### SESSION XIV: HIGHLIGHT POSTERS

**Moderators:** Ravi K. Ponnappan, MD and Glenn R. Rechtine, II, MD

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<td>Sukhvinder K. Kalsi-Ryan, BScPT, MSc, PhD; Michael G. Fehlings, MD, PhD</td>
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ANNUAL MEETING SCHEDULE  

Saturday, December 6, 2014 • Grand Cypress Ballrooms DEF

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Jae Hwan Cho, MD; Jung-Ki Ha, Dae Geun Kim, MD; Chang Ju Hwang; Choon Sung Lee, MD; Dong-Ho Lee, MD, PhD
Highlight Poster #1


Sukhvinder Kalsi-Ryan, BSc PT, MSc, PhD, Toronto, Ontario, Canada
Michael G. Fehlings, MD, PhD, Toronto, Ontario, Canada

Introduction: The diverse neurological presentation of cervical spinal cord injury (SCI) produces challenges in predicting endpoints, dosing of interventions and designing and executing clinical studies/trials. An improved appreciation of the recovery profiles of sensory, motor and complex functions of the upper limb after cervical SCI is essential to inform clinical trials. In order to consider primary and secondary outcome measures for interventions and the optimization of dosing and timing of therapies in acute and chronic SCI novel assessments and their associated recovery profiles evaluating the natural history of the disease are required. The objectives of this study were 1) to define the sensory, motor and prehension recovery profiles of the upper limb and hand and 2) determine the relationships between upper limb impairment and functional independence over the one year time course post injury.

Methods: A prospective observational longitudinal cohort study consisting of serial testing of 55 patients with acute cervical SCI was conducted. International Standards of Neurological Classification of SCI (ISNCSCI), Graded Redefined Assessment of Strength Sensibility and Prehension (GRASSP), Capabilities of Upper Extremity (CUE) Questionnaire, Spinal Cord Independence Measure III (SCIM-III) were administered at 0-10 days, 1, 3, 6 and 12 months. Analysis: The sample was sub-grouped according to AIS classification and further grouped according to conversion. Changes over time were plotted using means and standard deviations of the total and sub-groups of the sample. Pearson correlation coefficients were calculated among all measures at each time point to define relationships between impairment and function across the one-year timecourse.

Results: Individuals with traumatic tetraplegia show distinct patterns of recovery. Factors that distinguish sub-groups of the sample are: severity of injury (level of injury, completeness) at baseline and conversion from a complete to an incomplete injury. Figure 1 defines the whole sample with all measures administered, indicating that all SCI groups do show some degree of recovery, however, classification and conversion influence the recovery profile. Figure 2 further defines recovery of motor strength, sensation and prehension, indicating the hand recovers later than the larger muscles of the upper limb across the recovery timecourse.

Conclusions: In cervical SCI clinical recovery can be assessed using standardized measures that distinguish levels of activity and impairment. Specific recovery profiles of the upper limb over the one-year timecourse provide new insights and opportunity for understanding the natural history of the disease. As the next generation of SCI trials are focused on cervical SCI these recovery profiles will be useful in informing and defining study design and treatment protocols. Furthermore, analysis of recovery profiles of different clinical assessment tools for the upper limb will be meaningful to inform the design of trial protocols and expand inclusion criteria for cervical SCI studies.

Key words: upper limb, tetraplegia, recovery, outcome measure, sensorimotor function
Highlight Poster #1 (continued)


Figure 1: Recovery Profiles of the whole sample with all impairment measures

Figure 2: GRASSP strength, sensation, prehension SCIM of sub-groups over time course
Highlight Poster #2

Wide Laminectomy and C4/5 Foraminal Stenosis were the Risk Factors of C5 Palsy: Analysis of 206 Cervical Spondylotic Myelopathy Patients after Selective Laminectomy/Laminoplasty

Satoshi Nori, MD, Chiba, Japan
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Ryoma Aoyama, Chiba, Japan
Ken Ninomiya, Chiba, Japan
Junichi Yamane, Tokyo, Japan
Kazuya Kitamura, Kanagawa, Japan

Introduction: C5 palsy has been one of the challenging complications after posterior decompression for cervical spondylotic myelopathy (CSM). Since 2001, we have performed muscle-preserving selective laminectomy (LN) or LN combined with laminoplasty (LN/LP) for CSM, where level of decompression was selected by analyzing MRI and myelogram-CT. Since 2008, we have preoperatively planned the width of laminectomy (LW) which was set 2-3mm wider than spinal cord width (SW). Purpose of this study is to elucidate the risk factors of C5 palsy by reviewing the surgical outcomes.

Methods: Two hundred and six CSM patients underwent posterior cervical decompression without fusion. The incidence of C5 palsy was 3.4% (7 of 206). Out of 206 patients, 84 who underwent LN or LN/LP between 2006 and 2007 presented the incidence of palsy with 7.1% (6 of 84). During this period, we performed LN/LP for three or more levels decompression. The rest of 122 patients who underwent only LN between 2011 and 2012 presented the incidence with 0.8% (1 of 122). Using one-way ANOVA and logistic regression analysis, we statistically analyzed parameters between C5 palsy group and no palsy group such as difference between LW and SW, dimension of C4/5 foramen, procedure with or without LP, amplitude of posterior spinal cord shift at C4/5 level, postoperative C2-C7 sagittal alignment, numbers of consecutive decompression laminae, age at surgery, gender, operation time and blood loss.

Results: Univariate analysis showed difference between LW and SW was significantly greater in patients with C5 palsy (10.0 ± 3.6 mm, n=7) than those without (5.7 ± 4.2 mm, n=199) (p=7.9×10^-3). Dimension of C4/5 foramen was significantly narrower in patients with C5 palsy (1.7 ± 0.8 mm, n=8) than those without (2.9 ± 0.9 mm, n=404) (p=3.7×10^-3). Age at surgery was significantly older in patients with palsy (72.3 ± 7.6, n=7) than those without (62.7 ± 11.1, n=199) (p=0.02). Posterior spinal cord shift at C4/5 level was significantly greater in patients with C5 palsy (2.3 ± 1.2 mm, n=7) than those without (0.9 ± 0.9 mm, n=199) (p=7.5×10^-5). On the other hand, postoperative C2-C7 sagittal alignment, numbers of consecutive decompression laminae, operation time and blood loss were not statistically significant between patients with palsy and those without. Logistic regression analysis revealed that difference between LW and SW (Odds ratio (OR), 1.9; 95% confidence interval (CI), 1.01 to 3.42) (Figure 1), dimension of C4/5 foramen (OR, 0.01; 95% CI, 2.9×10^-4 to 0.45) (Figure 2) and age at surgery (OR, 1.5; 95% CI, 1.04 to 2.28) were considered as the risk factors of C5 palsy. Although it was not statistically significant (p=0.054), procedure with LP (OR, 122.2; 95% CI, 0.92 to 16156.71) might be related to C5 palsy.

Conclusion: Wide laminectomy, C4/5 foraminal stenosis and advanced age at surgery were considered as the risk factors of C5 palsy. Adequate planning of the laminectomy width can diminish the incidence of C5 palsy after selective laminectomy/laminoplasty.
Wide Laminectomy and C4/5 Foraminal Stenosis were the Risk Factors of C5 Palsy: Analysis of 206 Cervical Spondylotic Myelopathy Patients after Selective Laminectomy/Laminoplasty

**fig 1**

- **Difference between Width of Laminectomy (LW) and Spinal Cord Width (SW):** LW – SW (mm)

  ![Image](image_url)

  **Odds Ratio, 1.9; 95% CI, 1.01 to 36.42**

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<th>C5 Palsy</th>
<th>No C5 Palsy</th>
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<tr>
<td>Difference between LW and SW (mm)</td>
<td>10.0 ± 3.6 (n=7)</td>
<td>5.7 ± 4.2 (n=199)</td>
<td>p&lt;0.01</td>
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**fig 2**

- **Dimension of C4/5 foramen**

  ![Image](image_url)

  **Odds Ratio, 0.01; 95% CI, 2.9 × 10⁻⁴ to 0.45**

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<td>C4/5 foramen (mm)</td>
<td>1.7 ± 0.8 (n=8)</td>
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Highlight Poster #3

Investigation of Segmental Motor Paralysis after Cervical Laminoplasty using Intra-Operative Spinal Cord Monitoring

Nobuhiro Tanaka, MD, PhD, Hiroshima, Japan
Kazuyoshi Nakanishi, MD, Hiroshima, Japan
Naosuke Kamei, MD, Hiroshima, Japan
Takeshi Hiramatsu, MD, Hiroshima, Japan
Satoshi Ujigo, MD, Hiroshima, Japan
Norihiko Sumiyoshi, MD, Hiroshima, Japan
Takanori Rikita, MD, Hiroshima, Japan
Mitsuo Ochi, MD, Hiroshima, Japan

Introduction: Clinical worsening of motor functions remains a major problem that may occur after operative treatment of the cervical spine. Intraoperative neurophysiologic monitoring with transcranial electric motor evoked potentials (TceMEP) was performed on patients who underwent cervical laminoplasty. The purpose of the study is to evaluate the usefulness of intraoperative spinal cord monitoring with TceMEP for prediction of the occurrence of motor paralysis after cervical laminoplasty.

Methods: Two hundred forty-five consecutive patients [168 men and 77 women; mean age, 65 years (range, 27-89 years)] who were scheduled to undergo cervical laminoplasty were included in this study. There were 170 cases of cervical spondylotic myelopathy, 40 cases of ossification of the posterior longitudinal ligament (OPLL), 19 cases of cervical spondylotic amyotrophy and 16 cases of intervertebral disc herniation. All patients underwent posterior laminoplasty under intraoperative spinal cord monitoring with TceMEP. Transcranial electrical stimulations were delivered through pin-type electrodes and the evoked potentials were recorded over the deltoid, biceps and triceps muscles in the bilateral upper extremities and thoracic spinal cord.

Results: All patients showed sufficient postoperative recovery from their clinical symptoms. Postoperative C5 palsy developed in 6 patients (2.8%, 6 males and 1 female) but there were no critical decrease in the amplitude of the evoked potentials. The incidence of C5 palsy involved 5 of 170 (2.9%) cervical spondylotic myelopathy patients, 2 of 40 (5.0%) patients with cervical OPLL. No patients with cervical disc herniation or cervical spondylotic amyotrophy developed C5 palsy.

Conclusions: No abnormalities were observed on TceMEP monitoring even in those patients who developed postoperative transient C5 palsy. These results suggest that the development of postoperative segmental palsy after cervical laminoplasty is not associated with intraoperative injury of the nerve root or the spinal cord. Surgeons should be aware that segmental palsy is a possible complication of cervical laminoplasty even in the absence of intraoperative nerve injury.
Highlighted Poster #4

High Glucose-Induced Oxidative Stress Accelerates Premature Stress-Induced Senescence of Young Intervertebral Disc Cells of Rats through Mitochondrial Damage

Jong-Beom Park, MD, PhD, Uijeongbu, Korea, Republic of
Eun-Young Park, PhD, Uijeongbu, Korea, Republic of

Introduction: Diabetes mellitus (DM) is a major public health problem worldwide. Approximately 10% of all DM cases are type 1 (juvenile-onset) and the prevalence of type 1 DM among the under 20s continuously rise. DM is thought to be an important etiologic factor in premature intervertebral disc degeneration. Previous studies have reported a higher incidence of degenerative disc disease in patients with DM, relatively at younger age, than in the non-DM population. Glucose-mediated increase in oxidative stress is a major causative factor in development of DM-associated diseases. However, little is known about relationship among DM, mitochondrial damage, oxidative stress, senescence of young disc cells, and intervertebral disc degeneration.

Methods: Young nucleus pulposus (NP) and annulus fibrosus (AF) cells were isolated from 4-week-old rats, cultured, and placed in either 10% FBS (normal control) or 10% FBS plus two different high glucose concentrations (0.1M and 0.2M) (experimental conditions) for 1 and 3 days. We identified and quantified the mitochondrial damage and reactive oxygen species (ROS) (oxidative stress). We also identified and quantified the occurrence of senescence and telomerase activity. Finally, the expressions of proteins were determined related to replicative senescence (p53-p21-pRB) and stress-induced senescence (p16-pRB).

Results: Two high glucoses enhanced the mitochondrial damage in young NP and AF cells, which resulted in an excessive generation of ROS in a dose- and time-dependent manner for 1 day and 3 days compared to normal control. Two high glucoses increased the occurrence of senescence of young NP and AF cells in a dose- and time-dependent manner. Telomerase activity declined in a dose- and time-dependent manner. Both high glucoses increased the expressions of p16 and pRB proteins in young NP and AF cells for 1 and 3 days. However, compared to normal control, the expressions of p53 and p21 proteins were decreased in young NP and AF cells treated with both high glucoses for 1 and 3 days.

Conclusion: The current study demonstrated that high glucose-induced oxidative stress accelerates premature stress-induced senescence in young NP and AF cells in a dose- and time-dependent manner rather than replicative senescence. This may result in dysfunction of young NP and AF cells, leading to premature intervertebral disc degeneration. Thus, these results suggest that strict blood glucose control in young patients with DM could be important to prevent an excessive generation of oxidative stress and subsequently to prevent or to delay premature intervertebral disc degeneration in young patients with DM.
Highlighted Poster #5

Automated Detection of Occipitocervical Complex Injuries

Gerardo M. Myrin, MD, Temple, Texas
Christopher D. Chaput, MD, Temple, Texas
Brian A. Garner, PhD, Waco, Texas
Jacob Hoffman, BS, Waco, Texas

**Background:** Injuries of the occipitocervical complex (OCC) can be difficult to detect on CT scans due to the primarily ligamentous nature of the injury. Because these injuries are both rare and subtle, they are easily overlooked in the extensive radiographic workup of activated trauma patient. Missed injuries can lead to significant neurologic deterioration or even death, and fully automated screening of CT scans in the setting of significant polytrauma could minimize this risk. To date, no fully automated process has demonstrated the ability to reliably detect musculoskeletal injuries in general, much less ligamentous injuries of the OCC.

**Methods:** A computer aided automatic detection program was designed to interpret sagittal bone reconstructions as one-dimensional signals using a novel edge tracing technique. This software incorporated a support vector machine – a type of machine learning algorithm--that allows the program to “learn” the normal upper cervical anatomy after analyzing about 30 normal cervical CT scans. An experimental group was then created from a 911 trauma database to test the program. 90 normal CT scans and 10 with OCC injury were used, and all OCC injuries included in the experimental group had a Basion Dens Interval> 10mm and MRI evidence of ligamentous injury. The trained program analyzed this entire group for OCC injury and the results were compared to readings performed by physicians.

**Results:** The sensitivity and specificity of the software for OCC injury detection was 80% and 90%, respectively.

**Conclusion:** Software that incorporates machine learning algorithms can screen for OCC injuries that may easily overlooked by trained spine professionals. This study is proof of concept that even ligamentous injuries can be automatically detected on CT scans. These techniques have the potential to alert trauma care professionals of both obvious and very subtle musculoskeletal injuries in near real time.
Impact of Apex Angle of Anterior Compressing Factor and Preoperative C2-C7 Alignment on Postoperative Spinal Cord Alignment and C2-C7 Alignment

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Hisanori Mihara, PhD, Yokohama, Japan
Kenichi Watanabe, MD, Kawasaki Kanagawa, Japan

Introduction: Because cervical laminoplasty attempts indirect decompression from posterior, neural decompression status must be affected by the shape of anterior factors and also by total cervical alignment. We proposed the focal apex angle (FA angle) of the cord compression factor(s) as a significant indicator for successful decompression with cervical laminoplasty. This study investigated how the FA angle affects on the postoperative spinal cord alignment and neurological improvement following laminoplasty.

