation of the cervical spine alignment with the aging.

Results: C1-7 SVA, C2-7 SVA, CG-C7 SVA, TIA, NT and cranial tilt were found statistically different among four groups ($P < 0.01$). From Group A to Group D, the mean C1-7 SVA were 30.7mm, 26.0mm, 21.8mm and 36.9mm, the mean C2-7 SVA were 18.7mm, 14.7mm, 11.9mm and 24.7mm, the mean CG-C7 SVA were 19.6mm, 16.6mm, 9.4mm and 26.7mm. The mean TIA were 66.8°, 69.4°, 67.4° and 76.9°, the mean NT were 39.4°, 43.8°, 44.2° and 48.2°, the mean cranial tilt were 5.7°, 4.8°, 3.2° and 9.5°. Further linear regression indicated that TIA($r = 0.319$;$P < 0.01$) (Figure 1) and NT($r = 0.279$;$P < 0.01$) (Figure 2) were positively correlated with aging.

Conclusion: Both TIA and NT increase along with aging in asymptomatic population.

See Disclosure Index pages 39–89.

Figure 1. The correlation of TIA with aging.

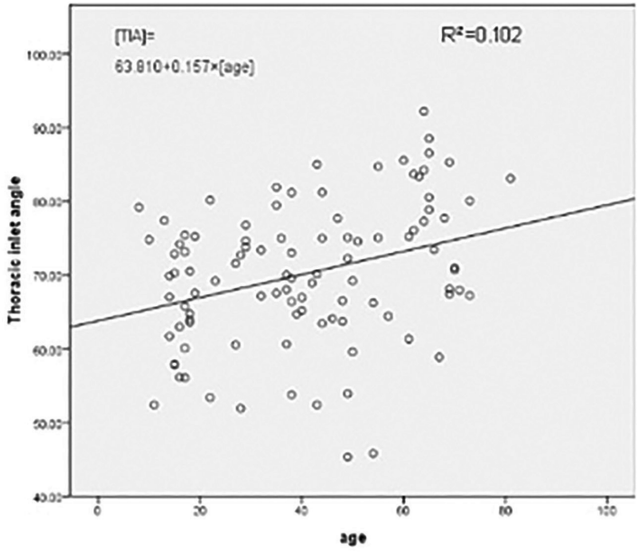
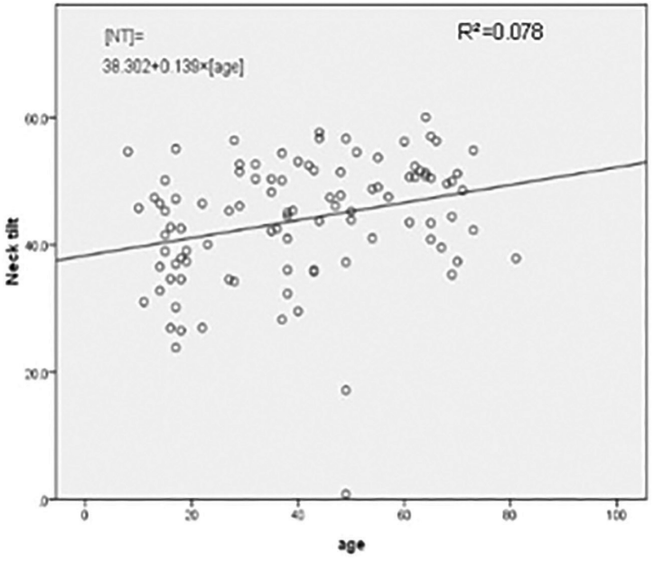


Figure 2. The correlation of NT with aging.



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The Etiology of Revision Surgery on Cervical Degenerative Diseases: Retrospective Study on More than 1,000 Primary Cases in a Single Institution

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Introduction: Revision surgery is occasionally required after cervical spine surgery. It has been shown that both causes and timings of revision surgeries vary due to surgical approaches and types of the diseases. The purpose of this study is to retrospectively investigate all the cases (more than 1000 cases) which required revision surgeries after primary cervical spine surgeries in our institution.

Materials and Methods: This study includes 1,450 cases which underwent cervical primary surgery between 1999 and 2014 in our single institution. The surgical approaches that we used were 1: Anterior decompression and fusion (ADF 520 cases), 2: Posterior decompression (Laminoplasty; LAMP 820 cases), 3: Posterior decompression and fusion (PDF 75 cases), 4: Anterior and posterior combined (A/P 10 cases), 5: Foraminotomy (25 cases). The diseases include cervical spondylotic myelopathy (CSM), cervical ossification of posterior longitudinal ligament (C-OPLL), cervical disc herniation (CDH), cervical spondylotic amyotrophy (CSA) and cervical spondylotic radiculopathy (CSR). Of all the 1,450 cases, we retrospectively investigated as follows; 1. revision surgery (Yes or No), 2. timing of revision surgery (x days after primary surgery), 3. cause for revision surgery. For this study, we used Kaplan-Meier survival curve for the analyses. We examined the revision surgery rate on each surgical approach. For the timing of revision surgery, we divided into two time frame. One is less than 3 months and the other is more than 3 months after primary surgery. We also analyzed 5 and 10 years survival rate for each surgical approach.

Results: Figure 1 shows Kaplan-Meier survival rate on all the cervical spine cases 1,450 total. Five year survival rate was 94 % and 10 year survival rate was 92%. Figure 2 shows Kaplan-Meier survival curve on each surgical approach. Of note, there is a relatively significant difference between ADF and LAMP (red and blue lines). Figure.2 also shows there are more than 5% survival differences in 5 and 10 years between ADF and LAMP. Figure 3 shows the main causes and the timing on each surgical approach. In the long term after primary surgery we found that in ADF group, adjacent segment disease was a main reason for revision surgery. In LAMP group, recurrence of stenosis at the same segments was the main reason for revision surgery.

Conclusion: We retrospectively analyzed more than 1,000 cervical spine cases performed in our hospital. We were able to find the different outcome between the anterior approach and posterior approach.

See Disclosure Index pages 39–89.

Figure.2

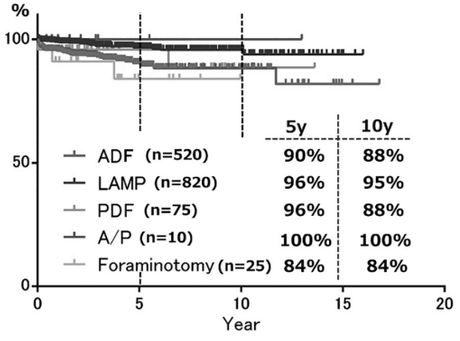

Figure.1

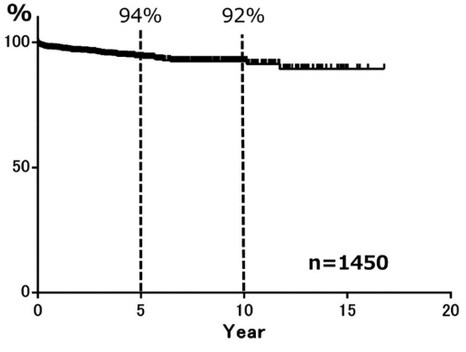

Figure.3

Surgical Approach	Revision Surgery Rate	Less than 3 months	More than 3 months
ADF	7.7%	Bone graft complication 1% Hematoma 0.8% C5 palsy0.4%	Adjacent Segment 2.3% Non-union 0.8%
LAMP	2.7%	Hematoma0.2% Infection 0.2% C5 palsy0.1%	Recurrence of stenosis 0.9%
PDF	5.4%	Implant issues 1.3%	Adjacent segment 1.3%
A/P	0.0%	—	—
Foramin-otomy	12.5%	Inadequate improvement 4.2%	Recurrence on different level 8.3%

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Total Disability Index (TDI) a Single Measure of Disability in Patients with Neck and/or Back Pain

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Introduction: The NDI and ODI are the two most common functional status measures for neck and back pain. While these instruments are intended to assess symptoms specific to either the neck or back, symptoms are infrequently isolated to a single region. Furthermore, no single patient reported outcome measure exists to evaluate those with combinations of neck and back pain. The purpose of this study is to 1) prospectively validate the previously developed Total Disability Index (TDI) which combines overlapping elements from the NDI and ODI with the unique items from each and 2) to demonstrate that TDI can generate component NDI and ODI scores with excellent reliability while providing a complete assessment of disability.

Materials and Methods: The14-item TDI derived from domains of the NDI and ODI was administered to consecutive patients with spinal deformity or combinations of neck and/or back pain presenting to a single spine practice. Patients were assessed with NDI, ODI, EQ5D and pain visual analogue scale (VAS). Validation of internal consistency, test-retest reproducibility, standard error of measurement (SEM) minimal detectable change (MDC) and validity of reconstructed NDI and ODI scores derived from TDI (rNDI and rODI) were assessed.

Results: 258 patients (mean age 52.8, 55% female) completed initial assessments, 161 with back pain, 105 with neck pain, 39 with back and neck pain, 57 with spinal deformity, and 31 with no pain or deformity. 155 (57.0%) patients completed retests. Patients represented a wide range of disability states (range NDI 0–88, ODI 0–92, TDI 0–94, mean NDI 30.0, ODI 35.2, TDI 33.0). Mean time between test and retest was 5.8 days. TDI demonstrated excellent internal consistency (Cronbach's alpha = 0.929). TDI test-retest reliability was excellent (ICC = .96, 95% [0.95–0.97]). Reconstructed NDI and ODI scores were similar to NDI and ODI, respectively (Table 1). In patients with only neck pain mean rNDI vs. NDI was 33.3 vs. 35.5 ($p < 0.05$). In patients with only back pain mean rODI vs. ODI was 39.5 vs. 38.8 ($p = .3$). In patients with both neck and back pain mean rNDI vs. NDI was 42.2 vs. 42.2 ($p = 0.9$) and mean rODI vs. ODI was 41.0 vs. 39.3 ($p = 0.5$). For TDI, NDI and ODI, SEM were 4.4, 4.9 and 4.7, and MDC were 12.1,13.5, and 13.0,respectively. TDI showed strong correlations with,NDI ($r = .87$), ODI ($r = .93$) and EQ5D ($r = .80$) and moderate correlations with most VAS categories (Table 2).

See Disclosure Index pages 39–89.

Conclusion: This study demonstrates that the shorter, less time consuming Total Disability Index is a valid and reliable measure of disability in patients with various combinations of back and neck pain. Reconstructed NDI and ODI scores derived from the TDI were similar to NDI and ODI scores.

	n	ODI	rODI	NDI	rNDI	TDI
Back pain only	83	38.77ϟ	39.49ϟ	24.60•ϟ	30.58•ϟ	33.12ϟ
Neck pain only	48	29.96ϟ	31.02ϟ	35.46•ϟ	33.25•ϟ	31.43ϟ
Neck & Back pain	39	39.28ϟ	41.03ϟ	42.21ϟ	42.15ϟ	41.14ϟ
Deformity	57	34.67ϟ	35.83ϟ	28.88ϟ	30.49ϟ	32.28ϟ
All patients	258	35.23•	36.21•	29.86•	32.11•	33.00

Table 1: Descriptives of reconstructed ODI/NDI (rODI/rNDI) scores with true ODI/NDI scores. (•) denotes significant differences ($p<0.05$) via paired t-test comparing true vs. reconstructed scores within cohorts. (ϟ) denotes significant differences ($p<0.05$) via one-way ANOVA compaing scores downwards between cohorts

	Pain or Deformity Category					
	Back only n=83	Neck only n=48	Back & Neck n=39	Deformity n=57	No Pain n=31	Total n=258
ODI	0.938•	0.938•	0.934•	0.911•	0.975•	0.931•
NDI	0.944•	0.944•	0.927•	0.851•	0.903•	0.868•
EQ5D	0.823•	0.823•	0.758•	0.814•	0.828•	0.796•
VAS neck	0.292•	0.292	0.541•	0.476•	0.401••	0.401•
VAS arm	0.146••	0.146	0.539•	0.471•	0.272	0.346•
VAS back	0.524•	0.524•	0.637•	0.58•	0.458••	0.541•
VAS leg	0.381•	0.381••	0.534••	0.548•	0.109	0.443•
•p<0.005						
••p<0.05						

Table 2 - TDI correlations with standard indices

Predictive Model for Return to Work after Elective Surgery for Cervical Degenerative Disease: An Analysis from National Neurosurgery Quality Outcomes Database Registry

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Background: Current costs associated with spine care are unsustainable. The productivity loss and time away from work in gainfully employed patients contributes greatly to the financial burden. Therefore, it is vital to identify the factors associated with returning to work after cervical spine surgery. We present a predictive model of ability to return to work (RTW) after cervical spine surgery for degenerative spine disease.

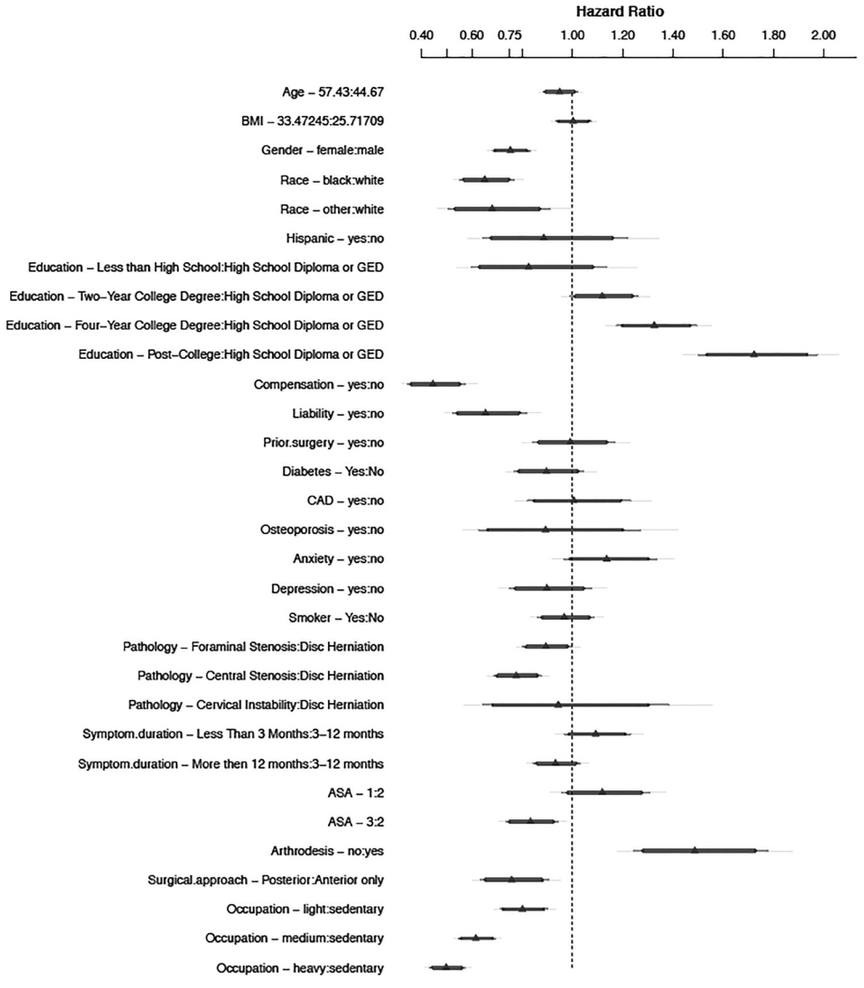
Methods: Total 2,565 patients undergoing elective spine surgery for degenerative cervical disease that were employed were entered into a prospective multi-center registry (N2QOD). Baseline and 3-month postoperative patient-reported outcomes neck disability index (NDI) were recorded. The time to RTW was defined as the period between operation time and date of returning to work. A multivariable Cox proportional hazards regression model, including an array of preoperative factors, was fitted for RTW. The model performance was measured by the c-index.

Results: 83.9% of patients (n = 2,152) returned to work within 3-months postoperatively. The risk-adjusted predictors of lower likelihood of RTW were female patients, non-white race, those on workers' compensation, those on liability insurance, those with diagnosis of stenosis, higher ASA grades, those operated through a posterior approach, and those occupied with a manual labor job. The likelihood of RTW within 3 months was higher in patients with higher education level, and those undergoing non-fusion surgeries (Figure 1). The c-index of our model performance was 0.66.

Conclusion: We present a novel predictive model for probability of RTW after cervical spine surgery. Spine care providers can use this model to educate patients and encourage them in shared decision-making regarding the RTW outcome. This will result in better communication between patients and clinicians and improve recovery expectations, which will ultimately increase the likelihood of a positive RTW trajectory.

See Disclosure Index pages 39–89.

Figure 1. Adjusted effect of predictors of RTW computed using a multivariable cox proportional hazard regression model. The hazard ratios (HRs) for the continuous variables (age, BMI, NDI) in the model were computed based on the upper and lower quartile values



Can the Rate at Which Spinal Fusion is Recommended to Patients be Predicted by Spine Surgeon Demographic Factors?

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Introduction: Over the last three decades, the utilization of elective spine fusion procedures, as well as their associated costs, has risen dramatically. Previous work has shown a high degree of variability in the utilization of the procedure across the United States, reflecting the lack of clear evidence-based guidelines on indications for the procedure. These findings have led to increased scrutiny of the utilization of elective spine fusion and have raised questions regarding the utility of the procedure for certain patients. The purpose of this study was to evaluate associations between surgeon-specific demographic factors and the rate at which elective spine fusion is recommended to patients. Given the potential complications and costs to the healthcare system, it is vital to understand what factors may be influencing variations in utilization of spine fusion procedures across the United States.

Methods: Data from Centers for Medicare and Medicaid Services (CMS) related to spine surgeon practice patterns was compiled and analyzed. Rate of spine fusion recommendation was defined as the number of spine fusion procedures (measured using Current Procedural Terminology (CPT) billing codes) performed by a surgeon per total number of unique Medicare beneficiaries seen. Inclusion criteria were either neurosurgeons or orthopaedic surgeons who performed 11 or more separate spine fusion procedures on Medicare patients between 2011–2013 as defined by this database. Surgeon demographic information was then collected from public record, including type of surgical training (orthopaedic or neurosurgeon), years in practice, practice setting (academic or private), type of medical degree (MD or DO), location of medical school (U.S. or foreign), gender, and geographic region of practice (West, Midwest, South, or Northeast).

Results: A total of 3,979 spine surgeons who practice in the United States met the inclusion criteria for this study (Table 1). Surgeons in this cohort performed fusion on 171,676 Medicare patients from 2011–2013, with an average rate of spine fusion recommendation of 7.5 ± 4.8%. Elective spine fusion recommendation rates were significantly higher for surgeons who practiced primarily in an academic vs. private setting (RR = 1.44, 95% CI [1.35–1.53]; $p < 0.0001$), were neurosurgeons vs. orthopaedic surgeons (RR = 1.10, 95% CI [1.05–1.15]; $p < 0.0001$), practiced in the West vs. Midwest, South, and Northeast region of the United States (RR = 1.20, 95% CI [1.14–1.27]; $p < 0.0001$, Figure 1), and had fewer than 27 years in practice (RR = 1.17, 95% CI [1.10–1.24]; $p < 0.0001$). Location of medical school, type of medical degree, and gender had no significant effect on surgeon practice patterns.

See Disclosure Index pages 39–89.

Conclusion: The recommendation rate for elective spine fusion varies widely according to type of practice, type of training, region, and experience. These findings continue to suggest poor scientific consensus on the indications for this procedure. Considering the potential complications and significant cost, as well as disagreement regarding indications, knowledge of theses trends may help to identify methods for developing greater consensus in the treatment of patients who may require elective spine fusion.

Table 1. Average fusion recommendation rates, organized by demographic variable.

		Number of Surgeons (Proportion of Cohort)	Average Fusion Recommendation Rate
Type of Surgeon	Orthopaedic	1,897 (47.7%)	7.4 ± 4.8%
	Neurosurgeon	2,082 (52.3%)	7.6 ± 4.8%
Type of Practice	Academic	362 (9.1%)	10.0 ± 5.7%
	Private	3,617 (90.9%)	7.2 ± 4.6%
Medical Degree	M.D.	3,803 (95.6%)	7.5 ± 4.8%
	D.O.	176 (4.4%)	6.8 ± 4.2%
Type of Graduate	U.S.	3,628 (91.2%)	7.4 ± 4.7%
	Foreign	351 (8.8%)	8.1 ± 5.5%
Gender	Male	3,895 (97.9%)	7.5 ± 4.8%
	Female	84 (2.1%)	7.3 ± 4.2%

Figure 1. Differences in elective spine fusion recommendation rates based on region.

Comparison of Single Level Anterior Cervical Discectomy and Fusion to Posterior Cervical Foraminotomy for Treatment of Cervical Radiculopathy: A National Healthcare Economic Perspective

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Introduction: Operative management to achieve nerve root decompression for symptoms of cervical radiculopathy is generally approached by either anterior cervical discectomy and fusion (ACDF) or posterior cervical foraminotomy (PCF). ACDF is more commonly performed, however current evidence suggests comparable efficacy in appropriately selected patients. Moreover, single center studies indicate PCF may be associated with significant cost savings. The objective of this investigation is to compare the two approaches in terms of safety and costs using a national insurance claims database.

Methods: This retrospective observational cohort study was conducted using the Truven Health MarketScan Research Database, spanning the years 2003 to 2014. A sequential algorithm was used to identify those undergoing single level ACDF or PCF for cervical radiculopathy. Individuals with multilevel decompressions, alternate interventions or diagnoses, less than 6-months of enrollment prior to the index procedure or less than 90-days of follow-up were excluded (Figure 1). Primary outcomes included mortality, adverse events and readmission to hospital over a 30-day period following intervention. Resource utilization was assessed through hospital length of stay and total payments to the health provider by a third party insurance provider, the individual themselves or Medicare. All payments were inflated to January 2016 values. Propensity score matching was used to balance groups on baseline covariates. Maximum caliper width was set to 0.25 times the standard deviation of the sample estimated propensity scores. The level for accepting statistical significance was set at 0.05.

Results: After screening, a total of 50,998 subjects over the age of 18 years old were included; the PCF cohort included 4,851 subjects and the ACDF cohort included 46,147. 70.6% of patients undergoing PCF were discharged on the same day, compared with 46.1% of ACDF cases ($p < 0.001$). Overall time in hospital was 0.27 [95% CI: 0.23, 0.30, $p < 0.001$] days shorter for the PCF cohort. Overall incidence of adverse events were 44.3/1000 cases for PCF and 42.1/1000 cases for ACDF. Adjusted difference was 1.4/1000 cases [95% CI: -5.4, 8.2; $p = 0.688$] and not significantly different between the two procedures. Vascular injury, post-operative dysphagia/dysphonia, cutaneous cerebrospinal fluid leak and deep venous thrombosis occurred with a significantly higher frequency in the ACDF cohort after propensity matching (Table 1). Conversely, wound infections and 30-day readmissions to hospital were significantly more frequent in the PCF cohort (Table 1). Mean unadjusted total payments were $15,281±12,225 for the PCF cohort and $26,849±16,309 for ACDF cohort. The adjusted difference was $11,757 [$11,365, $12,151, $p < 0.001$] for the index procedure and $11,420 [95% CI: $10,974, $11,866, $p < 0.001$] over a 30 day horizon; significantly favoring PCF from a cost reduction perspective.

See Disclosure Index pages 39–89.

Conclusion: Overall major adverse events were uncommon for either procedure. Hospital stay was shorter for those undergoing PCF, although 30 readmissions was significantly more common. The average cost difference including the 30-day post-operative period favored PCF and exceeded $11,000. This suggests a potential area for value improvement and implicates a need for additional clinical outcomes based study.

Figure 1. Flowchart outlining the sequential algorithm for case identification and exclusion. American Medical Association Current Procedural Terminology (AMA-CPT).

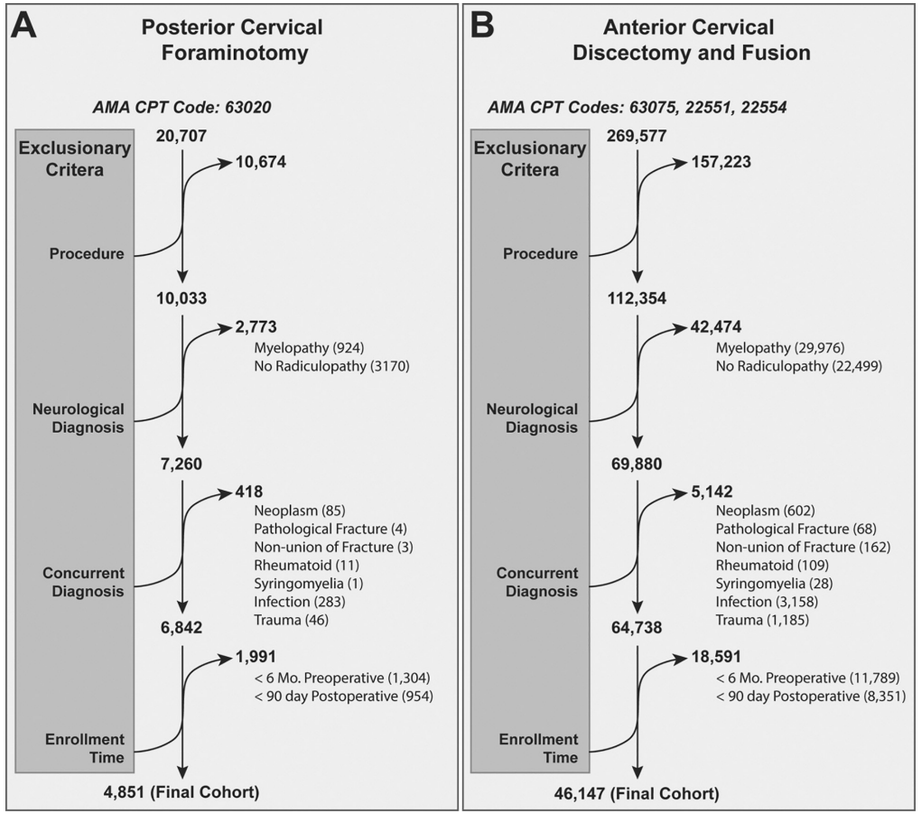

Table 1. Adverse Events over 30 Day Post-operative Period

	Unadjusted Rates (per 1000 cases)			Matched Difference (per 1000 cases)	
	PCF (n = 4,851)	ACDF (n = 46,147)	p value	Mean Difference (95% CI)	p value
30 Day Readmission	31.7	23.0	< 0.001	11.4 (3.1, 17.5)	< 0.001
30 Day Mortality	0	0.1	0.517	- 0.1 (-0.2, -0.0)	0.083
Adverse Events					
Any Adverse Event	44.3	42.1	0.470	1.4 (-5.4, 8.2)	0.688
Vascular Injury	0	0.2	0.305	- 0.2 (-0.3, -0.1)	0.003
Dysphagia/Dysphonia	1.7	16.2	< 0.001	-13.9 (-15.5, -12.3)	< 0.001
Incidental Durotomy	1.9	0.6	0.002	0.07 (-0.03, 1.2)	0.167
CSF Leak	0	0.2	0.391	-0.2 (-0.3, -0.04)	0.008
CNS Complication	2.9	3.6	0.440	0.4 (-1.2, 2.2)	0.646
Wound Infection	20.5	5.7	< 0.001	14.5 (9.8, 19.2)	< 0.001
Hematoma/Hemorrhage	3.9	3.5	0.672	0.1 (-2.2, 2.0)	0.931
Pulmonary Embolism	1.2	0.9	0.482	-0.2 (-1.0, 0.5)	0.569
Deep Venous Thromb.	0.6	1.4	0.168	-1.0 (-1.5, -0.4)	0.018
Cardiac	14.0	14.1	0.957	-0.4 (-4.2, 3.4)	0.842
Respiratory	2.9	3.9	0.292	-0.7 (-2.7, 1.3)	0.499
Urinary Tract Infection	0	0.4	0.647	-0.1 (-0.1, 0.0)	0.157

See Disclosure Index pages 39–89.

A Cost-Utility Analysis Comparing Elderly vs. Younger Individuals with Traumatic Cervical Spinal Cord Injury

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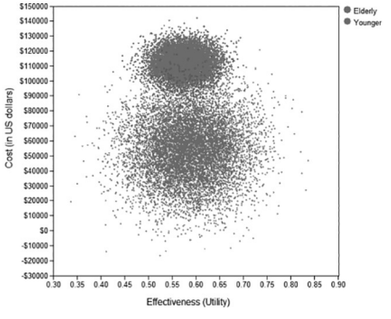
Introduction: The aging of the population has modified the epidemiology of traumatic spinal cord injury (SCI) as evidenced by the establishment of a bimodal distribution of injuries and increased frequency of fall-related injuries among the elderly. However, the economic implications of those changes in the epidemiology of SCI remain unclear. Given this, a cost-utility analysis (CUA) was undertaken to assess the economic impact of older age (≥65 years of age) in the context of acute surgical management and rehabilitation of traumatic cervical SCI.

Materials and Methods: The perspective of a public health care insurer was adopted in this CUA. The probabilities and rates of clinical events for this model were obtained from the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). Direct costs for the acute surgical and rehabilitation care included: hospital expenses; inpatient direct costs in a rehabilitation center; and physician fees. Utilities were generated from SF-36 data from the STASCIS. A time horizon of 6 months from SCI onset was used. Costs were estimated in 2014 US dollars.

Results: There were no significant differences between the age-related groups regarding sex distribution, severity and level of SCI, length of stay in the acute care and rehabilitation facilities, and frequency of postoperative complications. The baseline analysis indicated that the initial management of elderly individuals with SCI cost US$193,989.85 per QALY gained, whereas the initial management of younger individuals with SCI cost US$94,043.42 per QALY gained. Importantly, elderly and younger patients had similar utilities at the baseline analysis (0.58 vs. 0.59, respectively). The baseline analysis also suggested that the initial management of SCI among younger individuals has higher cost effectiveness when compared to elderly individuals at a willingness-to-pay of US$50,000. When considering acute care and rehabilitation management of younger adults with SCI as the baseline, the incremental cost-effectiveness ratio (ICER) analysis revealed an additional cost of US$5,655,557 per QALY gained when managing elderly patients with traumatic cervical SCI. The probabilistic analysis confirmed that spinal surgery in the elderly is more costly but similarly effective to younger adults after SCI, even though there is no definitive dominance (Figure 1).

Conclusions: The results of this economic analysis suggest that acute care and rehabilitation management of acute traumatic cervical SCI is more costly for elderly than younger individuals, while the treatment is equally effective in both age groups. The effects of pre-existing medical co-morbidities on the management costs of the elderly with SCI could potentially outweigh the age-related differences seen in this study. Furthermore, one can speculate that ageist attitudes in the health care system could adversely affect recovery of elderly patients with SCI and, theoretically, increase their treatment costs. Therefore, a future prospective cost effectiveness analysis addressing these important questions would be recommended to better understand the age-related differences in the cost effectiveness of initial management of individuals with SCI.

Figure 1. The incremental cost-effectiveness scatterplot for the probabilistic sensitivity analysis comparing elderly with younger individuals with traumatic cervical SCI. Each dot represents a result of a Monte Carlo simulation.



See Disclosure Index pages 39–89.

Cervical Disc Replacement vs. ACDF for Single and Multilevel Treatment of Cervical Degenerative Disc Disease: Seven-Year Clinical Results from an FDA Clinical Trial

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Literature has demonstrated cervical disc replacement (CDA) as safe and effective as anterior cervical disc and fusion (ACDF) for the treatment of symptomatic cervical degenerative disc disease (cDDD). Here we evaluate the clinical results of one and two-level CDA in comparison to an ACDF control group for the treatment of cervical degenerative disc disease through 7 years follow-up.

Materials and Methods: A prospective, randomized (2:1), concurrently controlled FDA study at 24 centers across the U.S. Patients had a diagnosis of symptomatic cDDD at one or two contiguous levels and no history of cervical spine surgery. The one-level arm had 164 CDA vs. 81 ACDF patients; the two-level arm had 225 CDA vs. 105 ACDF patients. ACDF with allograft and anterior plate was used as the control treatment. Clinical results include composite overall success, NDI, VAS neck/arm pain, SF-12 MCS/PCS, subsequent surgeries, and patient satisfaction.

Results: At 7 years, the overall follow-up rate was 80.2%. Overall success was statistically non-inferior for one-level CDA patients (CDA: 55.2% vs. ACDF: 50.0%) and superior for two-level CDA treatment (CDA: 60.8% vs. ACDF: 34.2%; $p < 0.0001$). Both the CDA and ACDF group showed significant improvement from baseline NDI scores, VAS neck/arm pain scores, and SF-12 MCS/PCS scores ($p < 0.0001$). Improvement in NDI was statistically similar between one-level treatments, while two-level CDA demonstrated significantly greater improvement compared to ACDF (35.7 vs. 27.8; $p = 0.007$). The ACDF group demonstrated a significantly higher rate of device-related subsequent surgeries following both one-level (3.0% vs. 12.3%; $p = 0.008$) and two-level treatment (4.9% vs. 16.2%; $p = 0.001$). Subsequent surgeries at adjacent levels were also significantly higher for one-level (3.7% vs. 13.6%; $p = 0.007$) and two-level ACDF (4.9% vs. 11.4%; $p = 0.04$). At 84 months, a higher percentage of CDA patients were very satisfied with their respective treatment (1L CDA: 90.9% vs. 1L ACDF: 80.8%; 2L CDA: 85.9% vs. 2L ACDF: 73.9%).

Conclusion: This long-term study demonstrates the continuing performance of CDA with Mobi-C as a safe and effective alternative to ACDF for treatment of cDDD out to 7 years. Clinical results demonstrate improvement in pain and function outcomes, and a high rate of patient satisfaction. Patients treated with CDA also demonstrated significantly lower rates of index and adjacent level subsequent surgeries and a significantly higher rate of overall success for two-level treatment.

Asia-Pacific Multicenter, Prospective, Randomized, Clinical Trial Comparing Arthroplasty vs. Anterior Cervical Discectomy and Fusion in the Treatment of Symptomatic Cervical Disc Degeneration

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Introduction: In multiple FDA-regulated trials in the United States, cervical total disc replacement (TDR) produced results similar or superior to anterior cervical discectomy and fusion (ACDF). The purpose of this study was to compare cervical TDR to ACDF in a prospective, randomized, multinational study in Asia.

Methods: The study involved 9 sites in 5 countries (Korea, Taiwan, Hong Kong, China, and Singapore) and was patterned after FDA-regulated TDR trials in the US, but also accommodated multinational participation. After signing consent, patients were randomized to TDR or ACDF using an interbody cage with synthetic graft and no anterior plate. The original design was to enroll 300 patients randomized in a 2:1 ratio of TDR:ACDF with 7 year follow-up. Due to slow enrollment, 120 patients were included (81 TDR, 39 ACDF) and outcomes reported for 3-year follow-up (>77%; follow-up rates after that were <50%). A composite success criteria was defined to be >20% NDI score improvement, neurological status improved/maintained, no device removals, revisions, re-operations, or supplemental fixation at the index level, and no adverse events related to the implant or procedure. Radiographic assessment was conducted by an independent core lab.

Results: There were no significant differences between the groups based on demographic factors or level(s) operated. At 36 month follow-up TDR success rate of 83.1% was statistically non-inferior to ACDF 79.3%. Mean NDI scores improved significantly in both groups and remained so throughout 3-year follow-up (Figure 1). Table 1 provides results on the other outcome assessments. The only significant differences were the satisfaction score and the mean percentage improvement in NDI scores being significantly greater for ACDF at 36 months. Mean range of motion of the TDR level(s) was 8.5° at 36 months and there were no cases of bridging bone, device subsidence, or device migration. There were 2 re-operations, both at an adjacent segment, after TDR (2.5%): one emergent ACDF 3 days post-operative for weakness and another patient underwent posterior decompression 34 months post-operative. With ACDF, there was one re-operation (2.6%), a posterior laminoplasty at the index and both adjacent levels 35 months post-operative.

See Disclosure Index pages 39–89.

Discussion: Despite challenges with enrollment and long-term follow-up, this study supports that multinational studies are feasible. ACDF results appeared to be somewhat better than in the US trials. The overall study results were similar to the US studies in that TDR was found to be a viable alternative to fusion in appropriately selected patients.

Figure 1. NDI scores improved significantly by 6 weeks and remained so through 36 month follow-up in both groups.

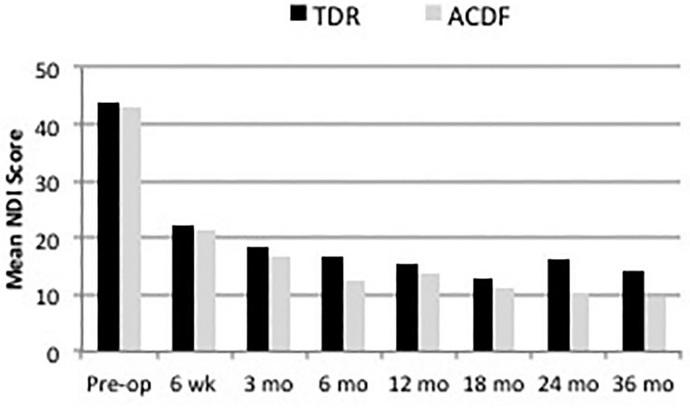

Table 1. Overview of mean scores on various outcome measures.

Outcome Assessment	TDR		ACDF	
	Pre-op	36 mo	Pre-op	36 mo
Mean NDI	44.0	14.2	42.8	9.3
Mean neck pain (VAS)	57.5	15.9	52.2	12.4
Mean arm pain (VAS)	63.3	20.5	66.4	11.7
Mean SF-36 PCS	38.9	51.2	40.8	53.0
Mean SF-36 MCS	35.5	48.0	36.9	50.1
Mean satisfaction (VAS)	NA	86.5	NA	90.3

The Health Impact of Symptomatic Adult Cervical Deformity: Comparison to United States Population Norms and Chronic Disease States Based on the EQ5D

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Introduction: Although adult cervical deformity (ACD) has been empirically associated with significant pain and disability, the magnitude of this negative impact has not been objectively quantified. Our objective in this study was to assess whether symptomatic ACD patients have substantial negative health impact based on the EQ5D compared with United States (US) normative and chronic disease state values.

Materials and Methods: ACD patients presenting for surgical evaluation and treatment were identified from a prospectively collected multicenter database. Baseline demographics, deformity characteristics, and EQ5D-3S scores were collected. EQ5D scores were compared with age- and gender-matched US normative and chronic disease state values.

See Disclosure Index pages 39–89.

Results: Of 121 ACD patients, 115 (95%) completed the EQ5D (61% women, mean age 61 yrs, previous cervical surgery in 46%). Diagnoses included: cervical sagittal malalignment (63%), cervical kyphosis (60%), proximal junctional kyphosis (9%) and coronal deformity (8%). Posterior fusion was performed in 86% (mean levels = 10), and anterior fusion was performed in 49% (mean levels = 5). 3-column osteotomy was performed in 21% of patients. The mean EQ5D index was 0.511, which is 35% below the bottom 25th percentile score (0.790) for a similar age- and gender-weighted normative population and worse than the bottom 25th percentile for several other chronic disease states (diabetes [0.708], ischemic heart disease [0.708], and myocardial infarction [0.575]). The EQ5D index of 0.511 seen in this ACD cohort is comparable to the bottom 25th percentile for blindness (0.543), emphysema (0.508) and heart failure (0.437). Based on EQ5D subscores, patients reported impact on mobility (87%), daily self care (47%), daily activities (91%), pain/discomfort (98%), and anxiety/depression (67%).

Conclusions: The health impact of symptomatic ACD is substantial, with an EQ5D index that is 35% below the bottom 25th percentile for a similar age- and gender-weighted normative population. The mean ACD EQ5D index score demonstrates comparable or greater health impact than multiple other chronic disease states, including ischemic heart disease, blindness, and emphysema.

Three-column Osteotomy for Correction of Cervical Deformity: Alignment Changes and Early Complications in a Multicenter Prospective Series of 24 Patients

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Introduction: Although three-column osteotomy (3CO; pedicle subtraction osteotomy [PSO] or vertebral column resection VCR]) can provide powerful alignment correction and disability improvement in adult cervical deformity (ACD), these procedures are complex and associated with high complication rates. Previous reports on complications associated with 3CO for ACD have been primarily based on retrospective complication collection, which may substantially underestimate the true rates. Our objective in this study was to prospectively assess early cervical alignment changes and complications in a series of ASD patients treated with 3CO.

Materials and Methods: ACD patients treated with 3CO with a minimum 90-day follow-up were identified from a prospectively collected multicenter ACD database. Complications within 90-days of surgery were collected using standardized forms and onsite study coordinators and classified as minor or major. Standing radiographic imaging was obtained at baseline and 90-days.

See Disclosure Index pages 39–89.

Results: All 24 ACD patients treated with 3CO (15 PSO/9 VCR) achieved minimum 90-day follow-up (71% women, mean age 62 yrs, previous surgery in 54%). Diagnoses included: cervical sagittal imbalance (92%), cervical kyphosis (38%), proximal junctional kyphosis (17%), coronal deformity (8%) and distal junctional kyphosis (4%). The mean number of posterior fusion levels was 13, and 4% also had an anterior fusion. The most common 3CO levels were T1 (38%), T2 (29%) and T3 (21%). A total of 25 (19 major/6 minor) complications were reported, with 14 (58%) and 6 (25%) patients affected, respectively. Overall, 17 (71%) patients had at least one complication. The most common complications were excessive blood loss (>1.7L, 25%), neurologic deficit (17%), distal junctional kyphosis (DJK, 8%), wound infection (13%), and cardiorespiratory failure (8%). Four (17%) patients required re-operation within 90-days (2 for nerve root motor deficit, 1 deep wound infection, 1 implant pain/prominence). Cervical sagittal alignment improved significantly following 3CO: cervical lordosis (CL, 3 to 13°, $p = .031$), C2-7 sagittal vertical axis (66 to 44 mm, $p < .001$), and T1 slope minus CL (46°, $p < .001$).

Conclusions: Among 24 ACD patients treated with 3CO, cervical sagittal alignment improved significantly following surgery. Overall, 17 (71%) patients had at least one complication (19 major/6 minor). The most common complications were excessive blood loss (>1.7L), neurologic deficit, DJK, wound infection, and cardiorespiratory failure. Future research focused on reducing these complications may present the greatest opportunities for safety and cost improvements for these procedures.

The Importance of C2-Slope as a Singular Marker of Cervical Deformity and the Link between Upper-Cervical and Cervico-Thoracic Alignment among Cervical Deformity Patients

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Introduction: Sagittal malalignment of the cervical spine has been associated with worsened postsurgical outcomes. Effective operative planning of cervical deformity requires improved knowledge of ideal fusion angles and the interdependence of upper and lower cervical spinal alignment. Current cervical deformity measures like the C2–C7 sagittal vertical axis (cSVA) focus on subaxial cervical alignment. The T1-Slope has been shown to be an important link between the cervical and thoracolumbar alignment. The purpose of this study is to assess C2-Slope as a singular cervical deformity parameter and to determine its role in upper-cervical and cervico-thoracic interdependence.