Methods: Subjects were 107 cervical compression myelopathy patients who underwent cervical laminoplasty. Patient ages ranged from 36 to 85 with a mean of 68.9 years old. Using a mid sagittal view of preoperative CT myelogram, we defined FA angle as the angle made by lines connecting postero-superior corner of the upper adjacent vertebra, apex of anterior factor onto the spinal cord and the postero-inferior corner of the lower adjacent vertebra. Total cervical alignment was measured between C2 and C7 vertebrae (C2-C7 angle) in standing lateral radiographs. Postoperative spinal cord alignment was classified into four types (Lordosis: type:L, Straight: type:S, Local Kyphosis type:LK, Kyphosis: type: K) using MRI. The neurological status was evaluated by the Japanese Orthopedic Association score.

Results: The mean FA angle was 30.2 degree, and the mean C2-C7 angle was 10.7 degree. The postoperative spinal cord alignment was classified as type LK or type K in 46 patients and their neurological recovery rate (34.2%) was significantly lower than 49.1% in the other types. In 27 patients with 15 degree or more C2-C7 angle, 22 patients (81.5%) demonstrated postoperative spinal cord alignment as type L or type S. Among 24 patients showing C2-C7 angle between 5 and 15 degree accompanied with 30 degree or less FA angle, 17 (70.8%) patients were classified as type L or type S. On the other hand, 13 patients (62.5%) out of 24 patients showing 5 degree or less C2-C7 angle demonstrated postoperative spinal cord alignment as type LK or type K and their neurological recovery rate indicated 35.9% in average.

Conclusions: The FA angle was considered as an important parameter for successful decompression effect for cervical laminoplasty particularly if a patient had straight alignment (5 to 15 degree of the C2-C7 angle) before surgery. We should pay attention not only on total cervical alignment but also on the focal prominence of the cord compression lesion.
An In-depth Comprehensive Evaluation of the Level of Evidence (LoE) of CSRS Annual Meeting Presentations (2001-2010)

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Harshad Dabke, MD, FRCS (Tr & Orth), Whiteparish, Salisbury, United Kingdom
John P. Dormans, MD, FACS, Philadelphia, Pennsylvania

Introduction: Cervical spine research society annual meetings (CSRS-AM) showcases best quality research in the field of cervical spine amongst professionals prior to their publication. Acceptance of a research paper for CSRS-AM is considered to be a mark of excellence and levels of evidence (LoE) are rating systems introduced by the AAOS to reflect quality of clinical research studies in 2003. The objectives of this study were to:
1) Evaluate and assess the LoE of all CSRS-AM abstracts over a ten year period in the new millennium (2001-10)
2) Analyze changing trends in LoE between two groups (Group I: 2001-03 and Group II: 2008-10).

Methods: The CSRS-AM proceedings books of 29th, 30th and 31st annual meetings (2001-03) were downloaded from www.csrs.org and 36th, 37th and 38th annual meetings (2008-10) were obtained. Two fellowship trained orthopaedic spinal surgeons independently graded LoE of each abstract as per AAOS LoE grading system on two separate occasions one month apart. All clinical studies were assigned a LoE (I-V) and categorized as either therapeutic, prognostic, diagnostic or decision-making / economic. Biomechanical, basic science, animal and lab based studies were marked as LoE not applicable (N/A). Any disparity in assigning LoE for any abstract was discussed by the authors and agreed by consensus. The corresponding full-text articles (if published and available) for each of the abstract was also retrieved and evaluated. Thus analyzed abstracts of the two groups were subjected to Fischer's exact test to determine statistical significance.

Results: A total of 855 abstracts (364 free-papers and 491 posters) from six annual meetings were reviewed. There were 427 abstracts in Group I and 428 in Group II. Majority of CSRS-AM presentations (85%) were therapeutic clinical and LoE N/A studies. Amongst the clinical studies, the proportion of LoE I & II studies had more than doubled from 20.32% in Group I to 46.66% in Group II which was extremely statistically significant (Fischer’s two tailed p<0.0001). There was a decline in LoE III & IV studies from 46.83% in Gr. I to 33.64% in Gr. II. The detailed analysis of all 855 abstracts with year and group-wise breakdown is summarized in Table 1. The sub-analysis breakdown of LoE for podium and poster presentations is illustrated separately in Tables 2a and 2b. Up to 40% of all abstracts were LoE N/A. Diagnostic and economic/cost-utility studies are increasingly presented and accounted for 5.3% of all abstracts.

Conclusion: The LoE of CSRS-AM abstracts in the first decade of the new millennium has had statistically significant improvement in LoE I & II studies for both free-papers (p=0.0003) and posters (p=0.002). This is a reflection of CSRS leadership and program committee’s emphasis in striking a balance between both basic science and clinical research. CSRS is the first specialist society affiliated to the AAOS to have undertaken a comprehensive in-depth analysis of all its annual meeting abstracts with respect to LoE. This study will serve as a baseline tool to evaluate future CSRS-AM presentations and a standard for other specialist societies to strive for / emulate.
An In-depth Comprehensive Evaluation of the Level of Evidence (LoE) of CSRS Annual Meeting Presentations (2001-2010)

Table 1: Year-wise and group-wise breakdown of all abstracts - CSRS-AM for LoE

<table>
<thead>
<tr>
<th>Year</th>
<th>Total abstracts</th>
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<th>Clinical Studies</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LoE I</td>
</tr>
<tr>
<td>2001</td>
<td>148</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>2002</td>
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<td>2003</td>
<td>129</td>
<td>62</td>
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<tr>
<td>Group I</td>
<td>427</td>
<td>176 (41.22%)</td>
<td>51 (11.94%)</td>
</tr>
<tr>
<td>2008</td>
<td>132</td>
<td>57</td>
<td>9</td>
</tr>
<tr>
<td>2009</td>
<td>141</td>
<td>52</td>
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<tr>
<td>2010</td>
<td>155</td>
<td>49</td>
<td>16</td>
</tr>
<tr>
<td>Group II</td>
<td>428</td>
<td>158 (36.92%)</td>
<td>126 (29.44%)</td>
</tr>
</tbody>
</table>

Ψ Represents percentage of entire group
¶ Represents percentage of clinical studies only

Table 2a: Year and group-wise breakdown of CSRS-AM podium presentations for LoE

<table>
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<th>Year</th>
<th>Total abstracts</th>
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<td>LoE I</td>
</tr>
<tr>
<td>2001</td>
<td>51</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>2002</td>
<td>58</td>
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<td>4</td>
</tr>
<tr>
<td>2003</td>
<td>57</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Group I</td>
<td>166</td>
<td>67 (40.36%)</td>
<td>27 (16.26%)</td>
</tr>
<tr>
<td>2008</td>
<td>54</td>
<td>12</td>
<td>5</td>
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<td>2009</td>
<td>66</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>2010</td>
<td>78</td>
<td>26</td>
<td>12</td>
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<tr>
<td>Group II</td>
<td>198</td>
<td>58 (29.30%)</td>
<td>79 (39.90%)</td>
</tr>
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</table>

Please click on the “Disclosure” link for author/participant financial disclosure information.
Table 2b: Year and group-wise breakdown of CSRS-AM poster presentations for LoE

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<th>Year</th>
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<th>Clinical Studies</th>
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<td></td>
<td></td>
<td>LoE I</td>
</tr>
<tr>
<td>2001</td>
<td>97</td>
<td>38</td>
<td>1</td>
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<tr>
<td>2002</td>
<td>92</td>
<td>32</td>
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</tr>
<tr>
<td>2003</td>
<td>72</td>
<td>39</td>
<td>7</td>
</tr>
<tr>
<td>Group I</td>
<td>261 (41.76%)</td>
<td>109 (41.76%)</td>
<td>24 (15.79%)</td>
</tr>
<tr>
<td>2008</td>
<td>78</td>
<td>42</td>
<td>4</td>
</tr>
<tr>
<td>2009</td>
<td>75</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>2010</td>
<td>77</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>Group II</td>
<td>230 (43.47%)</td>
<td>100 (43.47%)</td>
<td>47 (36.15%)</td>
</tr>
</tbody>
</table>
Responsiveness and Minimally Detectable Differences of a Clinical Impairment Measure Specific for Traumatic Tetraplegia: A Canadian Multi-Centre Assessment of the GRASSP Version 1.0

Sukhvinder Kalsi-Ryan, BSc PT, MSc, PhD, Toronto, Ontario, Canada
Michael G. Fehlings, MD, PhD, Toronto, Ontario, Canada

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 (inter/test retest) and validity are well established. Responsiveness and minimally detectable difference (MDD) testing is required to establish use in efficacy and interventional studies. The objectives of this study were to: 1) Develop responsiveness and MDD values for the GRASSP; 2) To establish how the measure can be applied in clinical trials and interventional studies as a tool to define effectiveness of new therapies.

Methods: A prospective longitudinal study including 55 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), Spinal Cord Independence Measure (SCIM), Capabilities of Upper Extremity Questionnaire (CUE) administered 0 to 10 days, 1, 3, 6, and 12 months post injury. Analysis: The standardized response mean (SRM) for GRASSP, ISNCSCI, SCIM and CUE were calculated for the 0 to 3, 6 and 12 month, pairs of data. Smallest real difference (SRD) was calculated for each subtest of the GRASSP. Pearson correlation coefficients were calculated to define concurrent validity across the recovery profile.

Results: SRM values for GRASSP strength and sensation scores were 0.20 to 0.30 greater than the related ISNCSCI SRM values at the (0 to 3, 6, 12 month pairs of data). MDD values for all subtests range between 2.76 and 9.23. Concurrent validity between SCIM/CUE and GRASSP range between 0.632 and 0.874 across the recovery profile. In Figure1 SRM values show how large the impairment change is between each timepoint and which assessment is most sensitive.

Conclusion: SRM values and longitudinal construct validity demonstrate the responsiveness of GRASSP scores. The SRM of GRASSP values also defines the GRASSP scores as being more sensitive than ISNCSCI sensory and motor scores. Subtleties that the GRASSP characterizes; are valuable in determining change over time; optimizing the field's ability to detect new efficacious treatments specific to traumatic tetraplegia. MDD values are useful in establishing how much change is attributed to true clinical change. With the new generation of SCI trials moving into cervical SCI the GRASSP is an appropriate measure to set specific meaningful endpoints for upper limb recovery.

Funding and Acknowledgements: Ontario Neurotrauma Foundation, Rick Hansen Institute, Physiotherapy Foundation of Canada, Canadian GRASSP Longitudinal Study Group

Please click on the “Disclosure” link for author/participant financial disclosure information.
Responsiveness and Minimally Detectable Differences of a Clinical Impairment Measure Specific for Traumatic Tetraplegia: A Canadian Multi-Centre Assessment of the GRASSP Version 1.0

Figure 1: Standardized Response Mean, calculations of responsiveness

Table 3: Minimally Detectable Difference (MDD) Values

<table>
<thead>
<tr>
<th>Subtest of GRASSP</th>
<th>SEM</th>
<th>SRD</th>
<th># of Items</th>
<th>Change in Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength R (0 – 50)</td>
<td>3.34</td>
<td>9.23</td>
<td>1</td>
<td>More than 5 pts</td>
</tr>
<tr>
<td>Strength L (0 – 50)</td>
<td>3.47</td>
<td>9.59</td>
<td>1</td>
<td>More than 5 pts</td>
</tr>
<tr>
<td>Sensation R (0 – 24)</td>
<td>2.88</td>
<td>7.96</td>
<td>0.5</td>
<td>More than 2 pts</td>
</tr>
<tr>
<td>Sensation L (0 – 24)</td>
<td>2.32</td>
<td>6.41</td>
<td>0.5</td>
<td>More than 2 pts</td>
</tr>
<tr>
<td>Pre Ability R (0 – 12)</td>
<td>.997</td>
<td>2.76</td>
<td>0.5</td>
<td>More than 2 pts</td>
</tr>
<tr>
<td>Pre Ability L (0 – 12)</td>
<td>.988</td>
<td>2.76</td>
<td>0.5</td>
<td>More than 2 pts</td>
</tr>
<tr>
<td>Pre Perf R (0 – 30)</td>
<td>2.16</td>
<td>5.97</td>
<td>0.5</td>
<td>More than 3 pts</td>
</tr>
<tr>
<td>Pre Perf L (0 – 30)</td>
<td>1.93</td>
<td>5.33</td>
<td>0.5</td>
<td>More than 3 pts</td>
</tr>
</tbody>
</table>

MDD values were calculated for each subtest score; these values confirm how much of the change between scores is potentially due to error or real clinical change. These values are useful in the development of endpoints for clinical trials, while responsiveness values are useful in determining efficacy of an intervention.
**Full Body EOS Analysis of the Maintenance of Functional CBVA and Horizontal Gaze among Hypo-lordotic vs. Hyper-lordotic Patients**

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Renaud Lafage, MS, New York, New York  
Emmanuelle Ferrero, MD, New York, New York  
Barthelemy Liabaud, MD, New York, New York  
**Bassel Diebo, MD, New York, New York**  
Shian Liu, BS, New York, New York  
Justin S. Smith, MD, PhD, Charlottesville, Virginia  
Christopher P. Ames, MD, San Francisco, California  
Eric O. Klineberg, MD, Sacramento, California  
Peter Passias, MD, New York, New York  
Themistocles S. Protopsaltis, MD, New York, New York  
Thomas J. Errico, MD, New York, New York  
Frank J. Schwab, MD, New York, New York  
Virginie Lafage, PhD, New York, New York

**Introduction:** Understanding various components of global alignment is essential in effective treatment of adult spinal deformity patients (ASD). Despite the development of full-body radiographic technology, sagittal plane assessment commonly remains limited to the spino-pelvic area. Evaluation of cervical and lower limb compensatory mechanisms has been poorly understood to date. C2C7 (CL) angle is traditionally used to assess cervical alignment, however new cervical parameters have emerged such as radiographic assessment of Chin Brow Vertical Angle (CBVA) to analyze horizontal gaze and T1 slope minus cervical lordosis (TS-CL), C2C7 sagittal vertical axis (C2C7 SVA) and Center of Gravity of the Head to C7 SVA (CGH-C7 SVA) reflecting cervical deformity. The objective of this study was to investigate the role of the cervical spine and lower limbs in maintaining erect posture and horizontal gaze in the setting of ASD.

**Methods:** In this retrospective study, ASD patients underwent low dose full-body X-Rays (EOS system). The inclusion criteria were functional horizontal gaze (CBVA between -4 and 17 deg). Patients were divided in 2 groups based on PI-LL mismatch: Hyper-lordotic (Hyper, PI-LL15°). Groups were compared in terms of sagittal spino-pelvic alignment, cervical parameters and lower limb compensatory mechanisms (Student T test). Cervical parameters analyzed were TS-CL (mismatch between the angle between superior endplate of T1 and horizontal line with C2C7 angle), C2C7 SVA, CGH-C7 SVA, C0C2 angle (figure). Correlations and regression were performed to predict lower extremity compensation.

**Results:** 86 patients (mean age 55.5 years, BMI 26.4, 75% female) were included: 29 Hypo and 57 Hyper. There was no statistical difference between the 2 groups for cervical/cranial parameters. By definition, Hypo patients (Table) had a significantly more sagittal spino-pelvic deformity (PI-LL, Sagittal vertical axis SVA, and T1 pelvic angle TPA) as well as a larger PI, Sacro femoral angle (SFA, hip hyperextension), KA (Knee Angle) and AA (Ankle Angle). These were well correlated with Thoracic Kyphosis (TK) in both groups (0.4<r<0.6, p<0.05). However, cervical parameters were negatively correlated with PI-LL mismatch in Hyper group only (-0.38<r<-0.54, p<0.05). In Hypo group, small correlation existed between KA and CL (r=0.26, p<0.05). In both groups, PI-LL was well correlated with Pelvic Tilt (PT) and TPA was well correlated with SFA and PT. For Hypo patients, TPA and PI-LL were correlated with KA and AA (Table). SVA wasn’t correlated with any compensatory mechanism in both groups.