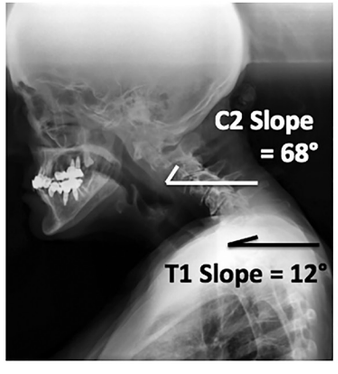
Methods: Global spinal alignment was studied in a prospective database of operative cervical deformity (CD) patients. Inclusion criteria were any of the following: cervical kyphosis (CK) > 10°, cervical scoliosis > 10°, C2-7 SVA > 4cm or CBVA > 25°. Patients were categorized in to two groups based on whether the apex of the deformity was in the cervical spine (C) or the cervico-thoracic (CT) region. The sagittal radiographic parameters analyzed included: upper cervical lordosis (C0-C2A), McGregor slope, C2-Slope, cSVA, C2–C7 Cobb (C2-C7A), T1-Slope (T1S), T1S-cervical lordosis (TS–CL),thoracic kyphosis (TK), and T1-Pelvic Angle (TPA). Correlation coefficients were determined separately for C and CT patients.

See Disclosure Index pages 39–89.

Results: 104 CD patients (C = 74, CT = 30; mean age 61.3 yrs, 56% women and 42% revision) were included. CT patients had larger deformities with higher cSVA and T1S at baseline ($p < 0.05$). C2-Slope correlated with C0–C2A (R = 0.60, $p < .001$), cSVA (R = 0.65, $p < .001$), C2–C7A (R = 0.54, $p < .001$), T1S (R = 0.37, $p < .001$) and TS-CL (R = 0.98, $p < 0.001$). Correlation of cSVA and C0–C2A was weaker (R = 0.48, $p < .001$). Both C and CT groups demonstrated significant correlations between C2-Slope and cSVA, C0–C2A, C2–C7A, TK and TS-CL (all $p < 0.05$). Similarly, both groups demonstrated significant correlations between T1S and C2-Slope, C2–C7A, cSVA and TK ($p < 0.05$). Using linear regression analysis, cSVA of 4cm corresponded to C2-Slope of 36° ($r2 = 0.43$).

Conclusion: The C2-Slope correlated with both upper cervical and subaxial cervical alignment parameters. The extremely high correlation of C2-Slope and TS-CL (R = 0.98, $p < 0.001$) is explained by the fact that C2-Slope is a mathematical approximation of TS-CL and therefore C2-Slope is a simple substitution for it (Figure). Significant correlations between the upper and lower cervical spine exist in patients with cervical deformities, confirming the existence of inherent compensatory mechanisms to maintain overall balance. The C2-Slope is a useful marker of overall cervical sagittal alignment, acting as a link between the occipitocervical and cervico-thoracic spine. The C2-Slope defines the presence of a mismatch between cervical lordosis and thoracolumbar alignment required to maintain the head over the pelvis and to facilitate horizontal gaze.

Figure 1. Depiction of the C2-Slope in a patient with cervical deformity. The high C2-Slope and low T1-Slope demonstrate that the deformity is entirely within the cervical region. C2-Slope is a mathematical approximation of T1-Slope minus cervical lordosis since T1-slope and C7-slope are approximately equal as demonstrated.



T1 Slope – Cervical Lordosis
= T1 Slope – (C7 Slope- C2 Slope)
= T1 Slope – (C7 Slope- C2 Slope)
≈ C2 Slope

High C2 Slope (>36)

Low T1 Slope (<32)

Upper Cervical and Infra-cervical Compensation in Cervical Deformity Patients

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Introduction: Reciprocal compensatory mechanisms for standing alignment have been described in thoracolumbar deformity. Such mechanisms have not been studied prospectively in patients with primary cervical deformity. With wide variations in surgical management of cervical deformities, it is important to appreciate the compensatory mechanisms in such deformities for better pre-operative planning strategies. The purpose of this study is to report upper and infra-cervial sagittal compensatory mechanisms in patients with cervical deformity and evaluate their changes post-operatively.

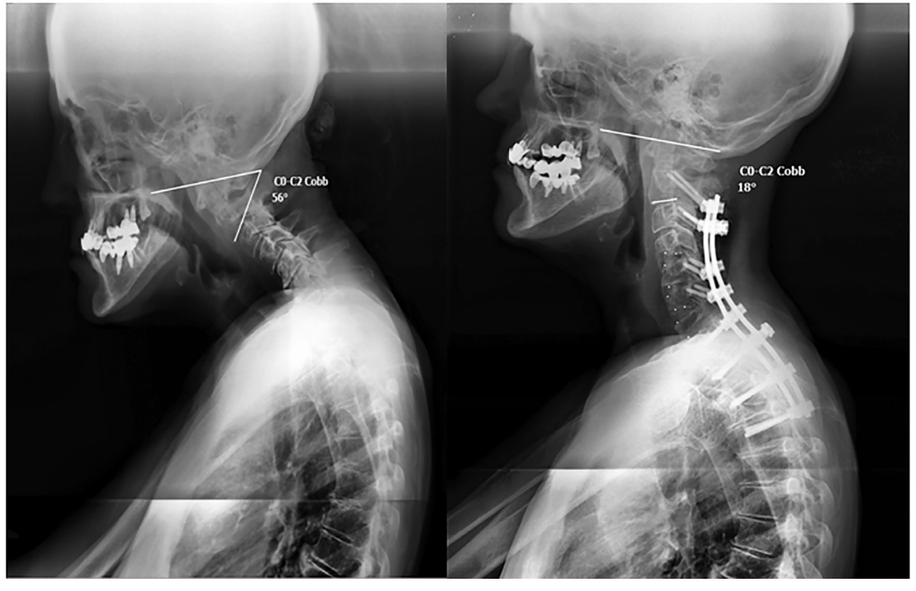
Methods: Global spinal alignment was studied in a prospective database of operative cervical deformity patients. Inclusion criteria were any of the following: cervical kyphosis (CK) > 10°, cervical scoliosis > 10°, cSVA > 4cm or CBVA > 25° with minimum 3 months follow-up. For this study, patients who had a previous fusion outside of C2 to T4 spinal segments were excluded. Patients were sub-classified by increasing severity of their cervical kyphosis (CL: < 0°, CK-low: 0–10°, CK-high: > 10°) and cSVA (cSVA-low: 0–4cm, cSVA-mid: 4-6cm, cSVA-high: > 6cm) and were compared for preoperative upper- cervical (C0-C2 Cobb) and infra-cervical sagittal alignment to determine compensatory recruitment. These compensatory alignment changes were further analysed at an early follow-up interval (min 3 months).

Results: 75 CD patients (mean age 61.3 yrs, 56% women) were included. Patients with progressively larger CK (CL = -11.5°, CK-low = 5.2°, CK-high = 25.3°) had a progressive increase in the upper cervical lordosis (CL = 34°, CK-low = 37°, CK-high = 44°, $p = 0.004$), C2S (CL = 28°, CK-low = 33°, CK-high = 48°, $p < 0.001$) and TS-CL (CL = 27°, CK-low = 33°, CK-high = 49°, $p < 0.001$). As the cSVA (mm) increased (cSVA-low = 22, cSVA-mid = 48.2 and cSVA-high = 75.4, $p < .001$), there was a progressive increase in C2S ,T1 Slope and TS-CL ($p < 0.05$) and patients compensated through increasing upper cervical lordosis (cSVA-low = 33°, cSVA-mid = 40°, cSVA-high = 43°, $p = .007$) and pelvic tilt (cSVA-low = 14.9°, cSVA-mid = 24.1°, cSVA-high = 24.9°, $p = .02$). At 3 months post-op, there was a significant improvement in cSVA (46mm to 34mm, $p < 0.01$), CK (6.5° to -7°, $p < 0.001$) and TS-CL (37° to 27°, $p < 0.001$) with resultant relaxation of upper cervical lordosis (39° to 35°, $p = 0.01$, Figure 1).

See Disclosure Index pages 39–89.

Conclusions: Patients with cervical malalignment tend to compensate with upper cervical hyperlordosis, presumably for the maintenance of horizontal gaze. As the cSVA increases, patients tend to exhibit increased pelvic retroversion. Following surgical treatment for the cervical deformity, there was relaxation of upper cervical compensation.

Figure 1. Pre-and post-operative cervical radiographs of a patient with cervical kyphosis who underwent posterior spinal fusion from C2-T4, (A) Preoperative cervical radiographs showing upper cervical hyper-lordosis, (B) 3 months post-operative radiograph showing resolution of the upper cervical hyper-lordosis.



Assessment of a Novel Adult Cervical Deformity (ACD) Frailty Index (FI) as a Component of Preoperative Risk Stratification

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Introduction: The concept of frailty as a physiologic diagnosis was developed in geriatrics literature as an improved measure of aging and vulnerability to adverse events. Frailty has since been shown to be a better predictor of major complications than age in general surgery. Following a validated model, we developed a novel ACD-FI and assessed the value of this index as a component of risk stratification.

Methods: A frailty index was constructed using 40 variables contained in a multicenter adult cervical deformity database using a validated method from geriatric literature. The ACD-FI score was calculated as the average of all variables and used to stratify patients into 3 frailty cohorts: <0.2=not frail (NF), $0.2-0.4$=frail (F), >0.41=severely frail (SF). We then performed a multivariate logistic regression to determine the relationship between ACD-FI cohorts, incidence of major complications and hospital length of stay (LOS).

Results: Of 61 patients with minimum one year follow up, the average ACD-FI was 0.26 (range $0.25-0.59$). 17 patients were not frail, 34 were frail, and 10 were severely frail. The incidence of major complications increased with increasing frailty with a gamma correlation coefficient of 0.25 (ASE 0.22) (Figure 1). The unadjusted odds ratio of having a major complication was 1.13 [Confidence Interval $0.34-3.8$] and 2.75 [CI $0.55-13.7$] times higher for F and SF compared to NF patients, but it was not significant ($p>0.05$). After adjusting for important covariates such as operative time, the odds ratio of having a major complication was 159.7 [$1.10-23194$] ($p<0.05$) for F and 149265.5 [$12.2-1.8e+9$] ($p<0.05$) for SF compared to NF patients (Table 1). The incidence of medical complications correlated with frailty and had a gamma correlation coefficient of 0.30 (ASE 0.26) (Figure 1).

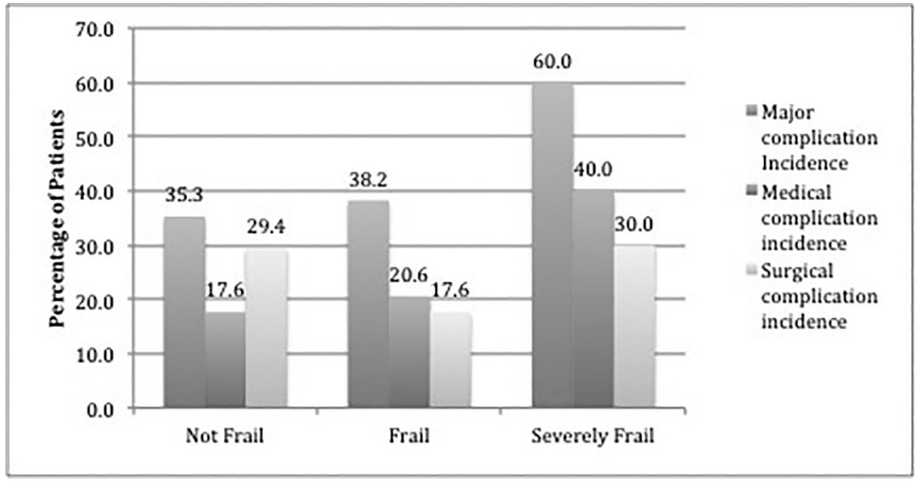
Conclusions: Increasing frailty was strongly associated with increased risk of major complications and medical complications for ACD patients undergoing surgery. This indicates the value of the ACD-FI to improve the accuracy of preoperative risk stratification and allow for adequate patient counseling.

See Disclosure Index pages 39–89.

Table 1. Multivariate Logistic Regression for Major Complication Incidence

	Odds Ratio (SE)	P Value	Confidence Interval
Frailty (NF = index)			
NF vs. F	14.6 (22.0)	0.075	0.76-279-56
NF vs. SF	785.8 (1955.7)	0.007	5.98-103229.7
Age (by decade)	0.26 (0.16)	0.077	0.08-0.87
Smoking Status (non-smoker = index)	0.59 (1.11)	0.78	0.01-24.17
Prior Cervical Spine Surgery	0.09 (0.11)	0.039	0.01-0.88
MD-reported gait instability	12.7 (15.4)	0.037	1.17-136.9
Diagnosis of cervical kyphosis	0.43 (0.42)	0.39	0.06-2.88
Estimated Blood Loss (L)	1.3 (0.16)	0.019	1.05-1.70
Operative Time (by 100 min)	0.55 (0.23)	0.16	0.24-1.27
Vertebral Column Resection Performed	4.4 (8.7)	0.45	0.10-205.10

Figure 1. Incidence of Major, Medical, and Surgical Complications amongst Not Frail, Frail, and Severely Frail Patients



How do Cervical Deformity Patients Keep their Balance? Manifestations of Thoraco-lumbar Compensatory Mechanism

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Introduction: While previous studies have defined cervical kyphosis in terms of regional kyphosis or chin-brow angle, cervical kyphotic deformity as it relates to global sagittal balance has not been well studied. Also correlation between cervical kyphosis and cervical sagittal imbalance has not been elucidated. Thus, the purpose of the present study is to elucidate correlation between cervical kyphosis and cervical sagittal imbalance, and to elucidate thoraco-lumbar compensatory mechanisms in primary symptomatic cervical kyphosis by analyzing full length standing spine x-rays.

Methods: A retrospective multi-center study was conducted. Patients with symptomatic primary cervical kyphosis on full-length standing radiographs were included (C-group: N=102). All patients had primarily cervical symptoms and underwent cervical reconstruction surgery or its candidate. Age and gender matched patients were selected from the adult spinal deformity database (TL-group: N = 119). Spino-pelvic parameters, various Cobb angles (cervical lordosis: CL, Thoracic kyphosis: TK, lower thoracic kyphosis: TK8-12, thoraco-lumbar junction: T10-L2), T1 slope and various SVAs (COG-SVA, C2-SVA, C7-SVA, COG-C7SVA and C2-C7SVA) were compared between C-group and TL-group. In addition, the C-group was divided into two sub-groups and assessed according to C7-SVA (positive: C7P-group N=48, negative: C7N-group N=54).

Measurements using the Cobb angle defined kyphosis as positive and lordosis as negative. Patients whose coronal imbalance > 30 deg. and patients with prior thoraco-lumbar long fusion were excluded. A non-paired t-test was used when comparing two groups. A p-value < 0.05 was considered as statistically significant.

See Disclosure Index pages 39–89.

Results: Cervical kyphosis was correlated with COG-C7SVA (R2=0.419, $p < 0.0001$). In the same way, there was a less robust but still significant correlation between TCL and C2-C7SVA (R2=0.228, $p < 0.0001$). Cervical kyphosis was correlated with more severe cervical sagittal imbalance.

C-group had a larger LL, TK, T8-12 than the TL-group ($P < 0.0001$, P=0.023). Also C-group had smaller T1 slope. Interestingly, C7-SVA was shorter in C-group (-2.0cm) than TL-group (TL-group=6.6 cm, $P < 0.0001$).

Between C7N-group and C7P-group, The C7N-group had a shorter COG-SVA 32.9mm as compared to C7P-group 115.9mm ($P < 0.0001$). There was a statistical significant difference in TK8-12 (10.1 and 16.2: P=0.011), T10-L2 (1.1 and 7.5: p=0.027), LL4-S (-34.6 and -26.6: p=0.0036), LL (-57.1 and -41.5: $p < 0.0001$) and PI-LL (-2.2 and 10.0: p=0.0003), and C7-SVA (-49.5 and 45.1: $p < 0.0001$), respectively. These results indicate that C7N-group had larger lumbar lordosis compensation, a more straight thoraco-lumbar junction, and larger thoracic kyphosis allowing for overall global balance of the head.

Conclusion: The current study showed that cervical kyphosis correlated with more severe cervical sagittal imbalance. Also, the current study showed that patients with symptomatic primary cervical kyphosis, modified their global spinal alignment including head position. The characteristic findings of thoraco-lumbar compensation were straightened thoracic and thoraco-lumbar junction with hyper lumbar lordosis, negative C7-SVA, less than 40mm of C2-SVA. However, even for patients with primary cervical pathology, the presence of large PI-LL and positive C7-SVA affect to the compensation mechanisms. As such, even patients with primary cervical disease should have a full length radiographic evaluation.

An Abridged SWAL-QoL Form to Assess Dysphagia following Anterior Cervical Spine Surgery

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Introduction: The SWAL-QOL survey is an instrument that has been applied to patients undergoing ACSS procedures as a means of objectifying swallow function. However, the SWAL-QOL is long, cumbersome and primarily utilized for otolaryngological procedures. The objective of this study is to identify the swallowing disorders (SWAL-QOL) questions most relevant to dysphagia following anterior cervical spine surgery (ACSS).

Materials and Methods: Retrospective analysis of a prospectively maintained surgical database of patients who completed a SWAL-QOL survey prior to undergoing an ACDF between 2014–2016. Patients undergoing ACDF procedures were administered the SWAL-QOL survey prior to surgery and at the 6- and 12-week postoperative visits. For each visit, a scaled SWAL-QOL score was calculated by adding the number of points scored and by dividing the total possible points. The average total scores, scores for each section, and scores for each question were compared between office visits using paired t-tests.

Results: Of the 78 eligible patients, 50 (64.1%) completed surveys at all three encounters and were included in the analysis (Table 1). The total scaled score at 6 weeks was significantly lower than the preoperative score (p=0.003) but returned to near baseline scores by 12 weeks (p=0.178) (Table 2). Of the 21 questions that demonstrated statistically lower scores from preoperative values, 16 also demonstrated a clinically significant decrease (>5.0%) from preoperative scores (Table 3). These 16 questions were included in the abridged survey developed for use in ACCS patients. Using this abridged survey, there was significant dysphagia present at both 6 weeks and 12 weeks following surgery (Table 4), and a greater percentage of patients are classified as having significant dysphagia when compared to the original SWAL-QOL survey (Table 5).

Conclusions: The results of this study suggest the full SWAL-QOL questionnaire may not be necessary to detect significant changes in swallowing function following an ACDF. Several sections and individual questions demonstrated minor or no changes at the postoperative visits. As a result, we propose a modified, 16-question SWAL-QOL survey including only the questions that were both statistically and clinically significant. This truncated survey may be better suited for use in cervical spine patients who typically present with less severe symptoms as compared to those with head and neck cancer, the population for which the SWAL-QOL was primarily designed.

See Disclosure Index pages 39–89.

Table 1. Baseline patient characteristics

	ACDF (n=50)
Age (Mean ± SD, years)	50.3 ± 8.7
Sex (n)	
Female	40.0% (20)
Male	60.0% (30)
Ethnicity (n)	
Caucasian	78.0% (39)
African-American	10.0% (5)
Hispanic or Latino	8.0% (4)
Other	4.0% (2)
Insurance (n)	
Medicare	2.0% (1)
Workers' Compensation	30.0% (15)
Commercial	68.0% (34)
Smoking Status (n)	
Non-Smoker	92.0% (46)
Smoker	8.0% (4)
Body Mass Index (Mean ± SD, kg/m2)	29.1 ± 5.4
Comorbidity burden (CCI)	2.2 ± 1.7
Highest Education Level	
Some High School	2.0% (1)
High School	34.0% (17)
Some College	22.0% (11)
College	24.0% (12)
Post Graduate	18.0% (9)
Number of operative levels (n)	
1-Level	62.0% (31)
2-Level	38.0% (19)
Operative Level (n)	
C3-C4	8.0% (4)
C3-C5	2.0% (1)
C4-C5	8.0% (4)
C4-C6	8.0% (4)

Table 1. Baseline patient characteristics

	ACDF (n=50)
C5-C6	16.0% (8)
C5-C7	28.0% (14)
C6-C7	30.0% (15)
Anterior plating (n)	
No	58.0% (29)
Yes	42.0% (21)

Table 2. Mean scaled swallowing scores by section number*

	Preop (n=50)	**6 weeks (n=50)**	**†p-value**	**12-weeks (n=50)**	**†p-value**
Total score (Mean ± SD)	**91.2 ± 7.7**	**87.6 ± 13.2**	**0.007**	89.5 ± 11.1	0.178
Section 1	**96.0 ± 9.9**	**86.8 ± 20.3**	**< 0.001**	90.8 ± 17.6	0.065
Section 2	95.3 ± 11.4	92.8 ± 14.1	0.062	94.1 ± 10.1	0.524
Section 3	91.3 ± 10.2	88.6 ± 14.3	0.117	89.2 ± 13.7	0.176
Section 4	94.2 ± 10.5	90.4 ± 17.7	0.123	93.0 ± 16.2	0.636
Section 5	**96.8 ± 9.8**	**93.0 ± 12.8**	**0.045**	**92.8 ± 13.3**	**0.022**
Section 6	**97.1 ± 6.3**	**92.3 ± 15.0**	**0.008**	**91.0 ± 16.5**	**0.007**
Section 7	**96.8 ± 8.7**	**90.4 ± 17.8**	**< 0.001**	**91.0 ± 16.6**	**0.006**
Section 8	**96.7 ± 10.5**	**91.7 ± 17.6**	**0.003**	93.2 ± 14.6	0.065
Section 9	66.9 ± 22.3	66.6 ± 19.4	0.916	69.4 ± 20.3	0.443
Section 10	100.0 ± 0.0	100.0 ± 0.0	--	100.0 ± 0.0	--
Section 11	98.0 ± 7.3	96.8 ± 7.4	0.322	98.0 ± 7.3	1.000
Section 12	97.6 ± 8.8	97.6 ± 10.4	1.000	98.0 ± 7.4	0.569
Section 13	**68.8 ± 16.7**	**63.6 ± 18.8**	**0.008**	**64.5 ± 22.8**	**0.047**

***Boldface** indicates statistical significance
†p-value calculated using paired t-test

See Disclosure Index pages 39–89.

Table 3. Mean question scores*§

	Preoperative (n=50)	6-weeks (n=50)	p-value†	12-weeks (n=50)	p-value†
Section 1: Swallowing – Overall Burden					
Question 1a‡	**4.74 ± 0.66**	**4.22 ± 1.11**	**< 0.001‡**	**4.48 ± 0.99**	**0.129‡**
Question 1b‡	**4.86 ± 0.45**	**4.46 ± 0.97**	**0.002‡**	**4.60 ± 0.83**	**0.041‡**
Section 2: Swallowing – Eating					
Question 2a	4.77 ± 0.71	4.75 ± 0.63	0.785	4.73 ± 0.60	0.688
Question 2b‡	**4.64 ± 0.94**	**4.26 ± 1.29**	**0.007‡**	4.44 ± 1.07	0.086
Question 2c	4.64 ± 0.94	4.68 ± 0.82	0.735	4.70 ± 0.76	0.700
Question 2d	4.66 ± 0.96	4.54 ± 1.03	0.135	4.66 ± 0.89	1.000
Question 2e	4.88 ± 0.46	4.80 ± 0.71	0.252	4.82 ± 0.48	0.497
Section 3: Swallowing – Symptom Frequency					
Question 3a	4.12 ± 1.02	4.02 ± 0.94	0.521	4.18 ± 0.98	0.690
Question 3b‡	**4.62 ± 0.64**	**4.32 ± 1.00**	**0.018‡**	4.36 ± 0.96	0.052
Question 3c	4.64 ± 0.63	4.58 ± 0.86	0.583	4.52 ± 0.86	0.371
Question 3d	4.12 ± 1.14	4.18 ± 1.21	0.762	4.24 ± 1.02	0.436
Question 3e	4.54 ± 0.79	4.46 ± 0.95	0.543	4.36 ± 1.01	0.229
Question 3f	4.56 ± 0.86	4.70 ± 0.79	0.109	4.62 ± 0.78	0.497
Question 3g	4.82 ± 0.52	4.74 ± 0.66	0.485	4.62 ± 0.88	0.133
Question 3h	4.52 ± 1.03	4.46 ± 0.97	0.690	4.40 ± 0.99	0.382
Question 3i‡	**4.08 ± 0.99**	**3.74 ± 1.10**	**0.020‡**	3.94 ± 1.24	0.375
Question 3j‡	**4.56 ± 0.79**	**3.98 ± 1.17**	**0.001‡**	4.28 ± 0.99	0.056
Question 3k	**4.84 ± 0.42**	**4.62 ± 0.78**	**0.033**	**4.64 ± 0.72**	**0.032**
Question 3l	4.88 ± 0.44	4.86 ± 0.45	0.743	4.78 ± 0.65	0.200
Question 3m	4.96 ± 0.20	4.88 ± 0.44	0.159	4.90 ± 0.36	0.261
Question 3n	4.64 ± 0.78	4.50 ± 0.97	0.341	4.60 ± 0.90	0.710
Section 4: Swallowing – Diet					
Question 4a	4.68 ± 0.71	4.48 ± 0.93	0.192	4.66 ± 0.71	0.894
Question 4b	4.74 ± 0.56	4.56 ± 0.88	0.130	4.64 ± 0.83	0.440
Section 5: Speaking – Difficulty Frequency					
Question 5a	4.82 ± 0.56	4.74 ± 0.60	0.400	4.70 ± 0.65	0.182
Question 5b‡	**4.86 ± 0.45**	**4.56 ± 0.79**	**0.008‡**	**4.58 ± 0.76**	**0.005‡**
Section 6: Swallowing – Concern Frequency					
Question 6a‡	**4.86 ± 0.40**	**4.58 ± 0.91**	**0.011‡**	**4.58 ± 0.88**	**0.042‡**
Question 6b	4.84 ± 0.47	4.70 ± 0.68	0.164	4.62 ± 0.88	0.101
Question 6c‡	4.90 ± 0.36	4.70 ± 0.76	0.032	4.58 ± 0.88	0.008‡
Question 6d‡	**4.82 ± 0.56**	**4.48 ± 1.05**	**0.018‡**	**4.42 ± 1.07**	**0.008‡**
Section 7: Swallowing – Emotion Frequency					
Question 7a	**4.86 ± 0.53**	**4.68 ± 0.84**	**0.028**	**4.66 ± 0.72**	**0.031**
Question 7b‡	**4.88 ± 0.44**	**4.52 ± 0.95**	**0.001‡**	**4.50 ± 0.93**	**0.002‡**
Question 7c‡	**4.88 ± 0.44**	**4.54 ± 0.93**	**< 0.001‡**	**4.56 ± 0.81**	**0.002‡**
Question 7d‡	**4.76 ± 0.59**	**4.40 ± 1.03**	**0.002‡**	4.52 ± 0.95	0.070
Question 7e‡	**4.82 ± 0.52**	**4.46 ± 0.99**	**0.004‡**	**4.52 ± 0.89**	**0.018‡**
Section 8: Swallowing – Social Life					
Question 8a	**4.84 ± 0.55**	**4.64 ± 0.85**	**0.006**	4.74 ± 0.63	0.341
Question 8b	**4.84 ± 0.62**	**4.60 ± 0.83**	**0.004**	4.72 ± 0.57	0.159
Question 8c‡	**4.84 ± 0.55**	**4.52 ± 0.95**	**0.005‡**	**4.58 ± 0.88**	**0.022‡**
Question 8d‡	**4.84 ± 0.55**	**4.58 ± 0.95**	**0.011‡**	**4.60 ± 0.95**	**0.051**
Question 8e	**4.82 ± 0.56**	**4.58 ± 0.95**	**0.022**	4.66 ± 0.77	0.146
Section 9: Other Physical Symptoms					
Question 9a	3.70 ± 1.18	3.50 ± 1.16	0.285	3.86 ± 1.11	0.420
Question 9b	3.42 ± 1.44	3.40 ± 1.20	0.916	3.62 ± 1.24	0.274
Question 9c	3.20 ± 1.26	3.14 ± 1.13	0.760	3.20 ± 1.29	1.000
Question 9d	3.14 ± 1.31	3.26 ± 1.14	0.485	3.22 ± 1.23	0.699
Question 9e	3.26 ± 1.23	3.34 ± 1.12	0.659	3.46 ± 1.18	0.322

***Boldface** indicates statistical significance; †p-value calculated using paired t-test
‡Clinical significance determined by 5% decrease from preoperative value and included in final survey
§Not Shown: Section 10 = Feeding Tube Use; Section 11 = Consistency of Food; Section 12 = Consistency of Liquids; Section 13 = Overall Health

See Disclosure Index pages 39–89.

Table 4. Mean scaled swallowing scores for abridged survey*

	Preop (n=50)	6 weeks (n=50)	†p-value	12-weeks (n=50)	†p-value
Total score (Mean ± SD)	**95.0 ± 8.0**	**87.9 ± 16.2**	**< 0.001**	**89.4 ± 16.0**	**0.007**
Physical Symptom score	**91.0 ± 9.4**	**83.4 ± 16.9**	**< 0.001**	**86.4 ± 16.7**	**0.017**
Quality of Life score	**96.7 ± 8.1**	**89.9 ± 16.9**	**< 0.001**	**90.8 ± 16.6**	**0.007**

***Boldface** indicates statistical significance
†p-value calculated using paired t-test

Table 5. Percent of patients experiencing clinically significant dysphagia*

	6 weeks (n=50)	12-weeks (n=50)
Original SWAL-QOL Total score	32.0% (16)	18.0%% (9)
Abridged SWAL-QOL Total score	40.0% (20)	30.0% (15)
Physical Symptom score	40.0% (20)	34.0% (17)
Quality of Life score	36.0% (18)	26.0% (13)

*Clinically significant dysphagia was defined as a > 5.0% decrease from preoperative score

Is there a Difference in CT-Based Fusion Rate when using Structural Allograft Bone vs. PEEK Cages for ACDF?

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Introduction: Allogeneic bone has been considered the recent gold standard for cervical fusion. Recently, PEEK cages have become more widely used and are advantageous for their radiolucency and modulus of elasticity similar to native bone. Despite these advantages, surgeons cite their relative hydrophobicity and non-biologic interface for bone ingrowth as deterrents for use. However, few studies have directly compared materials using a robust assessment of fusion.

Methods: A prospectively maintained surgical database of patients who underwent 1-, 2-, or 3-level ACDF by a single-surgeon was retrospectively reviewed. Patients were stratified based on materials used; PEEK spacers (n = 116) or fresh-frozen tricortical allograft (FFTA; n = 115). All ACDFs were supplemented with conventional anterior plating and additional local bone autograft. The PEEK spacer was filled with a synthetic hydroxyapatite bone graft extender. Differences in patient demographics and preoperative characteristics were assessed using independent sample t-tests and Chi-squared tests. The material utilized and its effect on postoperative outcomes was analyzed using multivariate linear regression adjusted for preoperative characteristics (age, sex, smoking status, BMI category, Charlson comorbidity index, and number of operative levels).

Results: A total of 231 patients were included in the analysis (PEEK: 116; FFTA: 115). The FFTA cohort had a greater comorbidity burden (3.7 vs. 3.2, $p = 0.04$), and underwent more single level fusions than the PEEK cohort (56% vs. 18%, $p < 0.001$). Patients in the PEEK cohort experienced higher CT-based fusion rates (99.0% vs. 89.4%, $p = 0.001$) and required fewer revision procedures (1.0% vs. 8.9%, $p = 0.006$) compared to the FFTA cohort. There were no differences in complication rates or patient reported outcomes (visual analogue scale or short form-12 survey) at any time point.

Conclusions: In a direct comparison of outcomes following ACDF between PEEK and FFTA, higher fusion rates and fewer revisions were observed when using a PEEK spacer. This may be partially explained by the use of a biologic bone graft extender and more frequent use late-in-career in the PEEK cohort. There was no evidence that the hydrophobicity and non-ingrowth surface of PEEK implants resulted in any clinically significant issue. Therefore, the surgeon's priority should remain meticulous surgical technique with proper endplate preparation, and future studies delineating cost-effectiveness of synthetic spacer and biologic combinations are warranted.

See Disclosure Index pages 39–89.

Level of Evidence: III

Table 1. Baseline characteristics.*

	PEEK (N = 116)	VG2 Allograft (N = 115)	p-value
Age (Mean ± SD, years)	53.4 ± 9.4	51.6 ± 12.6	0.213
Sex (n)			0.953
Female	44.0% (51)	44.4% (51)	
Male	56.0% (65)	55.7% (64)	
Body Mass Index			0.469
Non-obese (BMI < 30)	62.1% (72)	57.4% (66)	
Obese (BMI ≥ 30)	37.9% (44)	42.6% (49)	
Smoking status (n)			0.172
Non-smoker	85.2% (98)	78.3% (90)	
Smoker	14.8% (17)	21.7% (25)	
Number of Levels (N)			**< 0.001**
1-level ACDF	**18.1% (21)**	**55.7% (64)**	
2-level ACDF	**74.1% (86)**	**43.5% (50)**	
3-level ACDF	**7.8% (9)**	**0.9% (1)**	
Comorbidity Burden (CCI)	**3.2 ± 1.7**	**3.7 ± 2.1**	**0.044**
Preoperative VAS (Mean ± SD, min)	6.3 ± 2.1	6.4 ± 2.0	0.780

SD = Standard deviation; BMI = Body Mass Index; CCI = Charlson comorbidity index; VAS = Visual Analogue Scale; N = number of patients
Boldface indicates statistical significance.

Table 2. Outcomes.*

	PEEK (N = 116)	VG2 Allograft (N = 115)	†p-value
Operative Time (Mean ± SD, min)	**67.6 ± 19.6**	**64.7 ± 19.7**	**< 0.001**
Estimated Blood Loss (mL)	**42.8 ± 19.5**	**58.2 ± 46.1**	**0.007**
Length of Hospital Stay (hours)	**29.5 ± 19.6**	**41.7 ± 26.6**	**0.002**
Change in VAS (Mean ± SD) Δ			
ΔVAS at 6-weeks	-2.2 ± 2.4	-3.0 ± 2.3	0.144
ΔVAS at 12-weeks	-2.4 ± 2.6	-2.6 ± 2.5	0.941
ΔVAS at 6-months	-2.0 ± 2.7	-2.4 ± 2.7	0.980
ΔVAS at 1-year	-1.5 ± 2.2	-2.0 ± 2.1	--
Change in SF-12 MCS (Mean ± SD) Δ			
ΔSF-12 MCS at 6-weeks	-2.6 ± 10.6	-8.5 ± 6.9	0.138
ΔSF-12 MCS at 12-weeks	-2.0 ± 9.2	-3.4 ± 5.1	0.264
ΔSF-12 MCS at 6-months	-8.6 ± 14.5	-9.7 ± 6.6	0.635
ΔSF-12 MCS at 1-year	-1.1 ± 12.6	-1.6 ± 7.1	--
Change in SF-12 PCS (Mean ± SD) Δ			
ΔSF-12 PCS at 6-weeks	-1.3 ± 7.9	-1.8 ± 10.0	0.474
ΔSF-12 PCS at 12-weeks	-7.3 ± 8.3	-4.5 ± 6.0	0.380
ΔSF-12 PCS at 6-months	-8.1 ± 12.3	-7.3 ± 6.7	0.326
ΔSF-12 PCS at 1-year	-9.2 ± 10.6	-4.0 ± 2.8	--
Complications (N)	0.8% (1)	1.8% (2)	--
Durotomy (n)	0.0% (0)	0.9% (1)	
Aspiration/Re-Intubation (n)	0.0% (0)	0.9% (1)	
Pretracheal Hematoma^ (n)	0.8% (1)	0.0% (0)	
Transient Urinary Retention (n)	6.7% (8)	6.2% (7)	0.362
Transient Dysphagia (n)	12.6% (15)	5.3% (6)	0.099
Arthrodesis at 1 year (N)	99.0% (103)	89.4% (101)	0.001
Revision (N) ‡	1.0% (1)	8.9% (10)	0.006

SD = Standard deviation; VAS = Visual analogue scale; SF-12 = Short Form-12 Health Survey; MCS = Mental Component Summary; PCS = Physical Component Summary; N = number of patients; n = number of occurrences
Boldface indicates statistical significance
-- Statistical analysis was not performed for variables with ≤ 5 occurrences in a cohort
† P-value is from Poisson regression with robust error variance (binary outcomes) or multivariate linear regression (continuous outcomes) adjusted for age, sex, smoking status, BMI category, number of operative levels, and comorbidity burden
Δ Change in VAS/SF-12 = Postoperative VAS/SF-12 (6 weeks, 12 weeks, 6 months, 1 year) – Preoperative VAS/SF-12
^ Resolution of pretracheal hematoma without return to the operating room
‡ Revisions include pseudarthrosis (11)

See Disclosure Index pages 39–89.

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 and 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 (Table 1). 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. 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.

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

See Disclosure Index pages 39–89.

Long-Term Results of a Prospective Comparative Study of Anterior Decompression with Fusion (ADF) and Posterior Decompression with Laminoplasty for the Treatment of Cervical Spondylotic Myelopathy

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Introduction: It has been documented that both anterior decompression and fusion (ADF) and posterior decompression with laminoplasty (LAMP) are effective surgical procedures for cervical spondylotic myelopathy (CSM). Our prospective comparative study had shown that ADF was superior to LAMP in terms of neurologic outcomes at 5 years after operation. We here update data and present clinical and radiologic outcomes as long-term follow-up results.

Materials and Methods: After giving their informed consent, 95 patients were prospectively treated with ADF or LAMP for the treatment of CSM in our hospital from 1996 up to 2003. Every alternative year, 45 patients were enrolled to receive ADF (in 1997, 1999, 2001, 2003; ADF group), 50 patients were enroll to undergo LAMP (in 1996, 1998, 2000, 2002; LAMP group). Twenty patients who died during follow up and 25 patients who lost to follow-up were excluded. Fifty-one cases (ADF=24; LAMP=27) were investigated. Clinical outcomes were evaluated using Japanese Orthopaedic Association (JOA) scoring system and its improvement rate to compare the two groups. Radiographs were taken before surgery and at each year after surgery. The sagittal alignment of C2-7 lordotic angle and the range of motion (ROM) in flexion and extension were measured before and after operation.

Results: The average patient age was 58.3 year-old in the ADF group and 57.9 year-old in the LAMP group. The mean preoperative JOA score was 10.0 in the ADF group and 10.5 in the LAMP group. The mean JOA score of the ADF group improved up to 13.9 at 1 year, 15.0 at 3 years, 14.9 at 5 years, and 14.3 at 10 years postoperatively. On the other hand, that of LAMP group improved up to 14.1 at 1 year, 14.1 at 3 years, 14.1 at 5 years and 14.3 at 10 years after surgery. The JOA score in the ADF group was significantly better compared to that in the LAMP group, from 3 to 5 years after operation whereas almost similar at 10 years postoperatively. Complications included 2 cases of meralgia and 1 cases of C5 palsy in ADF group, 2 cases of C5 palsy in LAMP group. In addition, 1 case had asymptomatic pseudoarthrosis at 1 year after the operation and underwent re-operation in ADF group. Although no patients deteriorated myelopathy during follow up, JOA score decreased in 4 cases in the ADF and 1 patient in whom lumbar canal stenosis developed lower extremity symptoms and 2 patient in the LAMP group who had bladder dysfunction due to benign prostatic hyperplasia. The cervical lordotic angle of neutral position changed from 14.0° to 17.9° in the ADF group, 13.4° to 8.7° in the LAMP group. The ROM changed from 30.1° to 22.6° in the ADF group, 29.6° to 18.9°, respectively.

Conclusions: This report is the first prospective long-term follow-up study between ADF and LAMP for CSM. Although ADF was superior to LAMP for improvement of JOA score and the maintenance of the cervical lordosis angle at 5 years postoperatively, neurologic status was almost similar between the two groups at 10 years after surgery.

Predictive Model for Neck Disability Index 12 Months after Elective Surgery for Degenerative Cervical Radiculopathy: Analysis from National Neurosurgery Quality Outcome Database

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Introduction: Cervical spine surgery rates have increased by 206% from 1992 to 2005 among Medicare beneficiaries. The American Association of Neurological Surgeons launched the National Neurosurgery Quality and Outcomes Database (N2QOD) to benchmark outcomes based on individualized risk-adjusted patient indicators. Furthermore, the aggregate data can be utilized to build powerful prediction models for disability, pain, and quality of life.

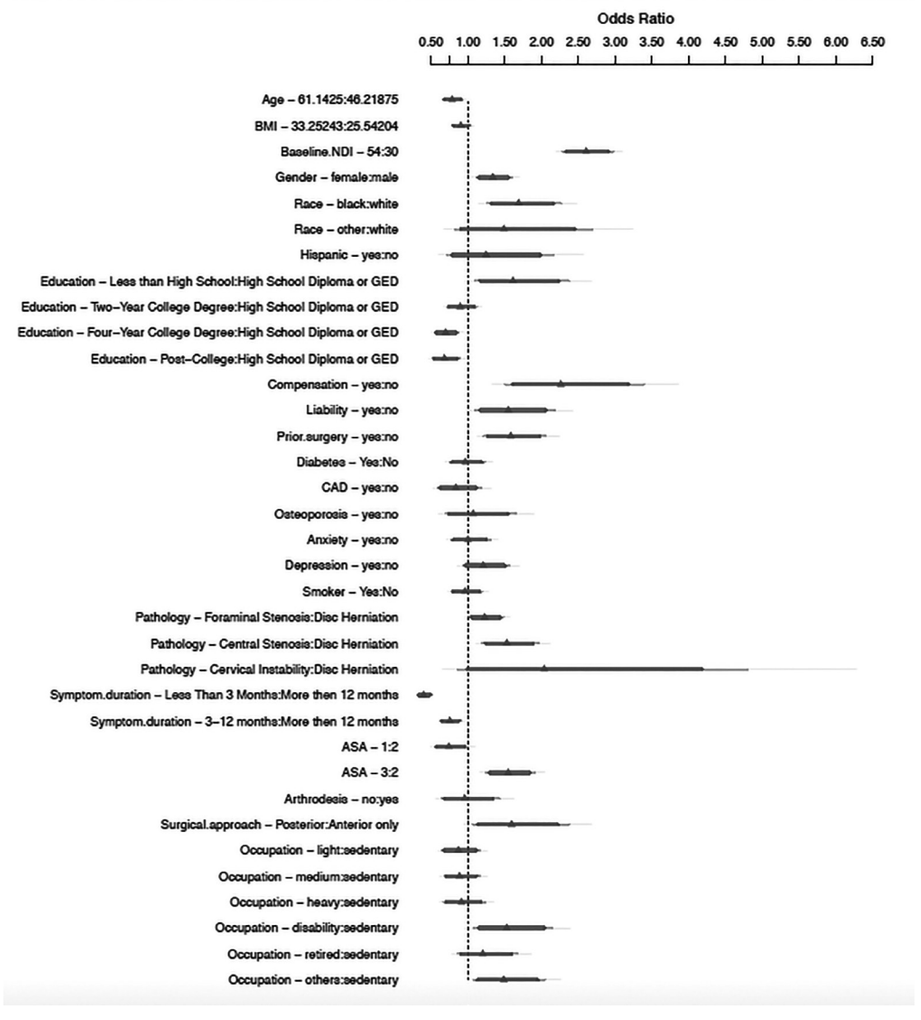
Methods: A total of 1964 patients undergoing degenerative cervical spine surgery for cervical radiculopathy were entered into a prospective multi-center national neurosurgery quality outcomes database. Baseline and 12-month neck disability index (NDI) scores were captured via telephone interview. A multivariable proportional odds ordinal logistic regression model was fitted for 12-month NDI. The calibration and discrimination of the models were internally validated using a bootstrapping approach.