**Conclusions:** In the maintenance of horizontal gaze and standing posture, poorly aligned patients recruit every lower extremity compensatory mechanisms including pelvic retroversion, hip extension, knee flexion and ankle flexion. However, in Hypo patients, regional cervical parameters such as TS-CL and C2C7 SVA which reflect cervical deformity are not related to compensatory mechanisms, although the C2C7 angle increase with KA to maintain horizontal gaze. Conversely, according to TS-CL and PI-LL negative correlation, Hyper patients decrease their cervical lordosis in response to the lumbar mismatch. Lower extremity compensation can be predicted from the magnitude of TPA sagittal parameter.
Full Body EOS Analysis of the Maintenance of Functional CBVA and Horizontal Gaze among Hypo-lordotic vs. Hyper-lordotic Patients

**Figure:** Regional sagittal cervical parameters. (A) C2-C7 SVA: horizontal distance between the line dropped from the center of C2 and the posterior superior corner of C7; (B) CGH-C7 SVA: horizontal distance between the line dropped from the center of gravity of the head and the posterior superior corner of C7; (C) T1 Slope: angle between the superior endplate of T1 and the horizontal. C2-C7; Angle using the Cobb method between the inferior endplate of C2 and the inferior endplate of C7.

<table>
<thead>
<tr>
<th></th>
<th>HYPER (N=29)</th>
<th>HYPO (N=57)</th>
<th>Comparison</th>
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<tr>
<td></td>
<td>Mean</td>
<td>Stdev</td>
<td>Mean</td>
</tr>
<tr>
<td>PLL</td>
<td>-20.1</td>
<td>3.5</td>
<td>28.2</td>
</tr>
<tr>
<td>PI</td>
<td>43.2</td>
<td>10.2</td>
<td>63.1</td>
</tr>
<tr>
<td>LL</td>
<td>-63.3</td>
<td>10.5</td>
<td>-34.9</td>
</tr>
<tr>
<td>T4-T12</td>
<td>51.3</td>
<td>13.8</td>
<td>25.6</td>
</tr>
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<td>T9SpL</td>
<td>-12.3</td>
<td>4.7</td>
<td>-9.6</td>
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<td>T1SpH</td>
<td>-5.1</td>
<td>3.1</td>
<td>-2.7</td>
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<td>1.5</td>
<td>2.1</td>
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<td>21.1</td>
<td>7.2</td>
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<tr>
<td>C2-C7</td>
<td>-8.1</td>
<td>15.6</td>
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<td>25.6</td>
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<td>24.1</td>
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<td>SFA</td>
<td>189.1</td>
<td>6.4</td>
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**Table:** Comparison sagittal parameters, correlation and linear regression between Under Corrected and Over Corrected patients.

Please click on the "Disclosure" link for author/participant financial disclosure information.
Validation of Correlation between Chin Brow Vertical Angle (CBVA), Slope of Line of Sight (SLS), and McGregor’s Slope (McGS) for Cervical Disability.

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Barthelemy Liabaud, MD, New York, New York
Bassel Diebo, MD, New York, New York
Shian Liu, BS, New York, New York
Eric O. Klineberg, MD, Sacramento, California
Peter Passias, MD, New York, New York
Christopher P. Ames, MD, San Francisco, California
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Themistocles S. Protopsaltis, MD, New York, New York
Thomas J. Errico, MD, New York, New York
Frank J. Schwab, MD, New York, New York
Virginie Lafage, PhD, New York, New York

Introduction: The maintenance of horizontal gaze is an essential function of upright posture and global sagittal spinal alignment. One of the parameters allowing measurement of the horizontal gaze is the CBVA, which is not well visualized on most standard lateral spine radiographs. This study proposes to evaluate the correlation of CBVA with two more accessible angles: the SLS and slope McGS, and to determine if these cranial parameters correlate with HRQOL measures.

Methods: Patients were identified from a multicenter database of 531 spine patients who underwent full body EOS X-rays with a variety of presenting complaints (primary cervical, lumbar, or adult scoliosis). Exclusion criteria were age<18y, total hip arthroplasty, total knee arthroplasty, neuropathic scoliosis, fractures, and tumor. Correlations between CBVA, SLS, and McGS and were assessed. Using a quadratic regression with ODI and CBVA, we established a severe disability range of values for the CBVA and then, by simple regression, a severe disability range of values for SLS and McGS.

Results: 435 patients were included (67% females, mean age 57±15yo, mean BMI 27.4±6.4 kg/m2). CBVA strongly correlated with SLS (r= .996, p<.001) and McGS (r= .862, p<.001). A significant negative correlation was observed between ODI and all 3 angles (Table). Using a quadratic regression with the ODI and CBVA lead to the following CBVA range of values corresponding to severe disability (17.7°) (Figure). A simple regression demonstrated the following severe disability ranges for SLS (18.5°), and for McGS (14.3°).

Conclusions: The maintenance of horizontal gaze, classically measured by the CBVA, is an essential element of cranio-cervical alignment. This study found that the SLS and slope of McGregor's line correlate strongly to CBVA and can be used as surrogate measures. The range of values for these measures corresponding to severe disability was identified. Further studies should be undertaken to evaluate these angles in severe cases of specific spinal pathologies.
Validation of Correlation between Chin Brow Vertical Angle (CBVA), Slope of Line of Sight (SLS), and McGregor’s Slope (McGS) for Cervical Disability.

Figure 1: Quadratic regression and range of CBVA corresponding to an ODI of 40

Table 1: Correlation between CBVA, SLS, McGS and ODI
Cervical Alignment Changes and Clinical Outcomes after Surgeries for Cervical Myelopathy Caused by Ossification of the Posterior Longitudinal Ligament with a Focus on Cervical Sagittal Balance

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Yoshiyasu Arai, MD, PhD, Saitama Prefecture, Japan
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Introduction: For cervical myelopathy caused by ossification of the posterior longitudinal ligament (OPLL), 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 (CNR< 50%) and normal cervical alignment, we performed laminoplasty (LAMP). Recently, a cervical sagittal balance according to the cervical sagittal vertical axis (CSVA) has received increased attention as an important determinant of clinical outcomes after surgery. We retrospectively investigated surgical outcomes for cervical myelopathy caused by OPLL with special attention to the concept of the cervical sagittal balance.

Methods: A total of 66 consecutive patients (55 male, 11 female; mean age 63.1 years) who received surgery for cervical myelopathy caused by OPLL at our hospital from 2008 and completed over a 1-year follow-up were enrolled. The average follow-up period was 2.5 years. ADF was performed in 29 cases (ADF group), PDF in 10 cases (PDF group) and LAMP in 27 cases (LAMP group). Cervical lateral X-ray images taken in the neutral standing position were evaluated preoperatively and at a final follow-up visit. The radiographic measurements included the following: (1) C2-7 lordotic angle (C2-7 angle) and (2) CSVA, which was measured as the distance between a plumb line dropped from the anterior margin of the external auditory canal and the center of the C7 vertebral body. The clinical results were evaluated using the Japanese Orthopedic Association score system for cervical myelopathy (C-JOA score).

Results: The C2-7 angles and CSVAs in the ADF and PDF groups were not affected by the operation, but those in the LAMP group were deteriorated (p<0.05). The mean recovery rate of the C-JOA score at the final follow-up stage was 54.2% in the ADF group, 56.2% in the PDF group and 44.1% in the LAMP group. The postoperative loss of cervical lordosis in the LAMP group was correlated with the preoperative CSVA (R=0.535, Figure 1), but those in the ADF and PDF groups were not. During the follow-up period, neurological deterioration was observed in 3 cases in the LAMP group, but no deterioration was observed in the ADF and PDF groups. In these 3 cases, the loss of cervical lordosis (average: 22.3°) and the local kyphotic change of the cervical spine at responsible levels were observed. In the LAMP group, the preoperative CSVAs of these deteriorated cases were higher than those of the other cases (average: 56.3mm/18.7mm; p<0.01).

Conclusions: Laminoplasty is not suitable for patients with cervical myelopathy caused by OPLL with a cervical sagittal imbalance, even in cases with normal preoperative alignment and slight OPLL.
Cervical Alignment Changes and Clinical Outcomes after Surgeries for Cervical Myelopathy Caused by Ossification of the Posterior Longitudinal Ligament with a Focus on Cervical Sagittal Balance

**fig. 1**

Relation between loss of cervical lordosis and preoperative CSVA in LAMP group

- Deteriorated case

Preoperative CSVA

Please click on the “Disclosure” link for author/participant financial disclosure information.
Clinical Results and Complications of Posterior Indirect Decompression with Kyphosis Correction and Fusion for Cervical Myelopathy Caused by Ossification of Posterior Longitudinal Ligament

Masahiko Takahata, MD, Sapporo, Japan
Kuniyoshi Abumi, MD, Sapporo, Japan

Introduction: Posterior decompression is the treatment of choice for all patients with cervical myelopathy caused by multilevel OPLL. However, this procedure does not achieve adequate decompression in patients with cervical kyphosis because the spinal cord cannot shift posteriorly. Also, the patient may not respond to posterior decompression in case that beak-type interrupted ossified lesion, which preserves segmental mobility, is responsible for myelopathy. In the present study, we examined the clinical outcomes of posterior indirect decompression with kyphosis correction and fusion for cervical myelopathy caused by OPLL to determine the efficacy of the procedure and the incidence of complications.

Methods: A retrospective study. Nine cases of cervical myelopathy caused by OPLL, who underwent posterior indirect decompression with kyphosis correction and fusion, were reviewed. There were 6 male and 3 female patients and mean age was 58 years (range 50-68). Medical records were reviewed to determine demographic data, neurological examination, imaging findings, surgical outcomes of the patients. Japanese Orthopaedic Association (JOA) score was used to assess physical dysfunction and neurological impairment.

Results: Seven patients have mixed type OPLL and remaining 2 have segmental type OPLL. Two of seven cases had prior history of laminoplasty, which did not improve myelopathy and symptoms at all. An average of 4 levels laminectomy and posterior kyphosis correction and fusion using pedicle screw system were performed on all 9 patients. All 9 cases had cervical kyphosis before surgery and were diagnosed as the "K-line" (-). The average amount of correction of the kyphotic deformity was 12 degrees in the fused segments, a reduction from an average of -11 to an average of 1 degree. Mean preoperative JOA score was 9.6. The clinical symptoms and the JOA score improved to 12 immediately after the surgery and to 13 at latest follow-up. Overall improvement ratio of JOA score was an average of 33 % at time of last evaluation. Surgical complications included 3 cases of postoperative C5 palsy. Of 3 postoperative C5 palsy patients, one recovered with additional C4-5 foraminotomy, 2 patients only showed partial recovery.

Conclusions: The study suggests that posterior indirect decompression with kyphosis correction and fusion is effective for cervical myelopathy caused by OPLL with cervical kyphosis. While anterior decompression and fusion is a standard option for such cases, this procedure may be indicated for the patients with multilevel mixed type or segmented type OPLL. However, given that posterior decompression with kyphosis correction and fusion has a high risk of C5 palsy, prophylactic foraminotomy are to be mandatory in this procedure.
Clinical Results and Complications of Posterior Indirect Decompression with Kyphosis Correction and Fusion for Cervical Myelopathy Caused by Ossification of Posterior Longitudinal Ligament

<table>
<thead>
<tr>
<th>Preop</th>
<th>Postop</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2-7: kyphosis 9 degree</td>
<td>K-line: (-)</td>
</tr>
<tr>
<td>C2-7: kyphosis 3 degree</td>
<td>K-line: (+)</td>
</tr>
</tbody>
</table>

***The FDA has not approved labeling the pedicle screw system for the described purpose***
Cellular Bone Matrices: Viable Stem Cell-Containing Bone Graft Substitutes

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Javier Z. Guzman, New York, New York
Motosem Al Maaieh, MD, New York, New York
Samuel K. Cho, MD, New York, New York
Sheeraz A. Qureshi, MD, MBA, New York, New York

Introduction: Advances in the field of stem cell technology have stimulated the development and increased use of allogenic bone grafts containing live mesenchymal stem cells (MSCs), also known as cellular bone matrices (CBMs). It is estimated that CBMs comprise greater than 17% of all bone grafts and bone graft substitutes used. We critically evaluated CBMs, specifically evaluating their technical specifications, existing published data supporting their use, US Food and Drug Administration (FDA) regulation, cost, potential pitfalls, as well as other aspects pertaining to their use.

Methods: A series of Ovid Medline and Pubmed-National Library of Medicine/National Institutes of Health searches were performed. Only articles in English journals or published with English language translations were included. Level of evidence of the selected articles was assessed. Specific technical information on each CBM was obtained by direct communication from the companies marketing the individual products.

Results: Five different CBMs are currently available for use in spinal fusion surgery. There is a wide variation between the products with regards to the average donor age at harvest, total cellular concentration, percentage of MSCs, shelf life and cell viability after defrosting. Three retrospective studies evaluating CBMs and fusion have shown fusion rates ranging from 90.2% to 92.3% and multiple industry sponsored trials are underway. Two of the published works do not disclose whether they have conflicts of interest and one study is industry sponsored. No independent studies exist evaluating spinal fusion rates with the use CBMs. All the commercially available CBMs claim to meet the FDA criteria under Section 361, 21 CFR Part 1271 and are not undergoing FDA pre-market review. The CBMs claim to provide viable MSCs and are offered at a premium cost. Numerous challenges exist in regards to MSCs survival, function, osteoblastic potential and cytokine production once implanted into the intended host.

Conclusions: CBMs may be a promising bone augmentation technology in spinal fusion surgery. While CBMs appear to be safe for use as bone graft substitutes, their efficacy in spinal fusion surgery remains highly inconclusive. Large, non-industry sponsored studies evaluating the efficacy of CBMs are required. Without results from such studies, surgeons must be made aware of the potential pitfalls of CBMs in spinal fusion surgery. With the currently available data there is insufficient evidence to support the use of CBMs as bone graft substitutes in spinal fusion surgery.
Cellular Bone Matrices: Viable Stem Cell-Containing Bone Graft Substitutes

<table>
<thead>
<tr>
<th></th>
<th>Osteocel® Plus</th>
<th>Trinity™ Evolution</th>
<th>Cellentra™ VCBM</th>
<th>AlloStem®</th>
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<td>Orthofix® (Lewinville, TX, USA)</td>
<td>Biomet® (Warsaw, IN, USA)</td>
<td>AlloSource® (Centennial, CO, USA)</td>
<td>Osiris Therapeutics, Inc. (Colombia, MD, USA)</td>
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<td>Cadaveric bone</td>
<td>Cadaveric bone</td>
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<td>Naturally occurring in bone</td>
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One-Level Treatment with Total Disc Replacement and ACDF: 5-Year Results from a Prospective Randomized Clinical Trial

Michael S. Hisey, MD, FAAOS, Denton, Texas
Hyun W. Bae, MD, Los Angeles, California
Reginald J. Davis, MD, Baltimore, Maryland
Donna D. Ohnmeiss, DrMed, Plano, Texas

Introduction: The two-year efficacy of total disc replacement (TDR) has been validated across a number of clinical trials. However, there is less data available for intermediate and long-term results. The purpose of this study was to compare the results of single-level TDR-treated patients with those of an anterior cervical discectomy and fusion (ACDF) control group through 5 years.