Results: There was a significant improvement in all NDI scores from baseline to 12-months after surgery NDI- (42±18 vs. 20±18) ($P < 0.0001$, paired t-test). In multivariable proportional odds ordinal logistic regression analysis, after adjusting for an array of patient-specific and surgery-specific variables, higher baseline NDI, female gender, African-American race, lower education, patients on Workers' compensation, liability insurance, those on disability, unemployed, prior history of surgery, those with diagnosis of stenosis, higher ASA grades, and patients undergoing posterior approach had higher odds of having higher NDI scores (higher disability) at 12-month following surgery. Factors associated with lower odds of having higher disability were older age, higher education, and preoperative symptom duration less than 3-months (Figure 1). The C-index for models' discrimination performance was 0.69.

See Disclosure Index pages 39–89.

Conclusion: We present a novel prediction model that can provide individualized risk-adjusted estimates of 12-month neck related disability outcomes for patients undergoing degenerative cervical spine surgery. This model has the potential to assist providers during the preoperative assessment of patients and to improve patient engagement in shared decision-making concerning treatment planning and thereby facilitate true-patient centered spine care.

Figure 1. Demonstrating odds ratio and confidence interval derived from the multivariable proportional odds ordinal logistic regression analysis for 12-month NDI scores.



Effect of Surgery Start Time on Day of Discharge in Anterior Cervical Discectomy and Fusion Patients

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a commonly performed spinal procedure that typically has a short acute recovery period. With an increasing focus on reducing hospital costs and a shift towards outpatient surgical practices, early patient discharge has become a priority for hospitals and physicians alike. However, the impact of surgery start time on the ability for same-day discharge has not been explored in spine surgery. Therefore, the purpose of this study is to compare time to discharge for ACDFs when compared as either a first case versus later surgical start times.

Materials and Methods: A prospectively maintained database of patients who underwent a 1 to 2-level ACDF for degenerative spinal pathology between 2013–2015 by a single surgeon was reviewed. Patients were stratified into two cohorts: those whose surgery was the first of the day, and those that underwent later surgeries. Baseline patient characteristics and perioperative variables were compared between cohorts using Student's t-test and Chi-square test. Same day discharge was tested for association with surgical start time using Pearson's chi-squared test.

Results: A total of 106 patients, divided into first surgery and later surgery cohorts of 60 and 46 patients, respectively, were included in the analysis. There were no significant differences in pre- or perioperative characteristics between cohorts (Table 1). Same-day discharge was achieved in 36.8% ($n = 39$) of all ACDF patients. A significantly higher percentage of same-day discharge was observed in the first surgery cohort compared to the later surgery cohort (45.0% vs. 26.1%; $p = 0.045$; Table 3).

Conclusions: Patients undergoing ACDF later in the day are at a higher risk for staying overnight than those who have the first surgery of the day. These results may influence operative scheduling, as performing ACDFs early in the day may result in a greater likelihood of same-day discharge, eliminating the increased resource utilization associated with an overnight hospital stay.

See Disclosure Index pages 39–89.

Table 1. Baseline characteristics by surgery start time

	First Surgery (N = 60)	Later Surgery (N = 46)	†p-value*
Age (Mean±SD, years)	50.7±8.5	52.9±11.0	0.261
Sex (n)			0.083
Female	51.6% (31)	34.8% (16)	
Male	48.3% (29)	65.2% (30)	
Smoking status (n)			0.254
Non-smoker	86.7% (52)	93.5% (43)	
Smoker	13.3% (8)	6.5% (3)	
Operative levels (n)			0.863
1-level	55.0% (33)	50.0% (23)	
2-level	38.3% (23)	43.5% (20)	
3-level	6.7% (4)	6.52% (3)	
Body Mass Index (n)			0.162
< 30 – Non-obese	51.7% (31)	65.2% (30)	
> 30 – Obese	48.3% (29)	34.8% (16)	
CCI	0.88±1.10	1.20±1.07	0.135
Preoperative VAS	6.4±2.0	6.3±2.3	0.740
ODI	47.3±15.5	48.5±15.8	0.796
Operative Time (min)	54.7±20.6	59.4±23.1	0.934
Estimated Blood Loss (mL)	35.6±16.7	36.4±14.6	0.282
Intraoperative Complication	0.0% (0)	2.2% (1)¶	--
In-Hospital Complication	0.0% (0)	0.0% (0)	--
30-Day Readmissions	0.0% (0)	2.2% (1)††	--

SD = Standard Deviation; CCI = Charleson Comorbidity Index; VAS = Visual Analog Scale; ODI = Oswetry Disability Index; EBL = Estimated Blood Loss

***Boldface** indicates statistical significance

†p-values calculated using Student's t-test, Chi-squared test, or Poisson regression with robust error variance controlling for age, gender, smoking status, number of levels, BMI category, CCI, preoperative VAS and preoperative ODI

¶ Incidental durotomy

†† One patient readmitted for postoperative dysphagia three days following surgery

Table 2. Surgery start and end times

	First Surgery (N = 60)	Later Surgery (N = 46)
Start Hour		
Mean±SD	7:49±0:15	12:19±2:12
Earliest	7:27	9:10
Latest	8:44	17:51
End Hour		
Mean±SD	8:43±0:29	13:19±2:05
Earliest	8:00	10:02
Latest	10:08	18:47
Operative Time		
Mean±SD	54.7±20.6	59.4±23.1
Shortest	0:22	0:32
Longest	1:40	2:12

SD = Standard deviation

Table 3. Discharge day by surgery start time

	First Surgery (N = 60)	Later Surgery (N = 46)	†p-value*
Day of Discharge			**0.010**
Same Day	**45.0% (27)**	**26.1% (12)**	
Postoperative Day 1 or later	**55.0% (33)**	**73.9% (34)**	

***Boldface** indicates statistical significance

† P-value is calculated from Poisson regression with robust error variance controlling for age, gender, smoking status, number of levels, BMI category, CCI, preoperative VAS, preoperative ODI, operative time and estimated blood loss

See Disclosure Index pages 39–89.

Does Age, Obesity, and Sex Affect Radiographic and Clinical Outcomes in Patients Undergoing Long Multilevel Cervical-Thoracic Fusions? Multi-Center Analysis

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Introduction: Cervical fusion is used to treat neck problems such as fractures, trauma and other causes of instabilities. We investigated the effects of age, obesity and sex on radiographic and clinical outcomes in patients undergoing multilevel cervical-thoracic fusions.

Methods: We assembled a multicenter (4 sites) radiographic and clinical database of patients that had undergone 3 or more level posterior cervical-thoracic fusions for degenerative disease from January 2008 to May 2013 with at least 2 years of post-operative (post-op) follow-ups. All radiographic measurements were performed by an experienced clinical researcher. For the analysis, obesity was defined as body mass index (BMI) > 30, non-obese as BMI ≤ 30 and age was grouped as age ≤ 65 years or > 65 years. Analysis of Variance (ANOVA) was used to investigate the effects of age, obesity and sex on outcomes. As needed, post-hoc analyses were conducted to determine specific group differences. Level of significance was set at $\alpha = 0.05$.

Results: 73 patients met the inclusion criteria. Patients were distributed uniformly in terms of obesity, gender and age. Based on ANOVA, age and obesity had significant effects on both radiographic and clinical outcomes ($p < 0.05$) but sex was found to be significant only in case of few radiographic outcomes. At 2 years follow-up, mean cervical lordosis improved significantly in non-obese and patients aged ≤ 65 years as compared to their counterparts ($p < 0.05$). Sex did not have any significant effect on this measure ($p > 0.05$). Mean T1 slope at 2 years follow-up improved significantly in males, non-obese, patients aged ≤ 65 years ($p < 0.05$). At 2 years follow-up, mean C2-C7 sagittal plumbline increased significantly in obese, patient aged ≤ 65 years and females as compared to their counterparts ($p < 0.05$). Sex did not have any significant effect on clinical outcomes such as visual analog scale (VAS) and Oswestry disability index (ODI) ($p > 0.05$). Both mean VAS and ODI at 2 years follow-up improved significantly in non-obese and patients aged ≤ 65 years as compared to their counterparts ($p < 0.05$).

Conclusion: Our analyses indicate that obesity and age have significant effects on radiographic and clinical outcomes in patients undergoing multilevel cervical-thoracic fusions. Interestingly, sex was found to significantly affect only some radiographic variables. Based on our findings we suggest that clinicians should be cautious while treating these patient populations with cervical-thoracic fusions for degenerative disease.

Effects of Age, Obesity, and Sex on Radiographic and Clinical Outcomes in Patients Undergoing Multilevel Posterior Cervical Fusions: Multi-Center Analysis

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Introduction: Cervical fusion is used to treat neck problems such as fractures, trauma and other causes of instabilities. We investigated the effects of age, obesity and sex on radiographic and clinical outcomes in patients undergoing multilevel cervical fusions.

Methods: We assembled a multicenter (4 sites) radiographic and clinical database of patients that had undergone 3 or more level posterior cervical fusions (with caudal fusion level of C6 or C7) for degenerative disease from January 2008 to May 2013 with at least 2 years of post-operative (post-op) follow-up. All radiographic measurements were performed by an experienced, independent clinical researcher. For the analysis, obesity was defined as body mass index (BMI) > 30, non-obese as BMI ≤ 30 and age was grouped as age ≤ 65 years or > 65 years. Analysis of Variance (ANOVA) was used to investigate the effects of age, obesity and sex on outcomes. As needed, post-hoc analyses were conducted to determine specific group differences. Level of significance was set at $\alpha = 0.05$.

Results: 104 patients met inclusion criteria. Patients were distributed uniformly in terms of obesity, gender and age. Based on ANOVA, age and obesity had significant effects on both radiographic and clinical outcomes ($p < 0.05$) but sex was found to be significant only in case of few radiographic outcomes. At 2 years follow-up, mean cervical lordosis improved significantly in non-obese and patients aged ≤ 65 years as compared to their counterparts ($p < 0.05$). Sex did not have any significant effect on this measure ($p > 0.05$). Mean T1 slope at 2 years follow-up improved significantly in males, non-obese, patients aged ≤ 65 years ($p < 0.05$). At 2 years follow-up, mean C2-C7 sagittal plumbline increased significantly in obese, patient aged ≤ 65 years and females as compared to their counterparts ($p < 0.05$). Sex did not have any significant effect on clinical outcomes such as visual analog scale (VAS) and Oswestry disability index (ODI) ($p > 0.05$). Both mean VAS and ODI at 2 years follow-up improved significantly in non-obese and patients aged ≤ 65 years as compared to their counterparts ($p < 0.05$).

Conclusion: Our analyses indicate that obesity and age have significant effects on radiographic and clinical outcomes in patients undergoing multilevel cervical fusions. Interestingly, sex was found to significantly affect only some radiographic variables. Based on our findings we suggest that clinicians should be cautious while treating these patient populations with multilevel cervical fusions for degenerative disease.

See Disclosure Index pages 39–89.

A Comparative Study of Operative Methods of Cervical Spondylotic Myelopathy in Elderly Patients

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Introduction: The number of surgical procedures in elderly patients has been increasing as the population has grown older; recently, spine surgeons have been more likely to encounter elderly patients with cervical myelopathy in need of surgical treatment. There are many reports about surgical treatment of elderly patients with cervical spondylotic myelopathy (CSM); however, there are no studies about the proper selection of surgical methods and comparison of their results in elderly CSM patients. The objective of this study was to review the results of operative methods in CSM patients aged 75 years or more.

Methods: Subjects were selected from among 304 CSM patients who underwent surgery between January 2005 and March 2015. A total of 62 operated CSM cases aged 75 years or more were included in this study (37 males and 25 females; average age 79 years). The neurological severity was assessed using the Japanese Orthopaedic Association score for cervical myelopathy (JOA). The JOA scores were evaluated before surgery and at final follow-up (postoperative 1 year), and calculated the improvement rate. Cervical sagittal alignment (cervical sagittal vertical axis [SVA]; C2–C7 SVA and cervical lordosis; C2–C7 Cobb angle) were measured before surgery and at final follow-up. There were 29 C3–7 laminoplasty procedures (LP group), 23 selective laminoplasty procedures (SLP group), and 10 anterior decompression and fusion procedures (AF group). A selective laminoplasty was performed in case that was diagnosed as 1 intervertebral level both clinically and electrophysiologically. For intraoperative electrophysiological level diagnosis, we recorded 3 different intraoperative Spinal Cord Evoked Potentials (SCEPs) (Figure 1). We evaluated differences in clinical data, surgical outcome, imaging studies and postoperative complications among the 3 treatment groups.

Results: The average preoperative JOA score was 8.2 points and the average JOA recovery rate was 45%. There were 3 cases of C5 palsy and 1 wound infection in AF group and LP group. Superior cervical intervertebral levels (C3/4 and/or C4/5) were affected in 85% of the patients with spinal-tract CSM. Operative duration and intraoperative bleeding in SLP group were significantly smaller than those in the other groups. There was no significant difference in the JOA recovery rates among the groups. About cervical sagittal alignment, (Postoperative-Preoperative) C2–7SVA was significantly larger in the LP group and also Cobb angle was tend to be reduced in LP group against SLP group (Table 1).

Conclusions: As mentioned in previous reports, the pathophysiology of CSM in elderly patients involves a decreased range of intervertebral motility because of degeneration of the middle and inferior cervical vertebrae associated with a relative increase in instability of the superior cervical vertebrae. This may contribute to the onset of CSM affecting the superior intervertebral levels, suggesting that it may be possible to manage CSM of the superior cervical intervertebral levels in elderly patients using selective decompression. Selective laminoplasty was less invasive and also could reduce the postoperative complication and maintain the cervical sagittal balance. Elderly CSM patients could be good indication for selective laminoplasty if the indication for surgery has to be selected carefully.

Figure 1. Measurements of intraoperative spinal cord evoked potentials (SCEPs).

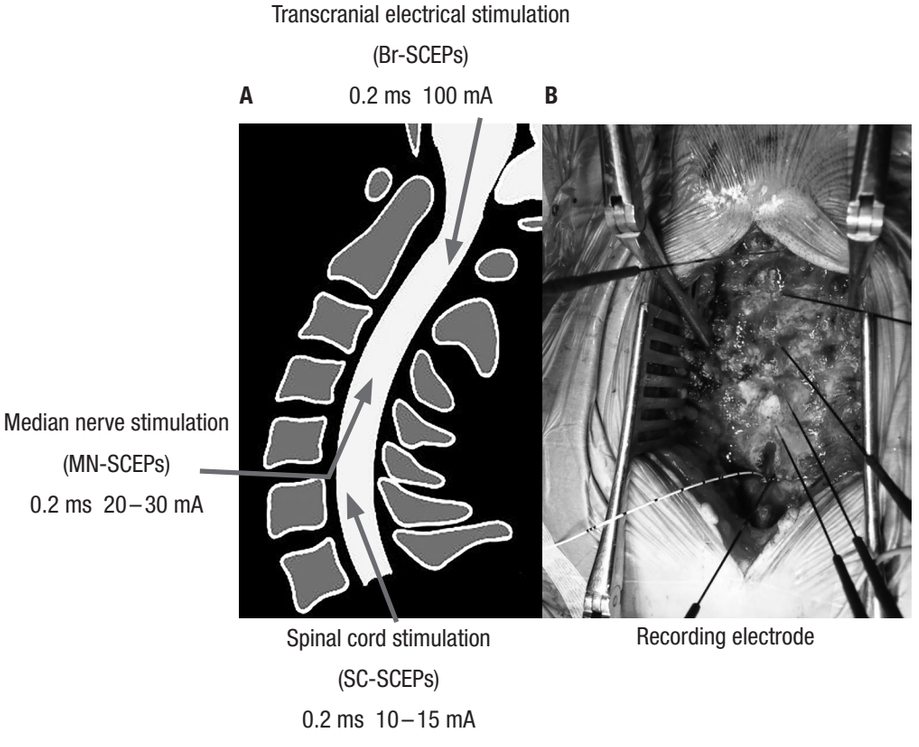

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Table 1. Demographic data of three groups			
Parameter	LP	SL	AF
Number	29	23	10
Age (years)	79±3	79±4	78±3
Gender (men/women)	20/9	14/9	3/7
Operative time (minutes)*	205±40	129±36	204±14
Intraoperative bleeding (g)*	160±123	60±66	127±82
JOA score (points)			
Preoperative	8.3±2.5	8.5±2.1	7.1±3.0
Final follow-up	12.1±2.8	12.2±2.6	11.5±1.1
Recovery ratio (%)	46.5±26.8	45±22	40 ± 22
Postoperative complication	3	0	1
Deep surgical site infection	2	0	0
Paraparesis (C5)	2	0	1
(Post-Pre) SVA (mm)*	14±16	-0.4±6	-0.5±10
(Post-Pre) Cobb angle (°)	-13±16	0.2±7	-7±9
Values are presented as mean±SD			
*P<0.01 Abbreviations: JOA, Japanese Orthopaedic Association scoring system for cervical myelopathy; LP, laminoplasty from C3 to C7; SL, selective laminoplasty; AF, anterior decompression and fusion; Post, postoperative; Pre, preoperative; SVA, cervical sagittal vertical axis			

The K-line in the Cervical Ossification of the Posterior Longitudinal Ligament is Different on Plain Radiographs and CT Images

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Introduction: We have reported the concept of the K-line for making decisions about the surgical approach for cervical ossification of the posterior longitudinal ligament (OPLL). However, the correlation of the K-line between radiographs and CT images remains unclear. The purpose of this study was to analyze whether the K-line measured from radiographs taken in the standing position was different from the K-line measured from CT images taken with the patient supine.

Methods: From January 2008 through May 2015, 65 patients with cervical OPLL underwent surgical treatment. The male to female ratio was 10:3, and the mean age was 63.0 years. The study population consisted of different types of OPLL: mixed (n = 39), segmental (n = 23), continuous (n = 2), and localized (n = 1). We investigated the K-line (+ or -) and the C2-7 angle at surgery, measured from cervical lateral radiographs in the standing position and sagittal plane cervical CT images in the supine position. We evaluated whether the K-line was different when measured from radiographs or CT images. We sorted patients into two groups defined by whether the K-line was different or the same in the two imaging modalities. Then we compared the two groups for differences in the C2-7 angle measured from radiographs or from CT images.

Results: Patients were divided into 35 K-line (+) patients and 30 K-line (-) patients based on radiographs. Of the K-line (+) patients, the K-line did not change when measured from CT images on 31 patients, but in four patients the K-line changed into K-line(-) when measured on CT images. The C2-7 angle of the 31 K-line (+) patients that were not different on radiographs and CT images was 11.1° in lordosis by radiograph and 11.2°in lordosis by CT. The C2-7 angle of the 4 K-line (+) patients whose measurement was different on radiographs and by CT was 9.3° in lordosis by radiograph and 9.5° in kyphosis by CT (P = 0.003). Of the K-line (-) patients, the K-line did not change in 29 patients when measured by radiograph or CT, but did change in one patient.

See Disclosure Index pages 39–89.

Conclusions: The K-line can change depending on whether it is measured from radiographs in the standing position or from CT images with the patient in the supine position. The C2-7 angle changes from radiograph to CT because the position of the patient's head changes when they are standing or supine.

When it is not possible to evaluate the K-line radiographically because of limitations imposed by the anatomical interference of the shoulder contour, which occurs most commonly in obese patients, it is important to be careful in evaluating the K-line by CT because it may be different than it would have been if measured radiographically.

Clinical and Radiographic Outcomes following Lateral Mass Stabilization at the Cervicothoracic Junction

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Introduction: Previous biomechanical studies of the cervical spine have demonstrated that the integrity of terminal dorsal ligaments is especially important at the cervicothoracic junction (CTJ). The results of these investigations have suggested extending cervical constructs that would otherwise end at the level of C7 to the T1 level in order to provide additional stabilization and limit adjacent segment degeneration at the CTJ. However, clinical studies investigating this complex anatomical area are lacking.

Materials and Methods: The medical records of patients who were identified as having posterior cervical laminectomy with lateral mass fixation of 3 or more levels terminating at the C7 or T1 levels were included within the study. Clinical and radiographic outcomes were compared between patients whose construct ended at the C7 level versus those in which the fusion extended past the CTJ to the level of T1.

Results: A total of 84 patients fit the inclusion criteria. Of those, 24 patients received lateral mass fixation constructs that ended at the C7 level whereas 60 patients had their constructs end at T1. There were no significant differences in demographics, surgical, or radiographic characteristics between cohorts, other than longer construct lengths in the T1 cohort. One-year postoperative radiographs demonstrated a higher C2–C3 disc angle and C2–C7 sagittal vertical axis in patients with fusion to the T1 level ($p < 0.01$ for both measurements). In addition, patients with fusion constructs ending at T1 had a significant increase in their C2–C7 sagittal vertical axis 1 year postoperatively when compared to preoperative measures ($p = 0.03$). There were no differences in complications, reoperations or adjacent level degeneration or disease between cohorts at average follow-up of 17 months.

Conclusion: This study represents an important clinical correlation of previous biomechanical studies. In contrast to the findings of these cadaveric studies, our clinical results demonstrate that extending a lateral mass fixation past the CTJ actually caused an increase in cervical kyphosis, which is a negative predictor of postoperative quality of life values.