Methods: This was a prospective, randomized, multicenter controlled clinical trial. It was conducted across 24 sites in the United States. The 1-level trial arm consisted of 245 patients randomized in a 2:1 ratio resulting in 164 patients treated with TDR and 81 with ACDF. Inclusion criteria included a diagnosis of symptomatic cervical degenerative disc disease at one level with no history of previous cervical fusion. TDR patients were treated with a Mobi-C® artificial disc (LDR Medical, Troyes, France). ACDF with allograft and anterior plate was used as the control. Outcome measures were collected at baseline, 6 weeks, and at 3, 6, 12, 18, 24, 36, 46, and 60 months postoperatively. Outcome measures included the Neck Disability Index (NDI), visual analog scales (VAS) assessing neck and arm pain, segmental range of motion (ROM), patient satisfaction, SF-12 MCS and PCS, major complications, subsequent surgery, and overall success (composite primary endpoint).

Results: Data were available for 130 TDR patients and 56 ACDF patients at 60 months. Both groups showed significant improvement from baseline NDI scores, VAS neck and arm pain scores, and SF-12 MCS/PCS scores through 60 months (p<0.01). The mean improvement from baseline NDI scores was similar between groups with a mean improvement of 36.9±20.2 for TDR patients and 34.8±19.1 for ACDF. Mean improvement in VAS neck pain score was 51.7±33.8 for the TDR group and 50.2±31.7 for the ACDF group. Mean improvement in VAS arm pain scores was 28.1±39.4 (right arm) and 32.2±38.2 (left arm) for the TDR population and 22.3±43.7 (right arm) and 37.7±39.9 (left arm) for the ACDF population. TDR patients had a mean improvement in SF-12 scores of 7.4±13.9 (MCS) and 14.3±11.7 (PCS) while the ACDF group had a mean improvement of 7.1±11.8 (MCS) and 14.0±10.7 (PCS). Mean segmental ROM remained preserved in the TDR group. The 60-month rate of major complications was similar between groups with a rate of 5.5% for TDR and 3.7% for ACDF patients. The percentage of patients who underwent a subsequent surgery was significantly less for the TDR group (TDR: 2.8% vs. ACDF: 11.1%, p<0.015). The patient satisfaction rate was higher for the TDR population with 92.0% of patients being “very satisfied” with their treatment after 5 years compared to the ACDF rate of 83.9%, though this difference was not statistically significant. The overall success analysis demonstrated non-inferiority of TDR to ACDF at 60 months with 65.9% of TDR patients and 60.7% of ACDF patients meeting the overall success criteria.

Conclusions: Five year data continues to support TDR as a safe and effective procedure for the treatment of symptomatic cervical degenerative disc disease. TDR patient outcomes remain similar or better than the ACDF control group while preserving segmental ROM.
The Effect Of Retropharyngeal Steroids On Post-operative Swelling And Dysphagia Follow Anterior Cervical Surgery

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Daniel K. Park, MD, Bloomfield Hills, Michigan

Introduction: Post-operative dysphagia is a frequently encountered complication following anterior cervical discectomy and fusion surgery (ACDF). Several studies have shown increased rates of dysphagia with greater number of fused levels at index operation. Numerous attempts at reducing the rate of post-operative dysphagia have been published including reducing endotracheal cuff pressures, anterior cervical plate design, and the use of intravenous steroids. Recently the use of retropharyngeal steroids placed at the end of surgery was shown to be successful in reducing post-operative soft tissue swelling and the rate of post-operative odynophagia in 1 and 2 level surgery. We sought to determine the efficacy of retropharyngeal steroids placed at the time of surgery to affect short term clinical outcomes following multi-level surgery (2-, 3-, 4-level ACDF).

Methods: A retrospective review of charts (1/1/2013 to 5/1/2014) pertaining to those patients that underwent a multi-level ACDF. The study population was compared to a matched cohort of patients operated on during the same time period. All patients received 10mg of intra-operative methylprednisolone at the start of surgery. The study group received an additional 80mg of solumedrol added to a gelfoam sponge place in the retropharyngeal space at the end of surgery. The control group received no additional steroids. Radiographic outcome measures included post-operative pre-vertebral swelling measurements at 1 day and 6 weeks post-operatively. Clinical outcome measures included Neck Disability Index (NDI), Bazaz-Yoo dysphagia and EAT dysphage scores taken pre-op, 6 weeks and 3 months post-operatively.

Results: Chart review identified 20 patients that received retropharyngeal steroids placed at the time of surgery. There were nine 2-level, ten 3-level and one 4-level ACDF procedures in this group which was compared to a control group with a matched number of levels. Baseline NDI and dysphagia scores were not statistically different between the steroid and control groups. Both groups demonstrated improvements in NDI scores post-operatively, but there were no differences between the groups. There were no significant differences in pre-vertebral swelling measurements at 1 day and 6 weeks post-operatively. The steroid group had significantly improved EAT scores compare to control (p= 0.017) and there was a trend towards improved Bazaz-Yoo scores at 6 weeks in the steroid group (p=0.06). When compared to baseline dysphagia scores, the steroid group did not demonstrate a significant worsening of their symptoms 6 weeks after surgery. However, the control group had significantly worse dysphagia scores compared to their baseline 6 weeks after surgery.

Conclusion: Dysphagia remains a commonly encounter complication follow anterior cervical surgery. A previous study has demonstrated the ability of retropharyngeal steroids to reduce post-operative odynophagia and prevertebral soft tissue swelling in 1- and 2-level ACDF. The data herein further expands upon that literature by demonstrating improvements in post-operative dysphagia scores in patients undergoing 2-, 3-, and 4-level surgery with the use of retropharyngeal steroids. Although encouraging, further prospective studies will be needed to determine the ultimate utility of retropharyngeal steroids in reducing the rate of dysphagia and long term follow-up will be need to determine its effect of fusion rates.
Progressive Cervical Spinal Cord Compression Induces Compensatory Neuroplasticity Of The Spinal Respiratory Circuitry

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Spyridon K. Karadimas, MD, PhD, Toronto, Ontario, Canada
Michael G. Fehlings, MD, PhD, Toronto, Ontario, Canada

Introduction: We hypothesized that, chronic progressive compression of the cervical spinal cord that results from cervical spondylotic myelopathy (CSM), elicits a distinct form of plasticity of the respiratory circuitry that prevents significant decline of respiratory function in this common clinical condition.

Materials: In this study, utilizing a novel clinically relevant model of CSM, where the cervical spinal cord is compressed progressively by the insertion of a biomaterial underneath the C4-C5 laminae above the PMNs. To neurophysiologically assess chronic compression induced respiratory plasticity, we performed a C2Hx injury at 2, 4, and 8 weeks post-material implantation and evaluated respiratory related diaphragmatic EMG. The neuroanatomical substrates that mediate this unique form of neurophysiological plasticity were assessed through detail analysis of morphological and functional alterations in spinal respiratory circuitry. The number of PMNs in the cervical spinal cord was identified via an intrapleural injection of cholera toxin B subunit (CTB) and quantified using unbiased stereology in CSM (2, 4, 8 weeks) and sham groups. CSM induced functional status of PMN was determined by evaluating the activity (cfos immunolabeling) of CTB labeled PMNs after an acute episode of hypoxia in sham and 2 and 8 week CSM animals. Additionally, CTB labeled PMNs were evaluated for changes in serotonin and glutamate receptors both strongly implicated in respiratory plasticity. Finally, alterations in synaptic connections from respiratory premotor neurons within the medulla to PMNs were assessed via an injection of synaptophysin specific anterograde tracer (TAT-Synaptophysin-GFP) and retrograde identification of PMNs by CTB in sham and 2 and 12 week CSM animals.

Results: In sham-operated mice, C2Hx immediately silenced the ipsilateral phrenic motor output. While, CSM mice did not display a complete loss of ipsilateral phrenic motor output following C2Hx. Interestingly, the extent of respiratory related diaphragmatic activity maintained following C2Hx was progressively augmented with increase compression duration with 100% of the animals that had CSM surgery for 8 weeks maintaining ipsilateral diaphragmatic activity following C2Hx while only 50% of those at 2 weeks showed ipsilateral EMG activity (Figure 1). Interestingly, the preservation of diaphragmatic activity was not associated with increased numbers of PMN as there was a decrease in the number of retrogradely labeled PMNs following CSM compared to sham. The preserved PMNs displayed an increase expression of glutamate and serotonin receptors.

Conclusion: This study provides novel insights into the chronic compression induced dynamic anatomical and functional modifications in respiratory circuitry that maintains adequate ventilation in CSM. The insights gained about the CSM-mediated plasticity of respiratory circuitry will facilitate the development of treatment strategies to improve respiratory function following traumatic and non-traumatic cervical spinal cord injury.

Progressive cervical spinal cord compression leads to unique neurophysiological plasticity. 50, 75 and 100 percent of animals had preserved left hemidiaphragmatic EMG activity that was rhythmic and synchronous with the contralateral side, at 2, 4 and 8 weeks CSM animals respectively.
Restabilization of the Occipitocervical Junction after a Complete Unilateral Condyllectomy: A Biomechanical Comparison of Unilateral and Bilateral Fixation Techniques.

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Darrel S. Brodke, MD, Salt Lake City, Utah
Andrew T. Dailey, MD, Salt Lake City, Utah

Introduction: During transcondylar surgical approaches to tumors at the anterior foramen magnum occipitocervical instability may result from resection of the occipital condyle. Initially, patients may be able to maintain a neutral alignment in the immediate postoperative period but over time severe occipitoatlantal subluxation may occur with cranial settling, kinking of the spinal cord, and neurological injury. This clinical scenario has received very little attention in the literature. We conducted a biomechanical analysis to evaluate potential fixation constructs to prevent the progression to severe deformity in patients who require radical unilateral condyllectomy during a skull base tumor resection.

Methods: Ten human cadaveric specimens (Oc-C2) underwent biomechanical testing. A complete unilateral condyllectomy was performed to completely destabilize one Oc-C1 joint, leaving the contralateral joint intact. Various unilateral and bilateral occipitocervical fixation configurations were tested. Occipital fixation was achieved using a plate affixed to the occipital keel with 4mm titanium screws. Titanium screws with polyaxial heads were inserted into either the C1 lateral mass or C2 pedicle. A titanium rod was inserted to connect the screws to the occipital plate. Tested configurations included: a bilateral Oc-C1 construct, a unilateral Oc-C1 construct on the resected side, a bilateral Oc-C2 construct, and a unilateral Oc-C2 construct on the resected side. Biomechanical testing was performed to compare range of motion and stiffness between constructs under physiological loads (1.5 N-m).

Results: After complete unilateral condyllectomy, bilateral fixation constructs (Oc-C1 and Oc-C2) provided more stability than unilateral constructs [up to 51% decrease in motion (p=0.001) and 122% increase in stiffness (p=0.003) for Oc-C1 fixation and up to 46% decrease in motion (p=0.004) and 149% increase in stiffness (p=0.005) for Oc-C2 fixation]. A bilateral Oc-C2 construct provided no biomechanical advantage over a bilateral Oc-C1 construct (lateral bending stiffness 1.80 vs. 1.37 N-m/deg, p=0.38; flexion-extension stiffness 2.89 vs. 1.23, p=0.08). A unilateral Oc-C1 construct decreased motion up to 73% compared to the destabilized state, but produced the least stiffness of all constructs tested.

Conclusion: Patients who undergo a radical unilateral condyllectomy require close surveillance for occipitocervical instability. A bilateral Oc-C1 construct provides suitable biomechanical strength and will enable preservation of atlantoaxial motion. A unilateral construct decreases abnormal motion but lacks the stiffness of a bilateral construct. However, given that in clinical practice most patients undergo a partial condyllectomy and only a small proportion of patients develop instability, a unilateral construct may provide enough support to prevent progression to severe occipitocervical subluxation in most patients.
What Specific Questions are Responsible in Driving NDI Superiority of Two-Level CDA Over Two-level Fusion. Post Hoc Item Analysis of Self-reported Outcomes of Two-Level Cervical Disc Arthroplasty (cdr, Mobi-C®) vs. Two-Level ACDF Treated Patients from the Ide Usrct.

Ashley T. Simela, DO, Los Angeles, California
Linda Kanim, MA, Los Angeles, California
Janice Kim, BA, Los Angeles, California
Hyun W. Bae, MD, Los Angeles, California

Background: Investigational Device Exemption (IDE) trial of two-levels treated with Cervical Disc Arthroplasty (CDA) vs. Anterior Cervical Discectomy Fusion (ACDF) demonstrated statistical superiority of ‘Overall Success’ in 66.0% of CDA treated patients compared to 36% ACDF treated patients at 48 months. The neck disability index (NDI) total score was the most significant component in determining patient-based overall success.

Purpose: The purpose of this study was to determine what specific NDI question or cluster of questions distinguished CDA vs. ACDF improvement. Also do these questions reflect a valid clinical difference in patients who received two level arthroplasty vs. fusion.

Study Design/Setting: Post-hoc item analysis of a comparison of differences in self-reported NDI questionnaire items for patients treated at two-levels with CDA vs. ACDF. Original study was a prospective, randomized 2:1 CDA vs. ACDF, multi-center, US-FDA IDE RCT at 24 sites. Self reported outcome measures were NDI, VAS neck pain and VAS arm pain. Patient Sample: There were 330 patients treated at two contiguous levels, 225 CDA patients (investigational) vs. 105 ACDF patients (control).

Methods: Patients with DDD at two-levels received either CDA (Mobi-C®) or ACDF. Clinical evaluations and self-reported outcome measures were collected pre-operatively and postoperatively at 6 weeks, 3, 6, 12, 18, 24, 36, and 48 months. The post hoc NDI item analysis included prospectively collected data from pre-operative (0 months), 24, and 48 month follow-up visits. A patient-based difference score was calculated for each NDI item (pre-operative value subtracted from follow-up value). Averages were calculated by treatment group and ranked. Improvements as NDI item difference scores were evaluated as a function of treatment (ANOVA, GLM-SAS). Patterns of change were assessed with Mantel-Haenszel Chi-Square.

Results: Separate analysis of the 10 NDI items revealed significantly more improvement (less disability) at 48 months compared to pre-op for CDA treated patients compared to ACDF treated patients in Recreation (-2.39 vs. -1.96, p< 0.04), Lifting (-1.93 vs. -1.39, p< 0.02), Reading (-1.80 vs. -1.40, p< 0.02), Headaches (-1.43 vs. -0.86, p< 0.01), Work (-1.95 vs. -1.44, p< 0.01). The least amount of improvement was reported for Personal Care (-1.24 vs. -0.86, p< 0.01). Ranking separatly by treatment, the NDI items with the greatest average improvement were Recreation (-2.39), Pain (-2.27) and Sleeping (-2.04) for CDA patients and Pain (-2.04), Recreation (-1.95), and Sleeping (-1.68) for the ACDF treated patients.

Conclusions: This post hoc analysis identified Recreation and other potentially important NDI items associated with the greatest improvements for CDA versus ACDF treated patients. Overall, the CDA treated patients reported greater improvement than ACDF patients statistically significantly on Recreation, Lifting, Reading, Headaches, Work and Personal Care. The effect of fusion of two levels seems to have the most impact in these activities. These differences were not apparent in the concurrent one level CDA vs. ACDF trial.
Venous Thromboembolism following Cervical Spine Surgery: Analysis from the ACS-NSQIP 2005-2012

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Sanjeev Kakar, MD, Rochester, Minnesota
Elizabeth B. Habermann, PhD, Rochester, Minnesota
Amy Wagie, MD, Rochester, Minnesota
Bradford L. Currier, MD, Rochester, Minnesota
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Introduction: The literature on venous thromboembolic (VTE) disease following cervical spine surgery is limited in comparison to studies regarding thoracolumbar surgery. The studies available are heterogenous involving specific subgroups of patients or variable screening surveillance methods. The registry studies currently available lack standardized follow-up or do not distinguish between specific subgroups. Given these limitations, the incidence and risk factors for VTE following cervical spine surgery need to be better established as VTE can lead to postoperative mortality, delays in discharge, readmission, and increased cost. The purpose of this study is to examine the incidence, timing, and risk factors for VTE following cervical spine surgery.

Methods: The American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) Participant Use Data File was utilized to identify 18,821 patients who underwent cervical spine surgery between 2005-2012. Multiple patient characteristics were identified including demographics, comorbidities, laboratory values, and operative factors. Thirty-day readmission data was obtained for 2011-2012. The incidence and timing (in days) of deep vein thrombosis (DVT) and pulmonary embolus (PE) were determined. Univariate analysis was performed to identify differences between patients who suffered a VTE event and those who did not. Multivariable logistic regression analysis was then performed to identify significant risk factors.

Results: Of the 18,821 patients identified as having had cervical surgery, the most frequent procedures were anterior cervical diskectomy and fusion (11,782, 62.6%), posterior cervical decompression (3824, 20.3%), and posterior cervical fusion (1360, 7.2%). Overall, 47 cases of PE (0.2%) and 96 cases of DVT (0.5%) were identified. VTE rates were highest in the subgroup of patients undergoing posterior cervical fusion with a 0.7% PE rate (p = .006) and a 1.8% DVT rate (p < .001). The mean time for diagnosis was 9.3 ± 6.6 days for PE and 10.5 ± 6.8 days for DVT. (Table 1) In 2011-2012, 22.3% of patients with VTE were readmitted. Several significant predictors of VTE were identified in univariate analysis including several demographics, comorbidities, laboratory values, and perioperative factors. (Table 2) Independent risk factors included female gender (OR 1.60, p = .015), African American race (OR 1.90, p = .004), albumin < 3 (OR 2.55, p = .005), WBC > 12 (OR 1.91, p = .014), INR > 1.6 (OR 1.82, p = .017), length of stay 6 days or greater (OR 4.44, p < .001), and quadriplegia (OR 2.38, p = .016) were identified in multivariable analysis. Of note, length of stay less than 3 days was protective (OR 0.38, p = .001).

Discussion: We report an overall thirty day PE rate of 0.2% and DVT rate of 0.5% following cervical spine surgery in a large multi-center database. The mean diagnosis was over one week following surgery and resulted in a 22.3% readmission rate. Several potentially modifiable risk factors were identified including several preoperative labs, nutritional status, operative efficiency, and length of stay. While quadriplegia has been previously demonstrated as a risk factor, further research is needed to determine why African American race and female gender were also independent predictors.
Venous Thromboembolism following Cervical Spine Surgery: Analysis from the ACS-NSQIP 2005-2012

Table 1. VTE Rates following Cervical Spine Surgery

<table>
<thead>
<tr>
<th>Procedure</th>
<th>N</th>
<th>PE rate (%)</th>
<th>Days until PE</th>
<th>DVT rate (%)</th>
<th>Days until DVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>18,821</td>
<td>47 (0.2%)</td>
<td>9.3 ± 6.6</td>
<td>96 (0.5%)</td>
<td>10.5 ± 6.8</td>
</tr>
<tr>
<td>ACDF</td>
<td>11,782</td>
<td>19 (0.2%)</td>
<td>8.8 ± 6.7</td>
<td>29 (0.2%)</td>
<td>11.0 ± 7.0</td>
</tr>
<tr>
<td>Decompression</td>
<td>3824</td>
<td>14 (0.4%)</td>
<td>7.9 ± 6.2</td>
<td>26 (0.7%)</td>
<td>10.0 ± 6.0</td>
</tr>
<tr>
<td>PSF</td>
<td>1360</td>
<td>9 (0.7%)</td>
<td>11.3 ± 5.8</td>
<td>24 (1.8%)</td>
<td>9.2 ± 7.4</td>
</tr>
<tr>
<td>Corpectomy</td>
<td>1189</td>
<td>3 (0.3%)</td>
<td>15.0 ± 10.1</td>
<td>12 (1.0%)</td>
<td>11.4 ± 7.5</td>
</tr>
<tr>
<td>Oncologic</td>
<td>292</td>
<td>2 (0.7%)</td>
<td>5.5 ± 4.9</td>
<td>5 (1.7%)</td>
<td>13.0 ± 7.0</td>
</tr>
<tr>
<td>Disc Arthroplasty</td>
<td>302</td>
<td>0 (0.0%)</td>
<td>-</td>
<td>0 (0.0%)</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Univariate Analysis of Risk Factors for VTE

<table>
<thead>
<tr>
<th>Variable</th>
<th>No VTE (n = 18691)</th>
<th>VTE (n = 130)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &gt; 70</td>
<td>2175 (11.6%)</td>
<td>33 (25.4%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female</td>
<td>8964 (48.0%)</td>
<td>44 (33.8%)</td>
<td>.005</td>
</tr>
<tr>
<td>African American</td>
<td>1879 (10.1%)</td>
<td>35 (26.9%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weight loss</td>
<td>102 (0.5%)</td>
<td>3 (2.3%)</td>
<td>.007</td>
</tr>
<tr>
<td>COPD</td>
<td>759 (4.1%)</td>
<td>11 (8.5%)</td>
<td>.012</td>
</tr>
<tr>
<td>CHF</td>
<td>43 (0.2%)</td>
<td>2 (1.5%)</td>
<td>.002</td>
</tr>
<tr>
<td>Hypertension</td>
<td>8443 (45.2%)</td>
<td>76 (58.5%)</td>
<td>.002</td>
</tr>
<tr>
<td>PVD</td>
<td>86 (0.5%)</td>
<td>3 (2.3%)</td>
<td>.007</td>
</tr>
<tr>
<td>Cancer</td>
<td>147 (0.8%)</td>
<td>4 (3.1%)</td>
<td>.003</td>
</tr>
<tr>
<td>Chronic steroid use</td>
<td>696 (3.7%)</td>
<td>11 (8.5%)</td>
<td>.005</td>
</tr>
<tr>
<td>Transfusion</td>
<td>49 (0.3%)</td>
<td>4 (3.1%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Prior Operation</td>
<td>168 (0.6%)</td>
<td>6 (4.6%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hematocrit &lt; 33</td>
<td>742 (4.0%)</td>
<td>17 (13.1%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>INR &gt; 1.6</td>
<td>11845 (63.4%)</td>
<td>110 (84.6%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Creatinine &gt; 1.5</td>
<td>418 (2.2%)</td>
<td>11 (8.5%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ASA class</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2</td>
<td>10733 (57.4%)</td>
<td>38 (29.2%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>3</td>
<td>7324 (39.2%)</td>
<td>73 (56.2%)</td>
<td></td>
</tr>
<tr>
<td>4/5</td>
<td>610 (3.3%)</td>
<td>19 (14.6%)</td>
<td></td>
</tr>
<tr>
<td>Functional dependence</td>
<td>86 (0.5%)</td>
<td>4 (3.1%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Operative time</td>
<td>141.1 ± 82.3</td>
<td>196.5 ± 122.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Length of stay</td>
<td>2.5 ± 4.3</td>
<td>11.7 ± 14.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Paraplegia</td>
<td>33 (1.8%)</td>
<td>7 (5.4%)</td>
<td>.008</td>
</tr>
<tr>
<td>Quadriplegia</td>
<td>189 (1.0%)</td>
<td>12 (9.2%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Smoking</td>
<td>5589 (29.9%)</td>
<td>28 (21.5%)</td>
<td>.038</td>
</tr>
<tr>
<td>BMI &gt; 35</td>
<td>3264 (17.5%)</td>
<td>29 (22.3%)</td>
<td>.147</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2727 (14.6%)</td>
<td>26 (20.0%)</td>
<td>.135</td>
</tr>
</tbody>
</table>
Patterns of Cervical Disc Degeneration - Analysis of Magnetic Resonance Imaging of over 1,000 Symptomatic Subjects.

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Introduction: Cervical intervertebral disc degeneration is a common finding on magnetic resonance imaging (MRI). Cervical disc degeneration often cause clinical problem, and it is important in the treatment of cervical spine to predict which level degeneration will subsequently occur. However, the progression patterns of degeneration are less well understood. Previously, we have developed a new classification system for cervical disc degeneration based on detailed analysis of the changes seen on MRI, which is simple, reproducible and related with functional parameters (Figure1). The purpose of this study was to evaluate the cervical disc degeneration on MRI using the classification system in a large population of symptomatic patients, and to provide baseline data on the pattern of cervical disc degeneration.

Materials/Methods: We performed a cross-sectional study of 1059 patients (566 female, 493 male) with a mean age was 48.1 (range 15-80) who underwent upright cervical MRI for symptoms of neck pain with or without neurological symptom. A total of 6354 cervical discs from C2/3 to C7/T1 were evaluated. Cervical disc degeneration was evaluated on T2-weighted MRI and graded into 4 categories; Grade 0: No degeneration, Grade I: Mild degeneration (decrease of nucleus intensity), Grade II: Moderate degeneration (positive disc bulge), Grade III: Severe degeneration (disc height decrease) (Figure1). The correlation between age and total grade of each patient was evaluated using Pearson's correlation test. Further, we defined positive degeneration as greater than Grade II, and the prevalence and pattern of degeneration was assessed in different age groups.

Results: Total grade of cervical disc degeneration was significantly correlated with age (p<0.01, R=0.603), and average number of degenerated disc levels is getting higher with age (10s:0.0, 20s:0.7, 30s: 1.3, 40s:1.7, 50s: 2.8, 60s: 3.1, 70s:3.5) (Figure2). Overall, the average score of disc degeneration was highest in C5/6 followed by C4/5 and C6/7. In the patient group with one level degeneration, C5/6 was most common degenerated level (51.2%) followed by C4/5 (19.8%) and C6/7 (16.7%). In the group with two levels degeneration, C5/6 & C6/7 was most common (40.7%) followed by C4/5 & C5/6 (27.6%) and C3/4 & C4/5 (14.1%). Skip level degeneration was found in 17% of the patients with 2 levels degeneration, 22% with 3 levels degeneration, 10% with 4 levels degeneration and 1.6% with 5 levels degeneration. C7/T1 and C2/3 was most unlikely to degenerate in cervical spine.

Conclusion: This cross-sectional study using MRI elucidates the prevalence of natural patterns of cervical disc degeneration in symptomatic middle aged patients. Severe disc degeneration is more common in middle cervical spine (C5/6), and progresses from the level to continuous level except for C7/T1 and C2/3. Contiguous-multilevel disc degeneration is more common than skipped level disc degeneration. This pattern may play a role in adjacent level disc degeneration associated with spinal fusion.
Patterns of Cervical Disc Degeneration - Analysis of Magnetic Resonance Imaging of over 1,000 Symptomatic Subjects.

Figure 1. Algorithm for the grading system and for the assessment of the cervical disc degeneration grade.
Patterns of Cervical Disc Degeneration - Analysis of Magnetic Resonance Imaging of over 1,000 Symptomatic Subjects.

Figure 2. Number of degenerated disc levels according to age
Relationship between the Timing of Reduction of Cervical Spine Dislocations and Neurological Recovery.

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Introduction: Although many studies have reported that it is desirable to perform reductions for cervical spine dislocation injuries as early as possible, the ideal timing remains unclear. When treating cervical spine fractures with dislocation, we perform closed or open reduction immediately upon arrival. We investigated the relationship between the interval from injury to reduction (referred to as "reduction time") and the neurological prognosis.

Methods: Of the 179 consecutive patients with cervical spinal cord injury treated at our hospital between 2007 and 2013, there were 42 patients with distractive flexion (DF) according to the Allen classification (35 males, 7 females; average age, 54.3 years) where the Asia Impairment scale (AIS) grade at the time of transportation from the sites of injury to the medical facilities ranged from A to D. We evaluated the reduction time and change in paralysis at one month after the injury using AIS.

Results: The AIS grade distribution at the time of injury was as follows: A, 21 cases; B, 8 cases; C, 7 cases; and D, 6 cases. The median reduction time was 7 hours (minimum, 3.5 hours; maximum, 21 days). Improvements of one AIS grade or more were observed in 18 of 42 patients (42.9%), consisting of 3 of 21 patients that were AIS A at the time of injury, 5 of 8 B patients, 6 of 7 C patients, 4 of 6 D patients. Reduction was completed within the determined cut-off value of 6 hours in 19 of 42 patients (45.2%), which consisted of 11 of 21 AIS A patients, 3 of 8 B patients, 3 of 7 C patients, and 2 of 6 D patients. Among these 19 patients, all 8 patients with an initial AIS grade of B to D showed improvement by one or more AIS grade (p=0.04). In the 13 AIS B to D patients where the reduction time was over 6 hours, only 7 patients (53.8%) showed improvement by one AIS grade or more. Among patients with an AIS grade of A, 2 of the 3 patients with a reduction time of less than 6 hours showed improvement. Among patients with an AIS grade of A, only 3 of 21 showed improvement, of whom 2 had reductions performed within 6 hours. Nine patients showed no improvement despite reduction times of less than 6 hours. Six patients had improvement of two or more AIS grades; they all underwent reduction within 8 hours of injury. In 5 of these patients, the reduction time was less than 6 hours.

Conclusions: In our case series, in patients with an AIS grade between B and D, more neurological improvement was observed when the reduction time was less than 6 hours. In AIS grade A patients, improvements were observed in some patients when the reduction time was less than 6 hours. These results provide a target for reduction and transportation times during the acute phase of treatment. Diagnosis and reduction of the dislocation, or transferring the patient to a medical facility that can perform reduction, should be conducted as early as possible.
Relationship between the Timing of Reduction of Cervical Spine Dislocations and Neurological Recovery.

**Fig 1:** The reduction time and neurological change on AIS B-D

- Improvement
- Unchanging
E-Poster #23

Analysis of Cervical Screw Placement Accuracy and Fixation in 137 Patients with Focus on Patients with Cervical Deformity using an Electrical Conductivity Device (ECD)

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Michael Mayer, MD, Bad Wildungen, Germany

Introduction: Cervical pedicle screws (CPS) are progressively more used for reconstruction of the destabilized cervical spine. The use of CPS bears the potential for screw misplacement and neurovascular injury. In particular, distorted and small osseous anatomy can make this challenging. To improve accuracy of CPS insertion the authors started to use a pedicle probe device with local electrical conductivity at the tip (ECD), which provides wing intraosseous real-time feedback (navigation). The purpose of this paper is to report the efficacy and accuracy of using this device for insertion of CPS and to report on the experience, especially with its use in the treatment of cervical deformities (CD).

Methods: Prospective assessment of 137 patients having a posterior fusion including CPS. Demographics, surgical data and complications were recorded. Patients received 18-30mm CPS. In C2, short pedicle screws or pars screws were used for sclerosed pedicles. For C2, preoperative CT-scans were assessed for evidence of bony destruction and/or sclerosed pedicles and the pedicle diameter was measured. Analysis of accuracy on postoperative CT-scans was done as follows (Figure1): Type-I resembles 'ideal & correct' screw placement; Type-II acceptable (<½-screw diameter out, ~2mm); Type-III unacceptable screw with potential for neurovascular injury. During screw-tract preparation, the surgeon documented whether signaling of the ECD indicating a bony breach caused termination of preparation or redirection of the ECD. The number of cases in which a 'close to target screw placement' was possible (Figure2), based on the navigation with the ECD, was recorded and appropriate screw length was assessed on the postoperative CT-scans.