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Table 1. Differences in Demographic and Operative Characteristics Between Cohorts

Patient Characteristics	Ends at C7 (n = 24)	Ends at T1 (n = 60)	p Value
Age	54.3±13.4	59.9±15.0	0.1
Female Gender	11 (46%)	23 (38%)	0.6
BMI	27.9±5.9	29.9±6.7	0.2
Current Smoker	6 (25%)	16 (27%)	1.0
Smoking History	12 (50%)	35 (58%)	0.6
Average Pack Years	20.0±12.3	21.7±13.7	0.7
Worker's Compensation	0 (0%)	1 (2%)	1.0
Diabetes	4 (17%)	18 (30%)	0.3
CAD	6 (25%)	23 (38%)	0.3
Anti-Depressants	12 (50%)	19 (32%)	0.1
Anxiolytics	8 (33%)	11 (18%)	0.2
Narcotics	10 (42%)	25 (42%)	1.0
Axial Neck Pain	12 (50%)	36 (60%)	0.5
Myelopathy	11 (46%)	40 (67%)	0.09
UE Pain	14 (58%)	31 (52%)	0.6
UE Numbness	9 (38%)	25 (42%)	0.8
UE Weakness	11 (46%)	33 (55%)	0.5
CSM	11 (46%)	32 (53%)	0.6
Pseudarthrosis	7 (29%)	8 (13%)	0.1
Deformity	2 (8%)	9 (15%)	0.5
# Levels Decompressed	1.6±1.4	2.7±1.4	< 0.01*
# Levels Fused	3.1±1.1	4.7±1.0	< 0.001*
EBL (cc)	291.5±337.6	338.6±253.8	0.5
Operative Time (min)	204.4±107.7	192.2±73.7	0.6
Length of Stay (days)	5.3±3.8	4.3±2.6	0.2
Complications	4 (17%)	12 (20%)	1.0
Symptomatic ASD	4 (17%)	6 (10%)	0.5
Reoperation	2 (8%)	4 (7%)	1.0
Wound Washout	1 (4%)	1 (2%)	0.5
Construct Failure	4 (17%)	15 (25%)	0.6

BMI: Body Mass Index; CAD: Coronary Artery Disease; UE: Upper Extremity;
CSM: Cervical Spondylotic Myelopathy; EBL: Estimated Blood Loss;
ASD: Adjacent Segment Degeneration
*p Values ≤ 0.05 were considered statistically significant

Table 2. Differences in 1 - Year Radiographic Outcomes Between Cohorts

Radiographic Outcomes	Ends at C7 (n = 24)	Ends at T1 (n = 60)	p Value
Pre Cobb Angle Post Cobb Angle *p Value*	-8.6±17.2 -6.7±7.9 *0.6*	-6.4±13.2 -6.6±15.1 *0.9*	0.5 1.0
Pre Gore Angle Post Gore Angle *p Value*	-12.0±17.6 -10.6±9.6 *0.7*	-9.6±15.4 -10.5±17.5 *0.8*	0.5 1.0
Pre C2/3 Disc Angle Post C2/3 Disc Angle *p Value*	17.9±11.1 19.7±7.3 *0.5*	24.2±14.6 27.0±15.6 *0.3*	0.06 < 0.01*
Pre C2-7 SVA Post C2-7 SVA *p Value*	31.4±17.4 32.7±14.2 *0.8*	38.4±15.6 45.0±18.0 *0.03**	0.08 < 0.01*
Pseudarthrosis	1 (4%)	2 (3%)	1.0
Kyphosis Above	2 (8%)	7 (12%)	1.0
Kyphosis Below	1 (4%)	7 (12%)	0.4
ASD Above	2 (8%)	7 (12%)	1.0
ASD Below	1 (4%)	3 (5%)	1.0

SVA: Sagittal Vertical Axis; ASD: Adjacent Segment Degeneration

See Disclosure Index pages 39–89.

Impact of Cranio-Cervical Balance on Surgical Outcome after Laminoplasty for Cervical Spondylotic Myelopathy

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Introduction: Spinal sagittal balance is considered one of the most critical factors affecting the health-related quality of life. Cranio-cervical balance may also have important role in cervical function, but there have been few studies focused on cranio-cervical balance in cervical myelopathy patients. The purpose of this study was to investigate the change in cranio-cervical balance after laminoplasty and its impact on clinical outcome.

Material and Methods: One hundred and fifteen patients (74 men, and 41 women) who underwent cervical laminoplasty for cervical compressive myelopathy and followed for more than 1 year were included in this study. Average age at surgery was 64.7 years, and average follow up period was 4.1 years. For the clinical evaluation, Japanese orthopaedic association score for cervical myelopathy (JOA score) and visual analogue scale of neck pain, upper extremity pain and numbness were evaluated before surgery, at 3 months, 1 year after surgery and at latest follow-up. Recovery rate of JOA score was calculated by the Hirabayashi method. For radiological assessment, preoperative and postoperative (at latest follow-up) plain cervical x-ray was used. The x-ray was taken in the neutral cervical position with the patient sitting and the upper arms extended downward. Cranio-cervical balance was evaluated using the distance between the plum line from the center of the C1 anterior arch and the posterosuperior corner of C7 (C1SVA). In this study, cranio-cervical imbalance was defined as C1SVA more than 40mm. For the analysis of change in radiographical parameter, Wilcoxon-signed rank test was performed. For the analysis of clinical outcome, patients were divided into 2 groups by preoperative C1SVA; imbalance group and balance group. Linear mixed model was used and each postoperative parameter was adjusted for age, time of evaluation and preoperative score.

Results: Average C1SVA was 34.3±18.1 mm and 37.3±19mm at the latest follow-up. There was not significant difference between the two time periods. Cranio-cervical imbalance was found in 27% preoperatively, and 36% at the latest follow-up. The change more than 20mm of C1SVA was found in 22%. The balance was improved in 26% of the patients with imbalance, whereas the imbalance was newly occurred in 21% of the patients with preoperative normal balance. Overall, JOA score and each VAS score were significantly improved after laminoplasty. However, the improvement of JOA score after laminoplasty was significantly worse in the patient with cranio-cervical imbalance. In the categories of JOA score, there were significant differences in motor function of upper extremity, motor function of lower and bladder function between the two groups. The imbalance did not affect to the postoperative improvement of neck pain, upper extremity pain and numbness.

Conclusion: The change of cranio-cervical balance after laminoplasty was seen in approximately 20% of the patients. Preoperative cranio-cervical imbalance is related to poor improvement of JOA score after laminoplasty.

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Preoperative Radiographic Parameters to Predict a Higher Pseudarthrosis Rate following Anterior Cervical Discectomy and Fusion

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Introduction: Various factors, including type of bone graft, number of fusion levels, and duration of follow-up, have been reported to influence occurrence of pseudarthrosis after anterior cervical discectomy and fusion (ACDF). However, to our knowledge, there has been no report on the relationships between preoperative radiographic parameters and postoperative pseudarthrosis. The purpose of this study was to determine whether postoperative pseudarthrosis could be predicted according to specific parameters on preoperative plain radiographs, including segmental and global cervical motion and T1 sagittal slope.

Methods: We retrospectively analyzed 84 consecutive patients (male:female = 45:39; mean age, 58.9±11.2 years) who underwent ACDF and were followed for more than 2 years. In all patients, allografts filled with local chip bone were inserted after discectomy and anterior plating was performed. On preoperative plain radiographs, various parameters were measured and analyzed; C2-C7 sagittal vertical axis (SVA), T1 sagittal slope, segmental motion, global cervical (C2-C7) motion, segmental interspinous motion, and location of fusion segments. Pseudarthrosis was diagnosed as interspinous motion > 1 mm with superjacent interspinous motion ≥ 4 mm on the magnified plain dynamic lateral radiographs at final follow-up. Multiple logistic regression was performed to analyze the risk factors of pseudarthrosis, and the receiver operating characteristic (ROC) curve was used to define a cutoff value.

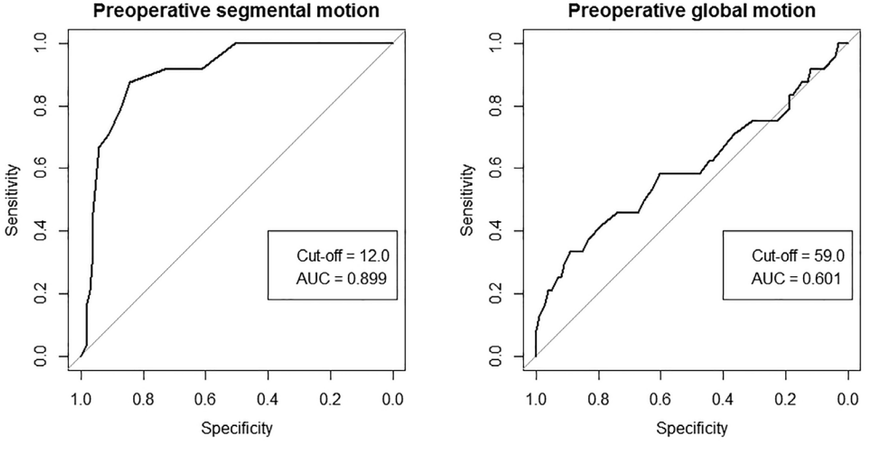
Results: Eighty-four patients (1 level in 49, 2 levels in 29, and 3 levels in 6) and 125 segments (4 at C3-4, 31 at C4-5, 55 at C5-6, and 35 at C6-7) were included. The pseudarthrosis rate was 29% based on number of patients (24/84) and 20% based on number of segments (25/125). Multilevel surgery and the lowest cervical fusion level showed a higher pseudarthrosis rate ($p = 0.01$). In multiple logistic regression analysis, C6-7 segment, greater T1 sagittal slope, and greater segmental motion were associated with a higher risk of pseudarthrosis ($P < 0.05$, respectively)(Table1). A cutoff value of segmental motion of 12° demonstrated pseudarthrosis with a sensitivity of 87%, specificity of 84%, and area under the curve of 0.899, indicating moderate accuracy (Figure 1).

Conclusions: Greater preoperative segmental motion, greater T1 sagittal slope, and the lowest fusion level (especially C6-7 segment) could be risk factors of pseudarthrosis following ACDF. According to the ROC curve, a preoperative segmental motion > 12° is likely to be a clue to predict the development of pseudarthrosis. Surgeons need to be aware of these risk factors which could be detected on preoperative plain radiographs and should consider various supportive procedures to enhance the fusion rate in those cases.

Table 1. Radiologic data of fusion group and pseudarthrosis group

	All segments (N = 125)	Fusion segments (N = 100)	Pseudarthrosis segments (N = 25)	p-value
Preoperative C2-C7 SVA (mm)	24.84±12.02	24.34±11.36	26.97±14.58	0.414
Preoperative T1 sagittal slope (°)	24.35±7.43	23.74±7.16	26.92±8.15	0.030
Preoperative segmental interspinous motion (mm)	6.69±3.18	6.55±2.90	7.31±4.18	0.403
Preoperative segmental motion (°)	9.97±4.42	8.73±3.73	15.17±3.20	< 0.001
Preoperative C2-C7 motion (°)	45.72±12.94	44.70±12.18	50.00±15.30	0.124
Surgical level				0.042
C3-4	4 (3.2%)	4 (4.0%)	0 (0%)	
C4-5	31 (24.8%)	28 (27.7%)	3 (12.5%)	
C5-6	55 (44.0%)	46 (45.5%)	9 (37.5%)	
C6-7	35 (28.0%)	23 (22.8%)	12 (50.0%)	0.016

Figure 1. ROC curve of the segmental motion and the global cervical (C2-C7) motion



See Disclosure Index pages 39–89.

Microendoscopic Selective Laminectomy vs. Conventional Laminoplasty in Patients with Cervical Degenerative Myelopathy having a Single- or Two-Level Spinal Cord Compression

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Introduction: Although a posterior shift of the spinal cord is considered to be the main concept of posterior decompression surgery for degenerative cervical myelopathy, several less invasive techniques, such as selective laminectomy and microendoscopic laminectomy via a unilateral paramedian approach, which do not require extensive spinal cord shift, have demonstrated good results. In this study, we investigated the efficacy of our minimally invasive technique, cervical microendoscopic interlaminar decompression (CMID) via a midline approach, for treating cervical myelopathy.

Methods: This is a retrospective study of prospectively enrolled patients who underwent laminoplasty (LP) or CMID for cervical spondylotic myelopathy (CSM) or the ossification of the posterior longitudinal ligament (OPLL) (occupying ratio of <40%) between May 2006 and April 2014. Patients with an anterior slip (>3 mm) or kyphosis (>10°) were excluded. All patients routinely underwent LP (C3–6 or C3–7) based on the concept of posterior spinal cord shift before December 2011, whereas CMID was performed at the affected one or two level(s) only in patients with a single- or two-level spinal cord compression after 2012. No patients that met the criteria underwent anterior surgery.

Surgical Procedure (CMID): For single-level cases (e.g., C5-6), partial laminectomy of C5 and C6 with approximately 15-mm width were performed via a midline intermuscular approach of approximately 16-mm skin incision. For two-level cases (e.g., C5-6 and C6-7), the decompression procedure was completed with C6 laminectomy (Figure 1).
We compared surgical outcomes and radiographic parameters between the CMID and LP groups in patients having a single- or two-level spinal cord compression.

Results: Of the 232 patients followed up for >2 years, 87 patients with a single- or two-level spinal cord compression, 46 with CMID and 41 with LP, were identified. There was no difference in the baseline demographic data of the patients between the two groups (CMID vs. LP): average age, 63.4 vs. 64.5; male/female, 32/14 vs. 23/18; follow-up period, 27.8 vs. 27.3 months; and CSM/OPLL, 35/11 vs. 30/11. Moreover, there were no significant differences in the preoperative outcomes and radiographic parameters. Two patients and one patient complained of C5 palsy and hematoma, respectively, in the LP group, whereas there were no complaints in the CMID group. The postoperative range of motion was worse and the degree of postoperative posterior spinal cord shift was larger in the LP group. Postoperative neck, arm, and scapular pain, physical function (PF) and general health (GH) of the SF-36 were significantly better in the CMID group (Table 1).

Conclusions: This study revealed that selective decompression by CMID demonstrated equivalent surgical outcomes as the conventional LP of C3-6 or C3-7, questioning the requirement of posterior spinal cord shift in such patients. Furthermore, the microendoscopic procedure via a midline intermuscular approach minimized blood loss and muscle trauma, resulting in no hematoma and less postoperative pain. Although the indication of CMID is limited and comparison with anterior surgery is mandatory, it can be a minimally invasive procedure for cervical degenerative myelopathy.

Figure 1.

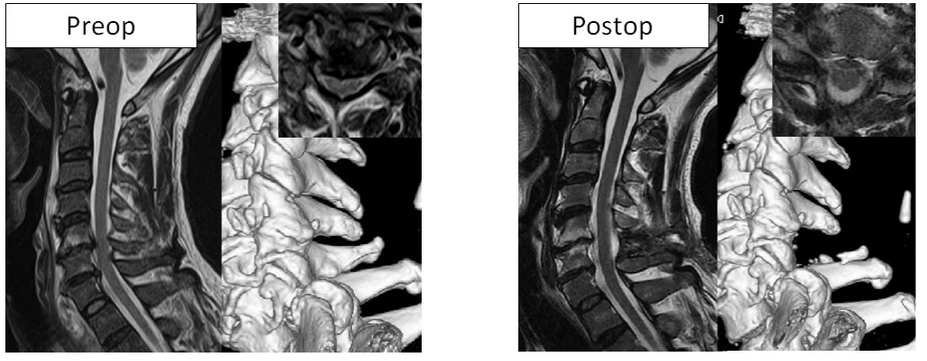

Table 1.

Table 1. Comparison of radiographic parameters and surgical outcomes between CMID and LP

		CMID average	SD	LP average	SD	P value
C27 Cobb (degrees)	*pre*	11.0	8.0	9.5	9.3	0.45
	post	10.7	8.7	11.5	12.4	0.76
C27 ROM (degrees)	*pre*	41.8	10.8	44.3	14.5	0.39
	post	42.1	10.6	28.2	12.4	0.00
C27 SVA (mm)	*pre*	1.9	1.4	2.0	1.2	0.76
	post	1.6	1.2	2.1	1.5	0.16
Spinal cord diameter (mm)	*pre*	4.2	0.9	4.2	0.7	0.76
	post	5.7	1.1	5.9	0.7	0.44
Posterior spinal cord shift (mm)		1.9	1.1	2.9	1.4	0.00
Numerical rating scale						
Neck	*pre*	3.3	2.7	3.7	3.2	0.52
	post	1.3	1.8	3.0	2.4	0.00
Arms	*pre*	3.8	2.8	4.4	3.0	0.35
	post	1.7	2.1	3.4	2.5	0.00
Scapular lesion	*pre*	2.0	2.6	2.2	2.6	0.64
	post	1.1	1.6	2.7	2.5	0.00
NDI	*pre*	34.0	15.5	35.2	18.9	0.74
	post	21.9	15.1	28.1	16.2	0.08
EQ5D	*pre*	0.58	0.11	0.57	0.17	0.94
	post	0.73	0.17	0.66	0.19	0.07
SF-36						
PF	*pre*	29.6	22.9	27.6	16.4	0.66
	post	41.5	18.4	31.5	16.7	0.01
RP	*pre*	29.7	18.0	26.5	15.0	0.40
	post	39.3	13.9	34.1	16.2	0.13
BP	*pre*	37.2	0.7	36.1	9.8	0.65
	post	44.6	10.1	40.8	11.3	0.11
GH	*pre*	44.0	9.3	41.8	9.4	0.30
	post	46.2	9.0	41.2	12.3	0.04
VT	*pre*	42.0	12.8	41.9	12.9	0.95
	post	45.1	12.9	44.1	11.6	0.70
SF	*pre*	37.1	16.5	34.4	15.7	0.46
	post	43.1	12.7	40.4	14.3	0.37
RE	*pre*	38.8	19.2	32.3	17.1	0.12
	post	43.7	15.5	38.9	15.2	0.16
MH	*pre*	44.7	12.9	40.8	15.4	0.23
	post	48.2	10.7	47.6	11.4	0.81
JOA score	*pre*	10.5	2.9	10.5	2.2	0.92
	post	13.2	2.7	13.3	2.1	0.84
	recovery rate	45.7	28.0	43.7	29.9	0.75

See Disclosure Index pages 39–89.

Correlation and Profile of Quality of Life and Functional Outcome Measures for Cervical Spondylotic Myelopathy after Surgery: A Cohort Study

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Introduction: In the present study we sought to 1) investigate the profile of functional outcome assessment by evaluating the modified Japanese Orthopaedic Association (mJOA) and quality of life by SF-36, 2) investigate the correlation between quality of life and functional outcome measures at different follow-up time, and then 3) further understand the ability of the various measures to predict favorable quality of life (health transition item) at different follow-up time for patients undergoing operation for CSM.

Methods: We used the modified Japanese Orthopedic Association (mJOA) assessment and the SF-36 to preoperatively evaluate the patients and again in continuous follow-ups conducted at three months, one year and more than two years after surgery. For evaluating the profile of health status measures (HSMs), changes in clinical effects in each group after surgeries were analyzed by the Wilcoxon rank-sum test. For investigating the correlation between the two HSMs, we computed the Spearman rank correlation analysis. To assess each HSMs' ability to discriminate HTI, we performed receiver operating characteristic (ROC) curve, area under the curve (AUC) and Spearman rank correlation analysis.

Results: 280 CSM patients were enrolled.

1.) The mJOA score was improved significantly at any follow-up time. At three months after surgery, the recovery of sensory function was better than motor function, while at one year after surgery and at the final follow-up time, the recovery of sensory and motor function had no significant difference. The mJOA score peaked 16.4 months after the surgery. Before surgery, all patients' QoL showed varying degrees of decreases in all sections compared to normal population. Two sections – role-physical, and role-emotional – showed the most significant declines. After surgery, with the exception of general-health and social-function at three months after surgery, all the other items at every follow-up time all showed significant improvement. The maximum recovery time point of the physical component score (PCS) was 20.1 months and mental component score (MCS) was 24.1 months after surgery.

2.) We found a correlation between improvement in the mJOA score and PCS at 3 months after surgery, but not in MCS. While at 1 year after surgery and the final follow-up, the improvement of mJOA was associated with both PCS and MCS.

3.) The AUC and correlation coefficient of PCS showed the highest of the four measures. The recovery rate of mJOA appeared to be the most accurate discriminator at one year after surgery. As for the final follow-up, the results were not consistent as the recovery rate of mJOA showed the highest AUC and the highest correlation coefficient was for MCS.

Conclusions: CSM patients can benefit from surgical treatment by significant improvement of neurological function and quality of life, with sensory function and PCS recovering more quickly than motor function and MCS. mJOA (16.2 months), PCS (20.1months) and MCS (24.1 months) reached their maximum recovery points in order. The most responsive indicator varies depending on the follow-up time.

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Malnutrition is More than Just Low Serum Protein and is Associated with Poor Outcomes and Increased Hospital Costs in Patients Undergoing Elective Cervical Spine Surgery

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Introduction: Risk factors for malnutrition include advanced age and chronic disease. Low serum protein markers such as albumin are commonly used to diagnose malnutrition. However, recent studies have demonstrated that these markers lack specificity in assessing nutritional status and can be influenced by a multitude of factors, most significantly, an underlying inflammatory state. The ICD-9 diagnoses of malnutrition are often made using more thorough criteria such as functional status, recent weight loss, caloric intake, and physical exam findings during nutritional assessments conducted by health-care staff. According to these criteria, even patients undergoing elective cervical spine surgery may be malnourished and large studies evaluating inpatient outcomes in this population are limited.