Results: A total of 202 CPS in C2 and 113 CPS in C3-C7 were placed. 51 patients showed fusion at the occipitocervical junction, 6 patients required subaxial surgery, and 80 patients received cervicothoracic surgery. Average age was 59yrs (10-87yrs). 61 patients (45%) had previous cervical surgery. Total surgical time was 245±101min, blood loss was 637±319ml. Diagnoses included AS in 19 patients (14%), rheumatoid arthritis in 32 (23%), neuromuscular deformity in 4 (3%), and 51% had CD. Number of fusion levels was 5.3±4.2. At follow-up of 1 year; no patient had revision surgery for CPS misplacement or a neurovascular deficit. There were no vertebral artery injuries. Analysis of pre-op CT-scans revealed 67 (33%) sclerosed C2-pedicles. Left/right diameter of the C2-pedicle was 5.6±1.7mm/5.4±1.6mm. In 49 screws (24%) 'close to target screw placement’ was successfully performed with appropriate screw length selection. Accuracy of CPS placement was 1.2±0.5 (1-3) for CPS in C2 and 1.4±0.7 (1-3) for CPS in C3-C7. Statistical analysis revealed no significant correlation with evidence of sclerosis or surgery in CD. Screw placement accuracy was significantly related to pedicle diameter (p= 0.004, r=−0.2).

Conclusion: In this series, usage of the ECD was deemed beneficial during manual preparation for pedicle screws particularly in patients with CD. An impassable cortical pedicle isthmus was correctly identified by the ECD allowing use of shorter screws without breaching. In patients with anomalous course of the VA and dysplastic anatomy, ‘close to target screw placement’ enabled safe insertion of the longest screws possible for the individual anatomy. With extension of indications for the ECD, it was shown to be of particular advantage in the use of CD with distortion of anatomical landmarks and morphology.

Please click on the “Disclosure” link for author/participant financial disclosure information.
Analysis of Cervical Screw Placement Accuracy and Fixation in 137 Patients with Focus on Patients with Cervical Deformity using an Electrical Conductivity Device (ECD)

Figure 1. Grading system to assess CPS placement accuracy

Figure 2. Illustration of 'close to target screw placement'

Anatomical parasagittal section of C2 (Fig.2a) reveals a slightly posterior course of the vertebral artery (VA) inside the C2 lateral mass, critically narrowing the path for a C2-pedicle screw. Drawing (Fig.2b) and clinical case example (Fig.2c) illustrate that given the navigation by the electroconductivity device, 'close to target screw placement', with the VA being the target, is possible thus safely maximizing insertion of the longest screw possible.
The Safety and Accuracy of Freehand Pedicle Screw Placement in the Subaxial Cervical Spine: A Series of 60 Consecutive Patients

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Jin Hoon Park, MD, PhD, Gangneung, Korea, Republic of

Introduction: Although the efficacy and safety of freehand screw fixation in thoracic and lumbar vertebrae is proven, reports on this technique of screw insertion in the subaxial cervical spine are lacking. So, this study aimed to assess the safety and accuracy of subaxial cervical pedicle screw (CPS) placement with freehand technique and to report the technical nuances.

Methods: From March 2012 to April 2014, 60 consecutive patients underwent posterior cervical fusion. The diagnoses were trauma (31 patients), degenerative disease (23 patients), discitis/osteomyelitis (two patients), pathologic fracture (three patients), and post-laminoplasty kyphosis (one patient). Preoperative computed tomography (CT) was performed in all patients. We included patients whose outer diameter of the pedicle was greater than 3.0 mm. The standard entry points were modified according to the CT anatomy of each patient. A small pilot hole was fashioned at a predetermined entry point. Then, a 2.5 mm diameter curved pedicle probe was slowly inserted with a medial trajectory into the pedicle. After ball tip probing and tapping, the screw was inserted. If ball tip probing was suggestive of risk to neurovascular structures, conversion to a lateral mass screw was performed. Postoperatively, a CT scan was performed in all patients and the conversion rate from pedicle to lateral mass screw was recorded. The breech rate of pedicle screws was also analyzed.

Results: There were 339 planned pedicle screws. There were 25 incidences (7.4%) of conversion to lateral mass screws. Lateral wall violation was observed in 15 pedicle screws (accuracy rate: 95.2%) on the postoperative CT scan. No medial, superior, and inferior pedicle wall violations were observed. There was no patient who developed symptoms related to vertebral artery.

Conclusions: The most important factors for safe and accurate freehand placement were the planning of the screw entry point using information from the preoperative CT scan, the achievement of an adequate medial angle for screw insertion through the use of a curved and small sized pedicle probe, the ability to detect pedicle breech with a ball tip probe, the proper conversion to a lateral mass screw when a breech is detected, and the ability to properly interpret the intraoperative X-ray image after screw insertion. By following these technical steps and with proper training, this freehand technique for insertion of CPSs may be safe and effective for posterior cervical fusion surgery.
Redefining High-Riding Vertebral Artery from the Perspective of the Trajectory of C2 Pedicle Screw

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Masashi Yamazaki, Ibaraki, Japan

Introduction: Pedicle screw (PS) instrumentation of C2 is widely used and has proved to be effective both biomechanically and clinically. However, the variable C2 anatomy can make instrumentation challenging and prone to potentially severe complications such as vertebral artery (VA) injury. If the course of VA is too medial, posterior or cranial, PS cannot be inserted safely through the isthmus of the pedicle; this condition is referred to as a high-riding VA (HRVA). Therefore, we should pay careful attention to the presence of HRVA preoperatively. However, there is no clear definition of HRVA. The purpose of this study was to redefine HRVA from the perspective of the trajectory of C2 PS.

Methods: Sixty-two patients who underwent posterior cervical fusion that included C2 between January 2009 and January 2014 were enrolled in this study (39 men, 23 women; mean age, 62.1 (19 - 84 years old)). All of the patients underwent preoperative computed tomographic angiography, resulting in total of 124 C2 pedicles analyzed. Using perpendicular plane to the pedicle axis in volume rendering and multiplanar reconstruction, the narrowest portion of the pedicle was identified as pedicle isthmus (Figure 1, 2). The heights of the outer diameter (a) and medullary cavity (b) at the pedicle isthmus, width of the outer diameter (c) and medullary cavity (d) at the pedicle isthmus were measured (Figure 3). C2 PS insertion was regarded not feasible when the height of the medullary cavity of the pedicle isthmus and/or width of the medullary cavity of the pedicle isthmus was 4mm or less.

Results: The average height (a) and width (c) of the outer diameter of pedicle isthmus were 10.2mm (7.0 - 13.3) and 7.9mm (2.3 - 12.9) and the average height (b) and width (d) of medullary cavity were 7.2mm (1.9 - 11.2) and 5.7mm (0.8 - 12.6). Twenty-three pedicles were 4mm or less in width. Among them, 5 pedicles were 4mm or less in both height and width. The pedicles were always concomitant with narrow in width. Therefore those 23 pedicles precluded C2 PS insertion.

Conclusions: The heights of the pedicle isthmus are not limited by vertebral artery groove (VAG) and all the cases with the height of the pedicle isthmus 4mm or less had also pedicle isthmus width 4mm or less. The result suggested that these cases had “narrow pedicle” but not HRVA (Figure 4). C2 PS is feasible in case with VAG in just cranial (Figure 5). The widths of the pedicle isthmus were limited by VAG. Therefore, only when VAG comes to cranial and medial, C2 PS cannot be inserted (Figure 6). Here we propose that HRVA is the condition with the height of the pedicle isthmus more than 4mm and width of 4mm or less.
Redefining High-Riding Vertebral Artery from the Perspective of the Trajectory of C2 Pedicle Screw

Fig. 1

Fig. 2

Fig. 3

Lat. Med.

Fig. 4

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Lat. Med.
Reliability Assessment of a Novel Cervical Deformity Classification System

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Introduction: Despite the complexity of cervical deformity and the significant impact on patient quality of life, there exists no comprehensive classification. An initial novel classification system has been recently designed with a deformity descriptor and 5 modifiers that incorporate sagittal regional and global spino-pelvic alignment and neurological status (Figure). Our objective was to characterize the intra- and inter-observer reliability of this classification.

Methods: A series of 10 cervical deformity cases, broadly representative of the classification system, were selected and sufficient radiographic and clinical history to enable classification were assembled. A panel of deformity surgeons was queried to classify each case twice, with a minimum of 1 intervening week. Inter- and intra-rater reliability measures were based on calculations of Fleiss kappa coefficient values.

Results: Twenty spine deformity surgeons participated in this study. Inter-rater reliability (Fleiss kappa coefficients) for the deformity descriptor rounds 1 and 2 were 0.489 and 0.280, respectively, and mean intrarater reliability was 0.584. For the modifiers, including the SRS-Schwab components, the inter-rater (round 1/round 2) and intra-rater reliabilities (Fleiss kappa coefficients) were: C2-C7 SVA (0.338/0.412, 0.584), horizontal gaze (0.779/0.430, 0.768), TS-CL (0.721/0.567, 0.720), myelopathy (0.602/0.477, 0.746), curve type (0.590/0.433, 0.564), PI-LL (0.554/0.386, 0.826), PT (0.714/0.627, 0.633) and C7-S1 SV A (0.071/0.064, 0.233), respectively. The parameter with the poorest reliability was the C7-S1 SV A, which may have resulted from differences in interpretation of positive and negative measurements.

Conclusion: The proposed classification provides a mechanism to assess cervical deformity within the framework of global spino-pelvic malalignment and clinically relevant parameters. The intra- and inter-observer reliabilities suggest moderate agreement and serve as the basis for subsequent improvement and study of the proposed classification.

Please click on the “Disclosure” link for author/participant financial disclosure information.
Cervical Deformity Classification

**Deformity Descriptor**

- **C**: Primary Sagittal Deformity Apex in Cervical Spine
- **CT**: Primary Sagittal Deformity Apex at Cervico-Thoracic Junction
- **T**: Primary Sagittal Deformity Apex in Thoracic Spine
- **S**: Primary Coronal Deformity (C2-C7 Cobb > 15°)
- **CVJ**: Primary Cranio-Vertebral Junction Deformity

**5 Modifiers**

- **C2-C7 sagittal vertical axis (SVA)**
  - 0: C2-C7 SVA < 4cm
  - 1: C2-C7 SVA 4 to 8cm
  - 2: C2-C7 SVA > 8cm

- **Horizontal Gaze**
  - 0: CBVA < 10°
  - 1: CBVA 10 to 25°
  - 2: CBVA > 25°

- **T1 Slope (TS) Minus Cervical Lordosis (CL)**
  - 0: TS-CL < 15°
  - 1: TS-CL 15 to 20°
  - 2: TS-CL > 20°

- **Myelopathy**
  - 0: mJOA=18 (None)
  - 1: mJOA=15-17 (Mild)
  - 2: mJOA=12-14 (Moderate)
  - 3: mJOA<12 (Severe)

- **SRS-Schwab Classification**
  - **T, L, D, or N**: Curve Type
  - **0, +, or ++**: PI minus LL
  - **0, +, or ++**: Pelvic Tilt
  - **0, +, or ++**: C7-S1 SVA

Please click on the “Disclosure” link for author/participant financial disclosure information.
Full Spine Analysis of Posterior Cervical Decompression and Fusion vs. Laminoplasty Correlated to HRQOL

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Introduction: Cervical mal-alignment, specifically increased C2-C7 plumbline more than 4 cm, has been associated with worse health related quality of life (HRQOL) following posterior cervical decompression/fusion (CDF). Worsening of the C2-C7 plumbline after laminoplasty (CLP) has also been demonstrated but, few studies have directly compared CDF and CLP in terms of regional cervical as well as global spinal alignment and HRQOL. The T1 Slope Minus Cervical Lordosis (TS-CL), the cervical answer to PI-LL, is a marker of cervical sagittal deformity. Novel global angular measures, the Cervico-Thoracic Pelvic Angle (CTPA) and T1 Pelvic Angle (TPA), have been described that define the relative proportion of cervical and thoracolumbar deformity, respectively (Figure1). This study investigates standing cervical and global spinal alignment in CLP vs. CDF. The goals are to identify how cervical deformity may impact alignment of subjacent regions of the spine and rotation of the pelvis in maintaining standing alignment and how these spinopelvic relationships affect HRQOL.

Methods: This is a retrospective analysis of CLP and CDF in which postoperative standing lateral neutral cervical and full spine radiographs were obtained. Regional cervical radiographs were available preoperatively and postoperatively. HRQOL included NDI and mJOA. Established cervical parameters included C2-C7 angle, C2-C7 plumbline, C2-T1 Tilt, C2 Slope, T1 Slope, TS-CL, and the C0-C2 angle. Global alignment parameters and spinopelvic measures included novel measures, the CTPA and TPA (Figure2), and established measures, the sagittal vertical axis (SVA), Pelvic Tilt, Thoracic Kyphosis, and lumbar lordosis. Static radiographic parameters were correlated with HRQOL and group comparisons were made.

Results: 54 patients were included (31 CDF, 22 CLP), with mean age 58.8y. (58% male) and 33.8 months mean follow-up. All patients received full spine radiographs postoperatively and cranial parameters were available in 36 patients. Mean NDI and mJOA were 16.0±12.6 and 14.4±3.0. The mJOA correlated with CBVA (r=-0.56, p=0.024), CTPA (r=-0.353, p=0.02), TS-CL (r=-0.3163, p=0.04), and C2 Slope (r=-0.321, p=0.04). There were no differences in age, sex, follow up time or mJOA between CLP and CDF. CDF had worse regional cervical alignment by TS-CL (26.7 vs. 15.7, p<0.01), C2-T3 plumbline (81.8mm vs. 66.1mm, p=0.04), and C2 slope (26.7° vs. 17.7°, p=0.03) and worse NDI (21.5 vs. 9.56, p<0.01) than CLP. CDF had more thoracic kyphosis (-38.6° vs. -29.7°, p=0.02) and worse global alignment by TPA (18.4° vs. 12.5°, p=0.04).

Conclusions: Cervical sagittal deformity, as identified by larger CTPA and larger TS-CL, correlated with worse mJOA regardless of surgical technique. Lower mJOA scores were also associated with larger CBVA. CDF patients had worse postoperative cervical sagittal alignment by TS-CL and C2-T3 plumbline and worse NDI compared with CLP. Cervical sagittal alignment is an important determinant of disability in patients following CDF and CLP.
Full Spine Analysis of Posterior Cervical Decompression and Fusion vs. Laminoplasty Correlated to HRQOL

Figure 1: Full Body EOS Radiographic Analysis of a Laminoplasty (CLP) patient. CTPA is a global angular measure of cervical sagittal alignment that does not vary with pelvic retroversion. CTPA is the angle of a line from center of C2 to the femoral heads (FH) and a line from the FH to the center of T1. TPA is a global angular measure of thoracolumbar deformity and an analog of SVA. TPA is the angle of a line from center of T1 to the FH and a line from the FH to center of the S1 endplate. (CL=Cervical Lordosis, T1S=T1 Slope, C2-C7 SVA=C2-C7 Plumbline, CTPA=Cervico-Thoracic Pelvic Angle)

Figure 2: Full Body EOS Radiographic Analysis of a Posterior Cervical Decompression and Fusion (CDF) patient. The CDF group had worse cervical sagittal alignment by C2-T3 plumbline and T5-CL. (CL=Cervical Lordosis, T1S=T1 Slope, C2-C7 SVA=C2-C7 Plumbline, CTPA=Cervico-Thoracic Pelvic Angle)
Modified K Line in MRI is a Powerful Tool to Predict Clinical Outcomes in Patients with Non-Lordotic Alignment after Laminoplasty for a Treatment of Cervical Spondylotic Myelopathy

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Introduction: We have previously reported the modified K-line (mK-line), which was defined as a line connecting the midpoints of the spinal cord at C2 and C7 on T1 weighted sagittal MRI, can predict postoperative insufficient decompression in patients with cervical spondylotic myelopathy (CSM) who underwent laminoplasty. Although it is very important for spine surgeons to predict postoperative clinical outcomes, particularly in patients with cervical malalignment such as kyphotic or sigmoid alignment, before selecting a surgical procedure for the treatment of CSM, few studies thus far has assessed a relationship between postoperative outcomes and anticipated spinal cord shifting quantified on MRI. The purpose of this study is to investigate whether mK-line can be a powerful tool to predict postoperative clinical outcomes in patients with non-lordotic alignment.

Methods: Sixty-one consecutive patients who underwent laminoplasty for the treatment of CSM between 2000 and 2011 at our hospital were retrospectively reviewed. Cervical sagittal alignment, as classified by Kamata and Matsumoto et al., was assessed based on lateral neutral X-ray, and then 23 patients whose cervical alignment was not lordosis were enrolled. An interval between the preoperative mK-line and anterior structure of the spinal canal at each segment of C3 to C6 levels (INTn; n=3-6, Figure 1) was measured on sagittal T1-weighted MRI. The sum of the INTn (INTsum=INT3+INT4+INT5+INT6) was then calculated as anticipated degree of posterior cord shifting. In addition, we defined INTmin as the minimum interval among INTn in each patient (Figure 1). The Japanese Orthopedic Association (JOA) scoring system and recovery rate of the JOA score for cervical myelopathy was evaluated as clinical outcomes.

Results: The mean age was 62.5 (± 9.1) years. The mean JOA score was 9.2 (± 3.0) points before surgery and 12.5 (± 2.8) points at final visit, respectively, yielding that mean recovery rate of JOA score was 42.1 (± 23.5) %. The number of patients with non-lordotic alignment was 8 for sigmoid, 7 for straight, 5 for kyphosis, and 3 patients for reversed-sigmoid alignment, respectively. Cervical alignment on MRI was closely associated with that on lateral neutral X-ray in each patient. A linear regression model demonstrated a significant correlation between INTmin and recovery rate of JOA score in these patients (y= 6.347x+22.36, y=the JOA score recovery rate, x=INTmin, r2=0. 25, p=0.018, Figure 2), whereas INTsum was not associated with recovery rate. From this analysis, recovery rate greater than 50% requires INTmin of > 4.35mm preoperatively.

Conclusion: The current study revealed that the preoperative mK-line can predict clinical outcomes in patients with non-lordotic alignment following laminoplasty by the measurement of INTmin, rather than that of INTsum. These results indicate that it might be important to recognize the apex of the kyphosis or anterior compression in presence of malalignment as a risk factor for lack of posterior cord shifting after laminoplasty, and that anterior decompression with fixation or posterior decompression with fusion should be applied to such cases.
Results of a Prospective, Multicentre, AOSpine International Study in 479 Patients on the Surgical Management of Cervical Spondylotic Myelopathy

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Introduction: Cervical spondylotic myelopathy (CSM) is a degenerative condition common in those over the age of 50 from all racial or ethnic backgrounds. Surgery to treat CSM has been increasingly shown to be effective, including in a recent the AOSpine North America study. However, this study was an exclusively North American and such functional improvement after CSM surgery in a global setting has not been studied. Here, we present results of a prospective, international multicentre study on the surgical management of CSM.

Methods: This study was multicenter, prospective observational representing the largest study on CSM to date. Between 2007 and 2011, 479 patients with CSM were prospectively enrolled in a 16 sites based in Asia Pacific (AP) n=150, Europe (E) n=126, Latin America (LA) n= 80 and North America (NA) n=123. Demographic information, surgical technique and functional outcome parameters including the modified Japanese Orthopaedic Assessment scale (mJOA), Nurick Score, Neck Disability Index (NDI), Short Form (SF36v2) were collected.

Results: The study cohort consisted of 310 males and 169 females with a mean age of 56.4 ± 11.91 years. The majority of patients had anterior surgery (57.7%). Consistently, at 24 months follow up there was significant improvements on all outcome measures (mJOA, Nurick, NDI and SF36v2) (P < 0.001). The mean mJOA score improved from 12.50 (95% C.I., 12.24--12.76) to 14.90 (95%C.I., 14.64-15.16); the NDI improved from 36.38 (95%C.I., 34.33-38.43) preoperatively to 23.20 (95%C.I., 21.24-25.15); and the SF36v2 PCS and SF36v2 MCS improved from 34.28 (95%C.I., 33.46-35.10) to 40.76 (95%C.I., 39.71-41.81) and 39.45 (95%C.I., 38.25-40.64) to 46.24 (95%C.I., 44.94-47.55), respectively (p<0.0001). Of the cohort 22.34% of patients experienced complications, most of which were transient. Fourteen (14) patients had new postoperative neurological complications in the form of radiculomyelopathy.

Conclusions: This large multicenter prospective study has demonstrated that Surgery for degenerative CSM is effective at improving function in patients from around the globe despite the heterogeneity of the patient population, variations in treatment approaches and the diversity of global healthcare systems. It also shows that surgery to decompress the cervical spinal cord is safe with low perioperative morbidity.
Results of a Prospective, Multicentre, AOSpine International Study in 479 Patients on the Surgical Management of Cervical Spondylotic Myelopathy

Table 1. Patient outcomes at 12 and 24 months

P-values are given for comparisons between preoperative and 12- or 24-month postoperative scores.

Values are means and 95% confidence intervals for the means.

mJOA: modified Japanese Orthopaedic Association; SF36v2: Short Form 36 Version 2.

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Preoperative</th>
<th>12 months</th>
<th>24 months</th>
<th>P-value</th>
</tr>
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<tbody>
<tr>
<td><strong>Functional Status</strong></td>
<td></td>
<td></td>
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<tr>
<td>Nurick Score</td>
<td>3.30 (3.19, 3.41)</td>
<td>2.03 (1.88, 2.18)</td>
<td>1.96 (1.80, 2.13)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>mJOA</td>
<td>12.50 (12.24, 12.76)</td>
<td>14.86 (14.60, 15.12)</td>
<td>14.90 (14.64, 15.16)</td>
<td>&lt;.0001</td>
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<tr>
<td><strong>Quality of life</strong></td>
<td></td>
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<tr>
<td>Neck Disability Index</td>
<td>36.38 (34.33, 38.43)</td>
<td>23.44 (21.57, 25.32)</td>
<td>23.20 (21.24, 25.15)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>SF36v2 Physical Functioning</td>
<td>31.56 (30.46, 32.65)</td>
<td>39.32 (38.13, 40.51)</td>
<td>38.86 (37.61, 40.10)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>SF36v2 Mental Health Score</td>
<td>39.45 (38.25, 40.64)</td>
<td>46.22 (44.96, 47.49)</td>
<td>46.24 (44.94, 47.55)</td>
<td>&lt;.0001</td>
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The Loss of Manual Dexterity and Related Upper Limb Disability in Cervical Spondylotic Myelopathy (CSM): Defining the Role of Upper Limb Assessment

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**Introduction:** Upper limb disability has significant implications on everyday function, and is critical to maintaining independence for people. The loss of manual dexterity is one consequence of cervical spondylotic myelopathy (CSM) that is a significant factor in upper limb disability and remains understudied. Deficits related to upper limb dysfunction are typically assessed subjectively by the clinician. Use of quantitative methods for upper limb assessment in CSM is limited. This study defines upper limb impairment as neurological deficit, characterized by sensory, motor and complex hand function tasks. Upper limb disability is defined as the inability to perform activities of daily living (ADLs) and characterized by the QuickDASH. The purpose of this study was to explore the relationships between impairment and disability; and determine the contributions of impairment to disability. The objectives of this work were to: 1) Characterize specific hand and upper limb impairments related to CSM and severity of disease; and 2) Define the optimal method for sensitive measurement of upper limb and hand impairment/function.

**Methods:** A prospective observational cross-sectional study enrolling 160 patients at time of CSM diagnosis was conducted. Baseline assessments were performed to quantify upper limb impairment and disability. The modified Japanese Orthopaedic Assessment (mJOA) scale was used to stratify the sample. Modified GRASSP was used to quantify sensation, strength, prehension and manual dexterity. Myelopathy Disability Index (MDI) and Quick Disability of the Arm Shoulder and Hand (QuickDASH) were used to quantify disability (global & upper limb). Analysis: T-tests between severity groups, linear regression and Pearson correlation coefficients were calculated for all variables within severity subgroups.

**Results:** All measures defined three distinct groupings of patients (mild moderate severe), however, dissimilar to the mJOA groupings. Table 1 defines the sample according to severity of CSM along with all measures administered. Linear models predicting QuickDASH scores in the mild patient group showed strength, sensation and prehension/manual dexterity as significant predictors of disability (p<0.05). MANOVA revealed a significant multi-variate main effect (F(2,7.0206), P<.001), and follow up significant uni-variate effects for strength and QuickDASH for severity groups.

**Conclusions:** Sensitive quantitative assessments of sensation, strength, prehension and manual dexterity define in greater detail the presence of impairment related to CSM, specifically when the symptoms are mild. Furthermore, sensitive assessments quantify and define the involvement of neurological deficit on upper limb disability. These findings are useful for early detection of the disease, detection of subtle changes and to determine the true impact of mild impairments on an individual’s life. The clinical application of these assessments will assist in clinical decision-making regarding management and establishing outcome after intervention.

Please click on the “Disclosure” link for author/participant financial disclosure information.
Maintenance of Overall Success in Patients Treated with Cervical Disc Arthroplasty and ACDF at One or Two Levels: Five-Year Results from an Investigational Device Exemption Trial

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Introduction: Overall success is a composite metric used in FDA IDE clinical trials to gauge the safety and effectiveness of an investigational treatment. Compared to ACDF, cervical disc arthroplasty (CDA) has demonstrated non-inferior overall success rates at one level of treatment and superior overall success rate at two levels of treatment at two-year follow-up. Here, we follow patients with overall success at two-years to five-years in order to determine if successful treatment with CDA or ACDF maintains similar efficacy at 5 years.

Methods: The study was a prospective, randomized, multi-center, concurrently controlled trial conducted as an FDA IDE clinical trial at 24 sites in the USA. Patients were randomized 2:1 to the investigational or control group. The investigational group received one or two-level CDA with the Mobi-C® Cervical Disc Prostheses and the control group received one or two-level ACDF with allograft bone and anterior plate. The 1-level arm included 245 patients (CDA: 164, ACDF: 81) and the 2-level arm included 330 patients (CDA: 225, ACDF: 105). Patients were evaluated pre-operatively and post-operatively at 6 weeks, 3, 6, 12, 18, 24, 36, 48, and 60 months. Outcome measures included NDI, VAS neck and arm pain, SF-12 MCS/PCS patient satisfaction/recommendation. CDA and ACDF patients achieving overall success 2 years were followed to 5-years and their outcomes compared.

Results: At the 2-years, 115 (73.72%) one-level TDR patients and 49 (65.33%) one-level ACDF patients achieved overall success. Of this subset of patients, 84.69% of CDA and 81.08% of ACDF patients maintained overall success at 60 months. For one-level patients demonstrating success at 24 months, the CDA group experienced similar changes in NDI and VAS neck/arm pain scores, SF-12 MCS/PCS scores, and patient satisfaction rates compared to their ACDF counterparts at 60 months. At 2 years follow-up, 154 (69.68%) TDR patients and 37 (37.37%) ACDF patients met the overall success criteria. Of two-level patients that had previously demonstrated overall success at 24 months, 82.84% of TDR patients and 64.52% of ACDF patients maintained success at 5-years (p=0.04577). From 24 to 60 months, CDA patients demonstrated significantly less increase in NDI (CDA:2.01 vs. ACDF:7.19, p=0.0293) and VAS neck pain (CDA: 4.84 vs. 14.5, p=0.0271) scores compared to ACDF patients. From 24 to 60 months, SF-12 PCS significantly decreased for ACDF patients while no significant decrease was seen in CDA patients (TDR:-0.44 vs. ACDF: -4.47, p=0.0224). Patient satisfaction at 60 months was significantly higher for the CDA success group (CDA:100.00% vs. ACDF:90.9%, p=0.0059). The percent of patients that would recommend their treatment to a friend was also statistically higher for CDA success patients at 60 months than ACDF success patients (CDA: 98.6% vs. ACDF: 87.9%, p=0.0117).

Conclusions: For one-level CDA and ACDF patients achieving overall success at 2 years, no differences in treatment effectiveness were observed at 5 years. For two-level patients with overall success status at 2 years, treatment with TDR demonstrates greater efficacy in regards to NDI scores, VAS neck pain scores, SF-12 PCS scores, and patient satisfaction rates compared to treatment with ACDF at 60 months follow-up.
The Anatomical Footprint of the C1 Pedicle Relative to the Lateral Mass as a Guide for C1 Lateral Mass Fixation

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Introduction: C1 lateral mass (LM) fixation requires intimate knowledge of C1 anatomy. It is often challenging to visualize the entire medial-lateral extent of the LM secondary to the C2 dorsal root ganglion, venous plexus, and dural sac. The C1 pedicle connects the posterior arch to the LM and can be used as an anatomical guide to the center of the C1 LM. The purpose of the study is to determine the relationship of the anatomical footprint of the C1 pedicle to the LM to help guide C1 screw placement.

Methods: 21 pairs (42 total LM) of fresh frozen C1 cadaveric spines were freed of soft tissue and the following anatomical measurements were made: Pedicle width, pedicle height, LM width, LM depth, amount of LM medial to the medial pedicle, maximum/minimum height of LM, amount of LM inferior to the inferior C1 pedicle, and the distance from the midline of the C1 arch to the medial pedicle. Based on these measurements, the following calculations were made: Percentage of LM medial and lateral to the medial pedicle and the distance of the center of the LM to the medial pedicle.

Results: The lateral wall of the C1 pedicle is 1.1 mm +/- 1.9 mm medial to the lateral border of the lateral mass. The average pedicle width is 9.0 +/- 1.1 mm, and the average pedicle height is 5.0 mm +/- 1.1 mm. The average LM width and depth are 17 +/- 1.6 mm and 17.2 +/- 1.6 mm respectively. There is 6.9 +/- 1.5 mm of LM medial to the inferior C1 pedicle, and the distance from the midline of the C1 arch to the medial pedicle. The C1 pedicle footprint occupies 59 +/- 9% of the LM resulting in 41 +/- 9% of the LM being medial to the medial pedicle. The distance from the midline of the C1 lamina to the medial pedicle is 13.5 +/- 2 mm. The center of the LM is 1.6 +/- 1.5 mm lateral to the medial pedicle. The concave nature of the C1 LM led to a maximum LM height of 20.6 +/- 2.4 mm and a minimum of 6.3 +/- 1.1 mm. In addition, 3.5 +/- 0.06 mm of the LM is inferior to the inferior aspect of the pedicle.

Conclusions: The C1 pedicle footprint occupies approximately 59% of the lateral aspect of the LM. The location of the center of the lateral mass is 1.6 mm lateral to the medial wall of the C1 pedicle. The medial wall of the C1 pedicle can be used as a guideline for locating the center of the LM for screw fixation and is located 13.5 mm from the midline of the C1 arch.
**Bowstring Effect of Longus Colli Secondary to Severe Spondylosis of Left Luschka Joint: A Potential Factor Contribute to Cervical Angina**

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**Introduction:** Cervical angina (CA) is defined as a paroxysmal precordialgia that resembles true cardiac angina but originating from a disorder of the cervical spine. Chest pain of cervical nerve root origin had been published in 1937. However, the mechanisms responsible for the chest pain in cervical spondylosis have not been clearly established till now. The purpose of this study was to evaluate the spondylotic hypertrophy of left luschka joint and atrophy of ipsilateral longus colli (LC) in CA patients. Our hypothesis is that bowstringed cervical sympathetic chain near the left LC was involved in the pathogenesis of CA.