Material and Methods: Utilizing *International Classification of Diseases, Ninth Edition, Clinical Modification* codes and data from the National Inpatient Sample from 2002 to 2012, 617 malnourished patients undergoing elective cervical spine surgeries for degenerative cervical disease were compared to 1,322,120 patients who were not diagnosed with malnutrition undergoing the same surgeries. Length of stay, post-operative complications, mortality, and total hospital charges were the primary outcome measures. Complications were classified as major or minor. Major complications included acute myocardial infarction, cardiac arrest, septicemia, septic shock, stroke, and pulmonary embolism. Minor complications included deep vein thrombosis, pneumonia, surgical complications, post-operative anemia, and urinary tract infections.

Results: Mean age upon admission of malnourished patients was 63.6 (SD = 13.4) compared to 52.9 (SD = 11.9) in patients not diagnosed with malnutrition ($p = < 0.001$). Major complications in malnourished patients were significantly increased when compared to patients with normal nutritional status (17.8% compared to 0.5%; $p < 0.001$). The rate of mortality was forty-one times greater in the malnourished population (4.1% compared to 0.1%; $p < 0.001$). Malnutrition was an independent risk factor for both major complications (OR = 6.07, 95% CI = 4.67 – 7.89; $p < 0.001$) and inpatient mortality (OR = 4.59, 95% CI = 2.92 – 7.22; $p < 0.001$). Patients who were malnourished had a more than six-fold increase in their mean lengths of stay (13.5 compared to 1.9; $p < 0.001$) and three-fold increase in total hospital charges ($46,528; SD = $43,475 vs. $16,767; SD = $11,351; $p < 0.001$.).

Conclusion: Risk factors for malnutrition include advanced age and chronic disease and the diagnosis of malnutrition is best made with a formal nutritional assessment. Recent literature has shown that serum protein markers are, oftentimes, not an accurate reflection of underlying nutritional status. As malnutrition substantially increases the risk of post-operative complications, mortality, length of hospital stay, and consequent total hospital charges, screening for malnutrition in those that are at higher risk of being malnourished may be prudent even in the setting of elective cervical spine surgery.

Posterior Rectangular Foraminotomy for Cervical Radiculopathy: Comparisons between Soft vs. Hard Discs, Single vs. Double Levels

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Introduction: Posterior cervical foraminotomy (PCF) is less commonly performed for cervical radiculopathy (CR) than anterior fusion, perhaps due to technical difficulty and long learning curves. Although there have been many long-term follow-up results of PCF, few studies has compared the outcomes of soft vs. hard disc, and single vs. double level radiculopathy. Recently, rectangular-shaped PCF has been a common procedure. But there has been no report on the outcomes following this technique. The purpose of this study is to report outcomes following rectangular PCF for CR.

Materials and Methods: We analyzed consecutive cases of CR patients who underwent rectangular PCF of 1-2 levels using a mini-open approach (superior-inferior: from cranial pedicle lower border to caudal pedicle upper border, medial-lateral: from uncovertebral joint area to the lateral border of the caudal pedicle). CR patients with intolerable neck pain, segmental instability and central disc herniation were excluded. Disc fragments were removed in all soft disc cases. We assessed the clinical parameters, characteristics of CR, estimated blood loss(EBL), surgical time, percent of symptom improvement, VAS of neck and arm pain (VAS-N and VAS-A), NDI and complications. Radiographically, we assessed disc degeneration by Kellgren grade, disc height, segmental motion and translation.

Results: A total of 62 patients were enrolled (M:F = 44:18, mean age 52.2 years, mean follow-up: 30 months, soft:hard disc = 23:39, single:double level = 42:20). The mean EBL was 35mL. Degree of VAS-A improvement on the first postoperative day (POD1) and two weeks were 69 and 89% respectively. Preoperative VAS-N and VAS-A were significantly improved (1.4 to 0.5 and 7.1 to 0.3) at the last follow-up. Seven patients (11%) had persisting arm pain (mean VAS 2.4) at the last follow-up. All radiographic parameters showed no significant difference. The mean EBL (50.7:26mL) and symptom improvement on POD1 (80:63%) were significantly greater for soft discs than hard discs. The mean surgical time (66:85 min) was longer in double level than single level PCF. The outcome parameters including VAS-N, VAS-A and NDI showed no significant differences between soft vs. hard disc, single vs. double levels at the last follow-up. No case required anterior fusion at the last follow-up.

Conclusions: Rectangular PCF, a wider foraminal decompression than conventional semicircular PCF showed favorable outcomes for both soft and hard discs, single and double level CR, without instability, axial pain or additional anterior fusion. About 90% of patients did not show radicular pain at the last follow-up. PCF appears to be a reliable primary surgical treatment option for CR caused by foraminal nerve root compression.

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Figure 1. Intraoperative picture (A) shows C6-7 Rt. Rectangular foraminotomy and separated dural sleeve of C7 root. A three-dimentional reconstructed CT image (B) of C4/5 Lt rectangular foraminotomy.

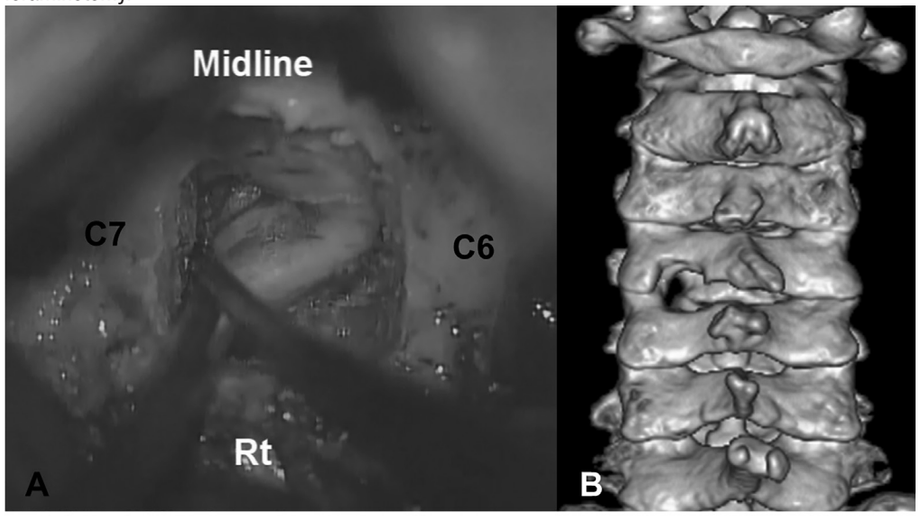
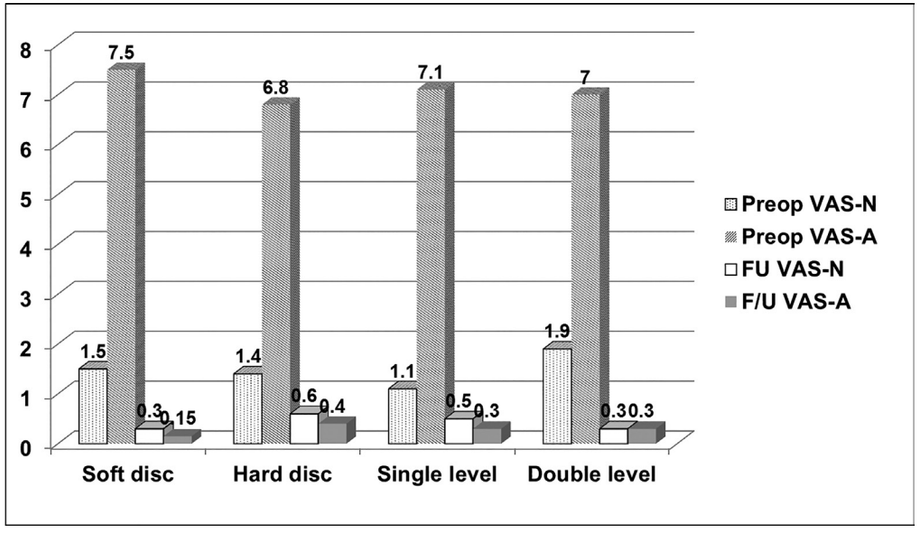


Figure 2. Comparisons of VAS-neck pain and arm pain between soft disc vs. hard disc, single level vs. double levels



Risk Factors for Poor Outcome after Laminoplasty for K-line(+) Type Cervical Ossification of the Posterior Longitudinal Ligament

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Introduction: Laminoplasty (LMP) is one of widely accepted surgical procedures for cervical ossification of the posterior longitudinal ligament (OPLL). We previously reported that K-line, which is a line connecting the midpoints of the spinal canal at C2 and C7, as a useful indicator for decision making to choose operative methods for cervical OPLL. OPLL did not exceed the K-line defined as K-line (+) and OPLL did exceed it defined as K-line (-). LMP often results in poor neurological recovery for K-line (-) cases because the rationale of LMP is indirect decompression obtained by posterior shift of the spinal cord. In contrast, we have been reported that LMP shows favorable outcome for K-line (+) OPLL. However, several K-line (+) OPLL patients show poor neurological recovery.

The purpose of the present study was to elucidate possible risk factors for poor outcome after LMP for K-line (+) OPLL.

Methods: The present study included 36 patients (male: female = 24:12) who underwent LMP at our institute and were followed at least 1 year after surgery. The mean age at surgery was 62.6 years old and the average follow-up period was 5.7 years. Clinical outcome was assessed with Japanese Orthopaedic Association (JOA) score for cervical myelopathy. The recovery rate was calculated using Hirabayashi's method. For radiographic evaluation, maximum occupation ratio of the OPLL, the segmental range of motion (Seg ROM) at maximum occupation level, C2-C7 angle (positive value indicates lordosis and negative value indicates kyphosis) and postoperative K-line were measured.

Results: Pre- and post-operative average JOA score was 9 points and was 12.6 points respectively, and then average recovery rate was 40.1%. Average maximum occupation ratio of OPLL was 48.4%. The average range of motion at maximum occupation level was 6.7 degree. The average C2–C7 angle was 11.1 degree preoperatively and 3.8 degree at last visit. K-line converted from plus to minus postoperatively in 7 patients. Statistical analyses with logistic regression revealed that the Seg ROM had negative impact on outcome. ROC analysis revealed that 7.5 degree of Seg ROM as cut-off value.

Conclusion: The patient whose Seg ROM is large can result in poor outcome after LMP for K-line (+) OPLL.

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Dural Tube Continues to Expand after Muscle Sparing Cervical Laminectomy

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Background: Dural tube expand immediately after the laminectomy. But we often saw the late expansion of dural tube after the muscle sparing laminectomies. The purpose of this study is elucidating how long dural tube continue to expand after the surgery and how much the amount of dural expansion affects surgical outcomes.

Materials and Method: We retrospectively examined 83 patients who underwent muscle sparing selective laminectomy of consecutive three laminae between C4 and C6 due to cervical myelopathy between 2012 and 2014. All patients were followed up more than 2 years. On the lateral radiographs, C2-7 Cobb angles in neutral position, range of flexion-extension neck motions (ROM), and C2-7 SVA were measured pre- and post-operatively in each patient. Neck alignment was classified to 4 types such as lordosis, straight, sigmoid and kyphosis with lateral x-rays. Anteroposterior(AP) diameter of dural tube was measured at mid-level of C5 vertebral body on T2 sagittal image pre- and post-operatively. Expansion ratio (ER) was defined as the amount of expansion diameter divided by the final amount of expansion diameter of dural tube. Operative outcomes were examined with JOA scores.

Results: Average age was 62.3 and average follow-up periods was 2 years and 9 months. There were 57 males and 26 females. The number of patients who suffered cervical spondylotic myelopathy, cervical OPLL, cervical spondylotic amyotrophy and cervical disc herniation was 62, 16, 4 and 1 respectively. The number of cases with lordosis, straight, sigmoid and kyphosis was 28, 21, 11 and 23. Pre- and post-operative C2-7 angles averaged 9.4±12.4 and 8.4±13.0 ($p = 0.2$). Pre- and post-operative ROM averaged 33.7±11.9 and 30.4±10.7 ($p < 0.05$). Pre- and post-operative SVA averaged 18.6±11.0 and 20.8±12.2mm ($p < 0.05$). AP diameter of dural tube, the amount of expansion of dural tube and ER at the particular time are shown on Table 1. From the results, the dural tube seemed to expand until 1 year after the surgery. ER classified with neck alignment at 6 months after the surgery was shown on Table 2. ER in the cases with kyphosis at 6 months was lower than that in the cases without kyphosis. This means that speed of dural expansion is late in kyphotic cases. Surgical outcomes classified by the amount of final expansion of AP diameter of dural tube were shown on Table 3. From the results, the amount of expansion of dural tube did not have great influence over neurological recovery.

Conclusion: Dural tube continues to expand for about 1 year after the surgery. The dural tube of patients with kyphosis expanded slowly. Small amount of dural expansion does not necessarily means bad surgical outcomes.

Table 1

	Pre OP	6 months	1 year	1.5 years	final
AP diameter of dura tube(mm)	8.5±1.1*	12.4±1.8*	13.3±1.9*	13.6±2.3	13.7±2.2
Expansion of AP diameter(mm)		2.8±1.8**	4.7±2.0	5.2±2.2	5.1±2.0
ER: Rate of expansion to the final value(%)		74.8±20.5**	91.2±15.8	94.9±13.5	100

*: statistically significant difference among three durations
**: statistically significant difference to the other durations

Table 2

	Lordosis(N:28)	Straight(N:21)	Sigmoid(N:11)	Kyphosis(N:23)
Rate of expansion to the final value(%) at 6 months	76.0±16.9	80.0±19.4	85.7±13.6	65.1±24.3*

*: statistically significant lower than in Straight and Sigmoid
, no significant difference between Kyphosis and Lordosis(p=0.06)

Table 3

Final expansion of AP diameter	0-3.9mm(N:24)	4.0-5.9mm(N:30)	6.0mm-(N:29)	ANOVA
Pre JOA score(full:17)	12.0±2.6	11.4±2.2	12.6±2.4	NS
Post JOA score	14.3±2.2	13.8±2.0	14.0±2.3	NS
Recovery rate(%)	50.7±26.8	44.3±23.5	34.7±30.7	NS

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i-Factor™ Bone Graft vs. Autograft in Anterior Cervical Discectomy and Fusion: Two-Year Follow-up of the Randomized Single-Blinded Food and Drug Administration Investigational Device Exemption Study

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Introduction: P-15 is a novel synthetic 15-amino acid polypeptide that mimics Type I collagen. i-Factor™ Peptide Enhanced Bone Graft (Cerapedics, Westminster CO) is a bone substitute composed of P-15 adsorbed onto anorganic bone mineral and suspended in an inert biocompatible hydrogel carrier. We report 24-month outcomes of patients who received i-Factor or local autograft during single-level ACDF for symptomatic cervical disc disease.

Materials and Methods: This pivotal prospective multi-center randomized FDA IDE single-blinded study from 2006–2013 investigated safety and efficacy of i-Factor compared to autograft in 319 patients at 22 North American sites. Patients were evaluated preoperatively and postoperatively to 24 months. Outcome measures were: fusion; neurologic and NDI functional outcomes; VAS neck and arm/shoulder pain scores; SF-36v2 PCS and MCS; and Overall Success (fusion and neurologic success, NDI improvement >15, and absence of reoperations and device-related serious adverse events). Patients received either i-Factor (N=165) or local autograft (N=154) in a cortical ring allograft implanted into the target vertebral interspace prior to fixation device placement.

Results: The 12-month follow-up rate was 136/159 (85.53%) and 139/151 (92.05%) in i-Factor and autograft patients, respectively. The 24-month follow-up rate was 117/150 (78.00%) and 127/149 (85.23%), respectively. At 24 months, fusion was 97.30% and 94.44% in i-Factor and autograft patients, respectively; neurological success was 94.87% and 93.79%, respectively. NDI improved 28.30 and 26.95, respectively; VAS arm improved 5.43 and 4.97, respectively; VAS neck improved 4.78 and 4.41, respectively, SF36v2 PCS improved 10.23 and 10.18, respectively, and SF36v2 MCS improved 7.88 and 7.53, respectively. Overall Success was greater in i-Factor versus autograft patients (69.83% and 56.35%, respectively). Twelve (7.45%) i-Factor patients and 16 (10.53%) autograft patients had reoperations.

Conclusions: Use of i-Factor in ACDF is effective and safe, and results in similar – and on some metrics superior – outcomes compared to local autograft at 24 months following surgery.

Keywords: i-Factor™ Bone Graft; P-15™ small peptide; cervical spine; fusion; arthrodesis; anterior cervical discectomy and fusion (ACDF), cervical radiculopathy, degenerative disc disease (DDD)

Comparing Health Related Quality of Life Outcomes in Patients Undergoing a Primary and a Revision Anterior Cervical Discectomy and Fusion

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Introduction: An anterior cervical discectomy and fusion (ACDF) for cervical radiculopathy or myelopathy is associated with significant improvements in health related quality of life (HRQOL) outcome metrics; however, 2.9% of patients per year will develop symptomatic adjacent segment disease (ASD). While significant literature exists demonstrating the development of ASD following an ACDF, there is a paucity of literature on the HRQOL outcome following a revision ACDF. The goal of this study is to compare HRQOL outcome metrics in patients undergoing a primary and a revision ACDF.

Materials and Methods: A retrospective review of prospectively collected data was performed to identify patients who underwent either a primary or a revision ACDF, and who had both preoperative and a minimum of one year post operative HRQOL outcome data. Patients who underwent surgery for a tumor, trauma or infection were excluded. Pre- and postoperative Short Form 12 Physical Component Score (SF12 PCS), Short Form 12 Mental Component Score (SF12 MCS) VAS neck, VAS arm and Neck Disability Index (NDI) scores were compared. Additionally, a propensity score for ACDF was generated using a logistic regression model based on attending, age, sex, diagnosis (radiculopathy, myelopathy or myeloradiculopathy), race, gender, BMI, smoking status, graft choice, number of levels and starting level. A linear regression was then used for the net change in each HRQOL outcome with both propensity score and revision versus primary as predictors to determine if patients undergoing revision surgery had similar improvements in HRQOL outcome metrics.

Results: A total of 360 patients (299 primary and 61 revision) who met the inclusion criteria were identified; the average follow up was 17.6 +/- 9.1 months, and the average follow up was slightly longer for patients undergoing revision surgery (24.2 +/- 11.8 months) compared to primary surgery (16.2 +/- 7.8 months, p=0.001). Demographic data is presented in table one. Significant improvement in SF12 PCS, NDI, VAS neck and VAS arm was seen in both groups, however only a significant improvement in SF12 MCS was seen in the primary group (Table 2).

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Linear regression analysis demonstrated that the SF12 PCS improved 4.47 +/- 1.63 less in the revision group compared to the primary group (p = 0.01). All other HRQOL outcome metrics demonstrated similar improvements between the groups. The net improvement in the SF12 MCS was non-significantly less in the revision group by 2.87 +/- 2.20 (p = 0.19). Similarly, the net improvement in the NDI was 1.33 +/- 3.24 less in the revision group (p = 0.68). Conversely, the net improvement in the VAS neck score was 0.51 +/- 0.52 more in the revision group (p = 0.33), and the net improvement in the VAS Arm score was 0.26 +/- 0.60 more in the revision groups (p = 0.66).

Conclusion: A revision ACDF for cervical radiculopathy or myelopathy leads to a significant improvement in the HRQOL outcome of the patient, and with the exception of the SF12 PCS, these results are similar to those of patients undergoing a primary ACDF.

Table 1. Demographic Data

	Primary	Revision	P Value
N	299	61	
Age	53.38 +/- 11.1	52.57 +/- 9.2	0.59
Gender (% Male)	46.49%	37.71%	0.26
Race			
Caucasian	79.93%	91.80%	0.028
African American	8.03%	3.28%	0.28
Other	12.04%	4.92%	0.12
Current Smoker	17.06%	18.03%	0.85
Diagnosis			
Radiculopathy	46.49%	54.10%	0.33
Myelopathy	26.09%	29.51%	0.76
Myeloradiculoapathy	27.40%	16.39%	0.08
Number of Levels	2.12 +/- 0.8	1.45 +/- 0.6	0.0001

Co-morbid Conditions			
Blood clots/DVT	1.67%	1.64%	< 1.00
Cancer	7.02%	3.28%	0.39
COPD	3.34%	4.92%	0.47
Diabetes	14.05%	14.75%	0.84
Heart Disease	5.02%	3.28%	0.77
High Blood Pressure	34.11%	24.59%	0.18
Kidney Disease	1.00%	1.64%	0.53
Pulmonary Embolism	0.67%	0.00%	< 1.00
Rheumatoid Arthritis	4.68%	4.92%	< 1.00
Stroke	1.34%	0.00%	< 1.00
Thyroid Disorder	10.37%	13.11%	0.5

Table 2. HRQOL Outcomes following an ACDF

	Primary			Revision		
	Preoperative	Postoperative	P Value	Preoperative	Postoperative	P Value
SF12 PCS	33.23 +/- 8.15	40.26 +/- 11.29	< 0.0001	33.79 +/- 9.95	36.69 +/- 10.28	0.04
SF12 MCS	45.50 +/- 12.06	49.31 +/- 11.70	< 0.0001	46.58 +/- 10/82	48.55 +/- 10.10	0.25
NDI	41.97 +/- 19.50	25.12 +/- 22.31	< 0.0001	42.15 +/- 19.03	23.88 +/- 20.68	< 0.0001
VAS Neck	5.62 +/- 2.91	3.15 +/- 2.88	< 0.0001	6.29 +/- 2.36	3.90 +/- 2.43	< 0.0001
VAS Arm	5.08 +/- 3.22	2.81 +/- 2.85	< 0.0001	5.63 +/- 3.01	3.33 +/- 2.61	< 0.0001

See Disclosure Index pages 39–89.

Can Thrombelastography Predict Venous Thromboembolic Events in Patients with Spine Trauma?

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Purpose: Despite increased bleeding risk during the acute trauma resuscitation, trauma-induced coagulopathy is associated with greater likelihood of hypercoagulability, and eventual venous thromboembolic (VTE) events. Rapid thrombelastography (r-TEG) is a whole blood assay that identifies both hypo- and hypercoagulable states. It has been shown that an elevated maximal amplitude (mA) value on admission can identify general trauma patients with increased risk of VTE. We hypothesized that (1) the risk of VTE is higher in patients with spine trauma than those without and (2) an elevated admission mA value could be used to identify patients with spine fractures at risk for VTE during initial hospital admission.

Methods: This is a retrospective review of a prospectively collected database of 9090 trauma patients admitted to an urban Level 1 trauma center between September 2009 – February 2011. We then evaluated only those patients who met highest-level trauma activation criteria, were 18 – 85 years of age and were direct scene transports. Patients with burn wounds greater than 20% total body surface area or who died within 30 minutes of arrival were excluded. Two groups were created, one presented with a spine fracture (SPINE) and those without a spine fracture (non-SPINE). VTE events were defined as those pulmonary emboli confirmed by computed tomography angiography and those symptomatic deep vein thromboses confirmed by venous duplex. Univariate analyses were conducted followed by purposeful regression analysis.

Results: 3005 patients met the inclusion criteria (722 SPINE, 2233 non-SPINE). SPINE patients were older (36 vs. 33), were more likely to be white (61% vs. 52%) and blunt trauma (93% vs. 74%); all $p < 0.05$. SPINE patients were more badly injured according to individual systems AIS scores, all $p < 0.001$. They also had lower systolic blood pressure (117 vs. 130), higher pulse (100 vs. 95) and lower GCS (9 vs. 13) on arrival; all $p < 0.05$. Despite more hypocoagulable rTEG values on arrival (alpha angle 72 vs. 73 and mA 63 vs. 64, both $p < 0.05$), SPINE patients had higher rates of VTE (8.5% vs. 3.4%, $p < 0.001$) and PE (5.2% vs. 2.4%, $p < 0.001$) as compared to non-SPINE patients. Stepwise regression generated three values to predict development of VTE (SPINE, ISS, and $mA > 65$). After controlling for gender effect, admission $mA \geq 72$ (odds ratio 4.81) was an independent predictor of VTE events during hospitalization in SPINE patients.

Conclusion: Admission r-TEG mA values can identify patients with spinal injuries who present with an increased risk of in-hospital DVT and PE. Patients with spine fractures and presenting with admission r-TEG mA value of ≥ 72 are at a 4.81 fold increased risk for in-hospital VTE. Admission rTEG values can help to identify patients at greatest risk for VTE and best target those who might benefit from an early, aggressive prophylaxis strategy.

See Disclosure Index pages 39–89.

Timing of Operative Intervention in Traumatic Spine Injuries without Neurologic Deficit

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Introduction: Numerous studies over the past two decades provide evidence favoring early operative intervention for traumatic unstable spine injuries with neurologic deficit primarily based on outcomes such as intensive care unit length of stay (ICULOS), ventilator days, hospital length of stay (HLOS), and in-hospital complications. Some studies also suggest that early intervention in incomplete neurologic injuries may be associated with increased neurologic recovery. However, a clear consensus on timing to operative intervention still does not exist in those with a normal neurological exam and unstable spine. We set out to calculate the optimal timing of operative intervention in traumatic spine injuries without neurologic deficit.

Materials and Methods: Retrospective chart review at a single level 1 trauma center was performed including patients with traumatic spine injuries without neurologic deficit admitted from December 2001 to August 2012. Time from admission to operative intervention was calculated. EBL was recorded based on anesthesia records. In-hospital complications, post-operative length of stay, ICU length of stay, and ventilator days were also recorded. Bivariate analyses (Mann-Whitney U test for continuous and Chi-square for categorical variables) were conducted to determine the impact of time to OR from the emergency department (ED) on EBL, complications, ICU stay, ventilation days and post-operative length of stay.

Results: 456 patients who underwent operative intervention for unstable traumatic spine injuries without neurologic deficits were included for analysis (Table 1). There was no significant correlation between the time to OR and EBL (P = 0.068) (Figure 1). Delayed surgery was defined as surgery after 72 hours of presenting to ED. There was no significant difference in the median EBL between the patients with early (< 72 hours; 350 ml, range 0 – 6700) and delayed surgery (> 72 hours; 500 ml, range: 0 – 3100) (P = 0.079). 132 (28.9%) patients had at least one complication following surgery and 49 patients (10.7%) had spine-related complications. Delayed surgery was associated with higher rates of complications overall (n = 51, 38.6% vs. n = 81, 25%, P = 0.003). There was no significant association between time to OR and occurrence of spine related complications (n = 18, 13.6% vs. n = 31, 9.5%, P = 0.135). Patients undergoing delayed surgery had higher median ICULOS [0 (0 – 47) vs. 2 (0-40), P < 0.001] and had higher ventilator days [0(0 – 39) vs. 1(0-24), P < 0.001]. The median postop LOS was significantly lower in patients who had early surgery [4 days (range, 0 – 46 days) vs. 6 days (range, 1 – 68 days) P < 0.0001]. There was no significant difference in the mortality rates between the early vs. delayed surgery groups [2.8% (n = 9) vs. 3.8% (n = 5) P = 0.381].

Conclusion: Earlier operative intervention was associated with decreased overall complications, ICULOS, ventilator days, postop length of stay and did not show an increase in EBL or mortality. Earlier operative intervention for traumatic spine injuries without neurologic deficit may provide better overall outcomes compared to delayed surgery.

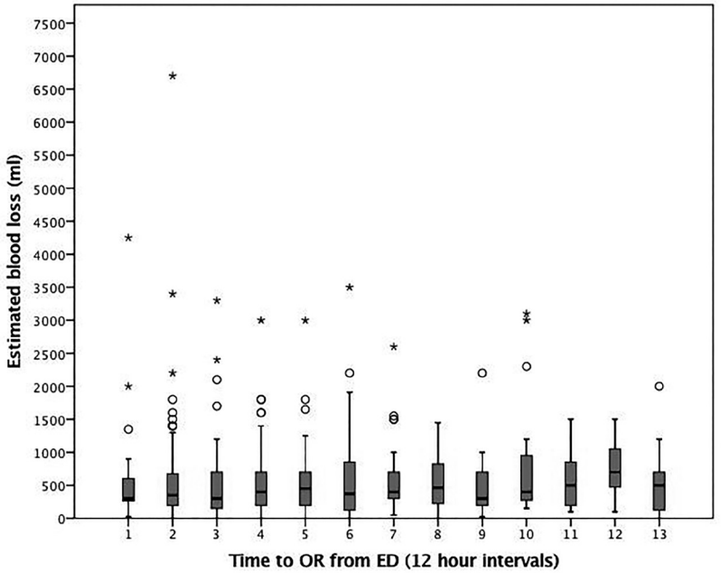
Table 1. Demographics and patient characteristics

	Early (< 72 hours) N = 324	Delayed (> 72 hours) N = 132	P-value
Age Median (range)	43 (16 - 95)	46.5 (17-90)	0.124
Gender (Male)	209 (65%)	78 (59%)	0.164
Smoking	120 (37%)	48 (36%)	0.472
ASA grades			< 0.0001
1	16 (5%)	3 (2%)	
2	109 (34%)	33 (25%)	
> 3	199 (61%)	96 (73%)	
Diabetes	37 (11%)	22 (17%)	0.093
Hypertension	77 (24%)	31 (23%)	0.513
Antiplatelet	34 (10%)	12 (9%)	0.397
Anticoagulants	9 (3%)	3 (2%)	0.525
Mechanism			
MVC	190 (59%)	84 (64%)	0.183
Motorcycle accidents	25 (8%)	13 (10%)	0.281
Fall	66 (20%)	22 (17%)	0.221
Transfer for outside hospital	194 (60%)	65 (49%)	0.02
Level of injury			0.14
Cervical and cervicothoracic	141 (44%)	45 (34%)	
Thoracic and thoracolumbar	93 (29%)	48 (36%)	
Lumbar and lumbosacral	90 (28%)	39 (30%)	
Surgical approach			0.499
Posterior approach	270 (83%)	106 (80%)	
Anterior approach	41 (13%)	22 (17%)	
Both	7 (2%)	2 (2%)	
Fusion	307 (95%)	124 (94%)	0.178
Duration of surgery (minutes)	184.3 ± 86.1 (160; 47 – 535)	215.1 ± 103.7 (199; 53 – 516)	0.005
Total median LOS (days)	6 days, (1 – 49 days)	11 days, (4 – 71 days)	< 0.0001

See Disclosure Index pages 39 – 89.

	Early (<72 hours) N=324	Delayed (>72 hours) N=132	P-value
Postoperative LOS	4 days, (0–46 days)	6 days, (1–68 days)	<0.0001
Number of levels (median, range)	3, (1–10)	3, (1–10)	0.81
ISS score (median, range) N=378	14 (1–48)	22 (4–59)	<0.0001
EBL (ml)	582 ml (0–6700 ml)	626 ml (0–3100 ml)	0.079
ICU days	0 (0–47 days)	2 (0–40 days)	<0.0001
Preoperative INR	1 (0.9–2)	1 (1–1.4)	0.001
Preoperative PCV	35 (21–48) units	28 (22–44) units	<0.0001
Preoperative WBC	11 (3–38) per mcl	10 (4–38) per mcl	0.001
Preoperative lactate levels	1 (0–6)	1 (0–2)	0.172
Ventilation days	0 (0–39)	1 (0–24)	<0.0001

Figure 1. Box-plot demonstrating the median estimated blood loss based on the time to OR from ED (divided in 12 hour intervals). o and * represents outliers.



Inflammatory Response, Glial and Axonal Survival within the Spinal Cord White Matter in the Elderly after Traumatic Spinal Cord Injury

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W. Dalton Dietrich, PhD, Miami, FL
Michael Norenberg, MD, Miami, FL
Michael G. Fehlings, MD, PhD, FRCSC, Toronto, ON, Canada

Introduction: Despite an increasing incidence of traumatic spinal cord injury (SCI) in the elderly in North America, relatively little has been reported to date regarding the role of age on outcomes after traumatic SCI. The proportion of elderly with SCI in the United States has increased from 5% (1973) to 18% (2003). Given this, an improved understanding of the consequences of age on SCI is required. This histopathological and immunohistochemical examination of postmortem spinal cord tissue was undertaken to evaluate whether age is a key determinant for cellular inflammatory response, oligodendroglial apoptosis and axonal survival after acute traumatic SCI.

Methods: This study includes post-mortem spinal cord tissue from 64 cases of SCI (at cervical or high-thoracic level) and 38 controls cases. Each group was subdivided into younger and elderly individuals (65 years or older at the time of injury). Alternating 6-microm sections from 2 to 3 segments caudal to the SCI and age/sex/level-matched segments from controls were stained for: (i) neuroinflammation (neutrophils, macrophages, cytotoxic-T/natural-killer cells, helper/regulator-T cells, and B-cell lymphocytes); (ii) apoptotic oligodendrocytes; (iii) axons; and (iv) extent of degeneration. The number of cells or axons was counted in the motor and sensory areas within the spinal cord using unbiased stereological techniques.

Results: There were 25 women and 77 men with a mean age of 58.6 years (range from 16 to 90 years). Of those, 53 individuals were elderly who died in the acute (n=20), subacute (n=14) or chronic stage following traumatic SCI (n=10); and there were 15 elderly individuals in the control group. In addition, there were 49 younger individuals who died in the acute (n=14), subacute (n=4) or chronic stage after traumatic SCI (n=8); and 23 younger individuals were included in the control group. Younger and elderly individuals had statistically similar number of neutrophils, macrophages, and lymphocytes in most of the stages following SCI. Yet, younger individuals showed significantly greater number of B-cell lymphocytes within the lateral corticospinal tracts in the subacute stage after SCI than elderly individuals. Younger and elderly individuals had statistically similar number of oligodendrocytes in apoptosis in all stages following SCI. The number of preserved axons did not significantly differ between younger and elderly individuals with SCI and without prior CNS injury. Extend of degeneration within the spinal cord white matter did not significantly differ between the two groups.

See Disclosure Index pages 39–89.

Conclusions: Our results indicate that age at the time of injury does not adversely affect the cellular inflammatory response, oligodendroglial apoptosis and axonal survival after traumatic SCI. Those results are consistent with prior clinical studies that have shown no significant effects of age on neurological and functional recovery following traumatic SCI when data analysis is adjusted for potential confounders. Indeed, our results support the notion that elderly individuals can potentially have similar benefits of the ongoing translational studies focused on neuroprotective strategies based on modulation of neuroinflammation. Based on our study, protocols of future translational studies and clinical trials for neuroprotective strategies focused on oligodendrocyte preservation of adults with traumatic SCI should include elderly individuals.

Adverse Events following Anterior Cervical Discectomy and Fusion: A Comparison of Spine Surgeons Perceptions and Reported Data for Rates and Risk Factors

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Benjamin J. Geddes, MD, New Haven, CT
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Andre M. Samuel, MD, New York, NY
Jonathan N. Grauer, MD, New Haven, CT

Introduction: Post-operative adverse events and risks factors for such complications play an important role in both decision making and setting patient expectations for surgeries such as anterior cervical discectomy and fusion (ACDF). In fact, differences in patients' expected pre-surgical and perceived post-surgical outcome have been shown to predict patient satisfaction. Given the importance of surgeon understanding of these factors, the purpose of the present study was to contrast surgeon perception and reported data for post-operative adverse events following ACDF and to assess the accuracy of predicting the impact of patient factors on such outcomes.

Methods: A survey investigating perceived rates of adverse events and impacts of patient risk factors on the occurrence of adverse events following ACDF for degenerative conditions was distributed to spine surgeons at the Cervical Spine Research Society (CSRS) 2015 Annual Meeting. For comparison, the corresponding rates and patient risk factors were assessed in patients undergoing elective ACDF from the National Surgical Quality Improvement Program (NSQIP) data years 2011–2014.

Results: From the CSRS survey, there were 110 responses (response rate of 44%) from attending physicians. From NSQIP, there were 18,019 patients who met inclusion criteria. Adverse event rates estimated by the surgeons at CSRS were close to those determined by NSQIP data (no greater than 1.5% different in any case, Figure 1). Surgeons overestimated the rate of 12 out of 17 (71%) post-operative adverse events by 0.10% to 1.50%. The largest overestimations were for urinary tract infection (overestimation of 1.50%, $P < 0.001$), and deep vein thrombosis (overestimation of 0.99%, $P < 0.001$). The greatest adverse event underestimation was readmission (underestimation of 1.2%, $P < 0.001$). Similarly, the estimated impact of patient factors was similar to NSQIP data (within relative risk of 1.5 in all cases, Figure 2). Surgeons overestimated the impact of 5 out of 10 (50%) patient factors on the occurrence of adverse events by relative risk factors of 0.56 to 1.48. The largest overestimations were for current smoking (overestimation of 1.48 relative risk, $P < 0.001$), and obesity ($BMI \geq 30$) (1.23, $P < 0.001$)

Conclusion: The current study noted that surgeons tended to closely overestimate the rates of most general health adverse events and the impact of patient factors after ACDF.

See Disclosure Index pages 39–89.

Figure 1

Incidence of Adverse Events for NSQIP Data and CSRS Perception

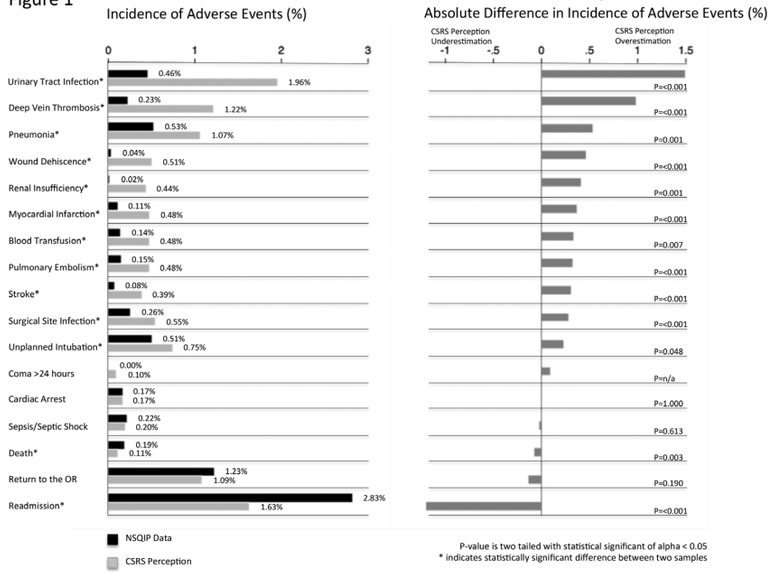
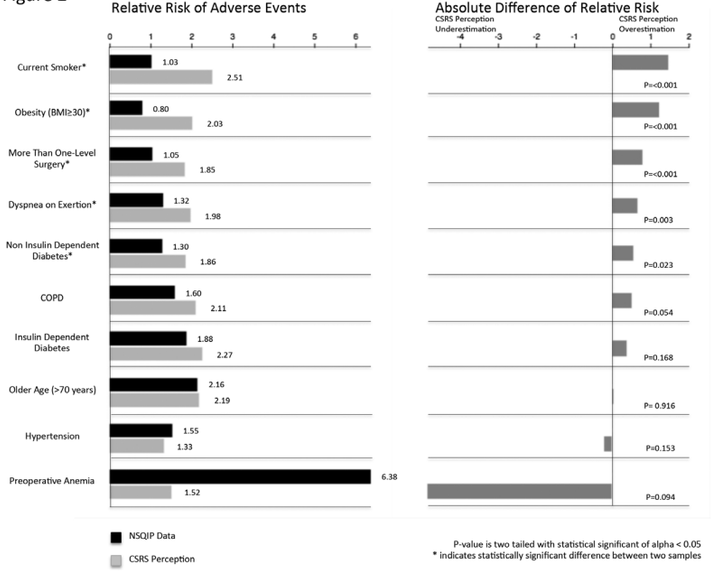


Figure 2

Risk Factors for Adverse Events for NSQIP Data and CSRS Perception



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Henry H. Bohlman, MD..... 2010
Mario Boni, MD 1986
Francis R. S. Boumphrey, MD 2012
Craig D. Brigham, MD 2013
David W. Cahill, MD 2003
Ralph B. Cloward, MD 2001
Jerome M. Cotler, MD 2014
Li Yang Dai, MD..... 2012
Joseph A. Epstein, MD 2006
J. William Fielding, MD..... 1998
Prof Gianfranco Fineschi 2010
Jacob J. Graham, MD..... 2000
Henry H. Herkowitz, MD 2013
Prof Dr Dietrich Hohmann 2012
Brian H. Huncke, MD..... 1995
Bernard Jacobs, MD 1992
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
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Raymond Roy-Camille, MD 1997
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Thomas S. Whitecloud III, MD..... 2003
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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 39.

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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2016 Instructional Course & Annual Meeting

DAILY SCHEDULE

DAILY SCHEDULE

Tues, Nov 29, 2016

12:00–7:00 pm	Technical Exhibit Set-up	*Metropolitan Ballroom*
3:00–7:00 pm	Early registration	*Frontenac Ballroom Foyer*

Wed, Nov 30, 2016 – Board of Directors Meeting

12:30–6:00 pm	Board of Directors Meeting	*Queens Quay*

Wed, Nov 30, 2016 – Instructional Course

6:00 am–7:00 pm	Registration	*Frontenac Ballroom Foyer*
6:30 am–6:00 pm	Technical Exhibits	*Metropolitan Ballroom*
6:30–8:00 am	Continental Breakfast	*Metropolitan Ballroom*
7:20 am–4:30 pm	Instructional Course	*Frontenac Ballroom*
9:30–9:50 am	Break	*Metropolitan Ballroom*
12:00 pm–1:00 pm	Lunch	*Metropolitan Ballroom*
3:05–3:30 pm	Break	*Metropolitan Ballroom*
4:30–6:00 pm	Faculty Appreciation Reception	*Frontenac Ballroom Foyer*

Thur, Dec 1, 2016 – Annual Meeting

6:00 am–5:00 pm	Registration	*Frontenac Ballroom Foyer*
6:30 am–12:00 pm	Technical Exhibits	*Metropolitan Ballroom*
6:00–8:00 am	Continental Breakfast	*Metropolitan Ballroom*
7:00 am–12:00 pm	Annual Meeting Scientific Session	*Frontenac Ballroom*
9:38–10:03 am	Break	*Metropolitan Ballroom*
12:00–3:30 pm	Industry Workshops	*TBD*
4:30–6:30 pm	Welcome Reception	*Metropolitan Ballroom*

Fri, Dec 2, 2016 – Annual Meeting

6:00 am–5:30 pm	Registration	*Frontenac Ballroom Foyer*
6:30 am–1:30 pm	Technical Exhibits	*Metropolitan Ballroom*
6:00–8:00 am	Continental Breakfast	*Metropolitan Ballroom*
7:00 am–5:18 pm	Annual Meeting Scientific Sessions	*Frontenac Ballroom*
9:02–9:32 am	Break	*Metropolitan Ballroom*
12:02–1:02 pm	Member Lunch & Business Meeting	*Queens Quay*
12:02–1:02 pm	Non-member Lunch	*Metropolitan Ballroom*
3:19–3:49 pm	Break	*Frontenac Ballroom Foyer*

Sat, Dec 3, 2016 – Annual Meeting

6:00 am–12:30 pm	Registration	*Frontenac Ballroom Foyer*
6:00–8:00 am	Continental Breakfast	*Frontenac Ballroom Foyer*
7:00 am–12:20 pm	Annual Meeting Scientific Session	*Frontenac Ballroom*
9:56–10:11 am	Break	*Frontenac Ballroom Foyer*
12:20 pm	Annual Meeting Adjourns	

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NOV 29–DEC 2, 2017!