**Methods:** Between June 2008 and December 2012, a total of 432 patients underwent anterior cervical surgeries because of cervical spondylosis. Eighteen patients had presented with CA. After exclude the true angina pectoris through electrocardiogram and/or coronary angiography, these 18 patients (male 7, female 11) were included into the retrospective matched cohort analysis for study group (Group 1). The control group (Group 2) was matched to group 1 in a 1:1 fashion using matching criteria of age, gender, weight, segmentation, number of levels, signal intensity on T2-weighted MRI, and comorbidities. Functional parameters (JOA, NDI, VAS scores), and radiologic parameters (cervical lordosis, ROM, area of Luschka joint’s osteophyte, area of LC) were evaluated.

**Results:** The most affected levels were C5/6 level in 10 cases, and C6/7 level in 8 cases. The mean area of left and right Luschka joint’s osteophyte (LJO) in group 1 (11.2±4.2 mm² and 9.6±3.7 mm²) were significantly higher than that in group 2 (3.5±0.6 mm² and 3.3±0.8 mm²). The mean area of left and right LC in group 1 (51.5±14.2 mm² and 58.3±13.7 mm²) were significantly lower than that in group 2 (77.9±17.2 mm² and 79.4±18.7 mm²). Area of left LJO was higher than in right, and area of left LC was lower than in right in group 1, but neither was significant. All the patients accepted ACDF or ACCF. Raised LC secondary to LJO was found intraoperative in group 1, especially in the left. Removal of the osteophytes, terminate the bowstring tension of LC (Figure 1). Chest pain alleviated in all patients after surgeries. The JOA scores significantly increased from 9.4±1.8 to 12.3±2.0 in group 1 (P<0.05), from 8.3±1.4 to 14.0±1.2 in group 2 (P<0.05), respectively. The NDI scores significantly decreased from 34.2 ± 3.8 to 23.6 ± 2.6 in group 1 (P<0.05), from 36.4 ± 3.6 to 17.2 ± 2.3 in group 2 (P<0.05), respectively. The improvement rates of JOA and NDI were significantly higher in group 2.

**Conclusion:** Evaluation the area of left LJO and ipsilateral LC could be helpful in diagnosing CA. Severe osteophyte formation in Luschka joint, followed by LC atrophy, and bowstringed sympathetic chain may be a potential factor contribute to CA. Anterior cervical surgical intervention could relieve the chest pain. Disability severity scores of cervical spondylosis such as NDI and JOA could not reflect true situation of CA.

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**Fig. 1. A, osteophyte in left Luschka joint; B, removal of the osteophytes and terminate the bowstring tension of longus colli.**
Pre-Operative Opioid Usage and Anxiety are Associated with Increased Non-Surgeon Visits for Spine-Related Pain within Postoperative Global Period

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Introduction: Many spine surgeons would assume they are the only physicians immediately directing a patient’s spine care during the postoperative period. However, it remains unknown if this is indeed true, especially given the multi-specialty approach of spine care and potential for ‘doctor-shopping.’ The purpose of this study is to assess the frequency and factors associated with spine related visits to physicians other than their surgeon (or PA/NP/other staff) within the 90-day global period following elective spine surgery.

Materials/Methods: 1116 consecutive patients undergoing lumbar, thoracolumbar, or cervical spine surgery for a structural lesion over a 24-month period were included. Patient demographics and surgery characteristics were prospectively recorded. Self-reported preoperative narcotic consumption was obtained at the initial preoperative visit and converted to daily morphine equivalent amounts (MEA). Preoperative Zung Depression Scale (ZDS) and Modified Somatic Perception Questionnaire (MSPQ) scores were also obtained at the initial preoperative visit and recorded as measures of depression and anxiety, respectively. Linear regression analysis for non-surgeon visits during global period included age, gender, American Society of Anesthesiologists (ASA) scale, preoperative MEA demand, type of surgery, primary vs. revision surgery, preoperative ZDS and MSPQ scores, and presence of surgical complication as covariates.

Results: 13.7% of patients visited a physician other than their surgeon for spine-related pain or discomfort during the first 90 days post-operatively. For these patients, the average number of visits was 1.9±1.8 (range: 1-14). In multivariate regression analysis, increased preoperative narcotic use was most significantly associated with non-surgeon visits (p=0.0002). Increased preoperative anxiety scores (MSPQ) were also significantly associated with non-surgeon visits (p=0.0008).

Conclusions: This study found a substantial number of patients visiting physicians other than their surgeon for spine-related problems during the postoperative global period, with the amount of preoperative narcotic use and level of anxiety directly associated with such visits. Surgeons should remain aware of this practice, not only for duplicate narcotic prescriptions, but also more importantly, for the potential for advised deviation from a surgeon’s post-operative care protocol.

Please click on the “Disclosure” link for author/participant financial disclosure information.
Non-Operative Treatment Modalities Prior to Cervical Surgery Affects Patient Outcomes: An Analysis of 1818 Patients

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Kristen E. Radcliff, MD, Egg Harbor Township, New Jersey
Alexander R. Vaccaro, MD, Philadelphia, Pennsylvania

Introduction: Optimal treatment algorithms have been extensively researched, particularly in the setting of a changing healthcare insurance system focused on efficient patient care. The effect of non-operative treatment modalities prior to surgery on patient outcomes in the cervical population remains unknown. The purpose of this study was to investigate if non-operative treatment modalities prior to surgery effect operative data, patient reported outcomes and the rates of complications.

Methods: A retrospective review of a prospectively-collected multi-center database was performed. Inclusion criteria were patients with cervical pathology requiring 1-2 levels of surgical correction and less than or equal to Grade 1 Spondylolisthesis. Data collected included baseline patient demographics, comorbidities, and non-operative treatment modalities. Patients were stratified into no pre-treatment (NoT) versus pre-treatment (PrT) if any of the following modalities were used pre-operatively: analgesics, bed rest, chiropracty, collar restraint, muscle relaxants, narcotics, NSAIDs, pain management, physical therapy, epidural steroid injections, oral steroids, and traction. A sub-analysis was performed on patients who utilized epidural steroid injections, physical therapy, and narcotics prior to surgery. Primary outcomes measures were the changes in health-related quality of life (HRQOL) scores (SF-36 and NDI) from baseline to two years post-operatively, operative data, and complication rates.

Results: A total of 1818 patients (757 NoT vs. 1061 PrT) were included. The most common pre-treatment included Narcotics (36%) physical therapy (35%), and NSAIDs (35%). (Tab 1) PrT patients were younger (52.3 vs. 50.6 years, p<0.01) and had lower rates of previous cervical surgeries (21.7 vs. 13.2%, p<0.01). No difference in patient baseline demographic characteristics existed between groups in terms of BMI, and smoking status. PrT had higher baseline SF36 PCS scores (33.2 vs. 35.8, p<0.01), however no difference existed in terms of NDI and SF36 MCS. PrT had shorter length of surgery (135 vs. 122min, p<0.01) and hospitalization (49 vs. 37hr, p<0.01), and less rate of CSF fluid leak (1.4 vs. 0.2%, p<0.01). However, no difference existed in overall complication rate and estimated blood loss. At 2 years PrT has significant higher SF36 PCS (36.6 vs. 39.1, p<0.01) and MCS (40.2 vs. 42.7, p=0.03) scores, however no difference was observed in NDI scores. No difference in mean decrease of HRQL scores was observed. Sub-analysis of individual treatments revealed epidural injections was associated with a mean decrease in SF36 MCS score (-2.54, p=0.042). Neither physical therapy nor narcotic use was associated with a mean decrease in scores at 2 years.

Conclusion: Effectively managing patients prior to surgery for cervical pathology is essential to optimize patient outcomes. Non-operative treatment modalities prior to surgery were associated with shorter length of surgery and hospitalizations, less CSF fluid leak complications, and improved SF36 scores at 2 years. Interestingly, epidural steroid injections were associated with improved SF36 MCS scores, while the most common treatment modalities (physical therapy and narcotic use) were not associated with improved HRQL scores. This study’s conclusions are limited by the differences in baseline characteristics between the two groups. However, the findings suggest that non-operative treatment modalities prior to surgery may help improve patient outcomes.
Non-Operative Treatment Modalities Prior to Cervical Surgery Affects Patient Outcomes: An Analysis of 1818 Patients

<table>
<thead>
<tr>
<th>Treatment Modality</th>
<th>Number of Patients</th>
<th>Percent of Patient</th>
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</thead>
<tbody>
<tr>
<td>Analgesics</td>
<td>600</td>
<td>33.0%</td>
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<tr>
<td>Bed Rest</td>
<td>288</td>
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<tr>
<td>Chemonucleolysis</td>
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<td>0.2%</td>
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<tr>
<td>Chiropractic</td>
<td>194</td>
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<tr>
<td>Collar</td>
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</tr>
<tr>
<td>Muscle Relaxants</td>
<td>506</td>
<td>27.8%</td>
</tr>
<tr>
<td>Narcotics</td>
<td>669</td>
<td>36.8%</td>
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<tr>
<td>NSAIDS</td>
<td>631</td>
<td>34.7%</td>
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<tr>
<td>Pain management</td>
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<tr>
<td>Percutaneous Discectomy</td>
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<td>Steroid Injections</td>
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<tr>
<td>Traction</td>
<td>123</td>
<td>6.8%</td>
</tr>
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</table>

Table 1. Number and percentage of patients who utilized pre-operative treatment modalities prior to cervical surgery.
Objective: Traumatic spinal cord injury (tSCI) is often treated surgically; however there is no consensus on indications and timing. Central cord syndrome (CCS) is a clinical diagnosis based on the ASIA Injury Scale (AIS) being C or D, and an upper extremity motor score (UEMS) being ≥5 points lower than the lower extremity motor score (LEMS). There is little consensus among clinicians on how best to treat patients with CCS. We aimed to determine any surgical practice or outcome differences in treatment of CCS patients with AIS C vs. D.

Design/Method: tSCI patients with complete records from the Rick Hansen Spinal Cord Injury Registry (RHSCIR), prospectively recruited from 2004-2013 from 18 acute care participating centres across Canada were studied. Those with AIS C/D and UEMS<LEMS of 5 or more points were classified as CCS. Data on the patient (e.g. age, ethnicity, neurology), treatment (surgery yes/no, time to surgery), and outcome (change in motor score and Functional Independence Measure (FIM)) were compared using chi-squared tests.

Results: 525 participants had complete data and CCS; in those with surgery data available (n=471), 75.9% had surgery (entire sample surgery rate was 86.8%). In participants with CCS, there was no difference between rates of surgery between those with AIS C vs. D, but AIS C patients had a shorter mean time from injury to surgery (81.4h vs. 109.0h, p=0.0051), a significantly larger change in motor score (38.3 vs. 9.6 points, p<0.0001), and a significantly larger change in FIM (30.1 vs. 14.9 points, p<0.0001) than AIS D patients.

Conclusion: There is no difference in surgical rates for CCS patients with AIS C/D at admission, however there is an association that favours a role for early surgical intervention. Surgeons should consider surgical intervention for AIS C patients presenting with CCS.

Support: Rick Hansen Institute, Health Canada
Surgical Training Using Three-Dimensional Simulation in Placement of Cervical Lateral Mass Screws: A Blinded Randomized Control Trial

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Introduction: The skills and knowledge that residents have to master has increased, yet the amount of hours that residents are allowed to work has been reduced. There is a strong need to improve training techniques to compensate for these changes. One approach is to use simulation-training methods to shorten the learning curve for surgeons in training. The objective of this study is to analyze the effect of surgical training using three-dimensional (3D) simulation on placement of lateral mass screws in the cervical spine on either cadavers or sawbones. The hypothesis is that resident training with (3D) simulation on placement of lateral mass screws in the cervical spine with both cadavers and saw bones will improve accuracy.

Materials/Methods: The study design is a blinded randomized control study. Fifteen orthopaedic residents post-graduate year (PGY) 1-6 were asked to simulate Magerl lateral mass screw trajectories from C3-7 on cadavers using a navigated drill guide but with no feedback as to the actual trajectory within bone (Baseline1). This was repeated to determine baseline accuracy (Baseline2). They were then randomized into three groups: Group 1, Control, did not receive any training, while Groups 2 and 3 received 3D navigational feedback as to the intended drill trajectory on Sawbones and Cadavers, respectively. All three groups then performed final simulated drilling (Final Test). All 3D images were de-identified and reviewed by a blinded single fellowship trained orthopaedic spine surgeon. Each image/screw was measured for starting site, caudad/cephalad angle, and medial/lateral angle to determine trajectory accuracy.

Results: The aggregate mean difference from a perfect screw was compiled for each session for each group. A negative difference shows improvement, while a positive difference shows regression. The difference between FinalTest and Baseline1 in the Control group was 2.4, suggesting regression. In contrast, the differences for group Sawbones was -8.2 and for group Cadaver was -7.2, suggesting improvement. When comparing the Sawbones and Cadaver groups to the Control group, the difference was statistically significant (p<.0001).

Conclusions: Training with 3D navigation significantly improved the ability of orthopaedic residents to properly drill simulated lateral mass screws. As such, training with 3D navigation may be a useful adjunct in resident surgical education.
Surgical Training Using Three-Dimensional Simulation in Placement of Cervical Lateral Mass Screws: A Blinded Randomized Control Trial
A New Skull Clamp Positioning System for Posterior Cervical Surgery: Clinical Impact on Cervical Sagittal Alignment

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Introduction: The success or failure of posterior cervical surgery is largely dependent on the positioning technique, because changes of the head-neck position of the patient during surgery is greatly influenced by the skill of the surgeon. The aim of this study is to analyze the utility of a novel skull clamp positioning system for quantitative cervical sagittal alignment during posterior cervical surgery.

Materials: This study included 21 male and 10 female patients (mean age, 68.6 years; range, 56-87 years) with cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament of the cervical spine who underwent laminoplasty using our new skull clamp positioning system.

Methods: The positioning system has a scale to adjust the head-neck position to achieve the intended cervical sagittal alignment (Figure 1). Before surgery, the patient was placed in the prone position in accordance with preplanned head-neck sagittal alignment (scale reading, 0°; position A). During surgery, the head was rotated sagittally and the head-neck position was changed to the “military tuck position” using our device to widen the interlaminar space (scale reading, 30°; position B). After completing the decompression procedure, the head was rotated back to the initial preplanned position again (scale reading, 0°; position C) (Figure 2). During this position change, the scale was useful in determining accurate positions of the patient. The scale reads from -15° to 35°. In the present study, we rotated the head of the patient sagittally from 0° to 30°. The C0-C1, C1-C2, C2-C7, and C0-C7 angles were measured on lateral radiographs taken at positions A, B, and C, respectively. The cervical range of motion from position A to B (dC0-C1, dC1-C2, dC2-C7, and dC0-C7) was calculated and differences between each time point were compared using the paired t-test. A two-tailed probability (p) value of <0.05 was considered statistically significant.

Results: Our proposed positioning system allowed us to obtain adequate, quantitative cervical sagittal alignment during posterior cervical surgery. The cervical range of motion for the C0-C7 angle (position A to B) was approximately 27° with a ratio of 1:1:1 for dC0-C1: dC1-C2: dC2-C7. There were no clinically significant differences observed between pre- and postoperative angles for C1-C2 and C2-C7 (Figure 1).

Conclusions: Sagittal neck position was quantitatively changed during posterior cervical surgery using a new skull clamp positioning system, enabling adequate final cervical sagittal alignment identical to the preplanned neck position.
A New Skull Clamp Positioning System for Posterior Cervical Surgery: Clinical Impact on Cervical Sagittal Alignment

Fig. 1  The head-neck positioning device
(a) The adaptor to lock skull tong
(b) The handle to fix the scale
(c) The scale

Skull tong with pin
Vest

Fig. 2  Position

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial prone position (just before surgery)</td>
<td>O</td>
<td>C7</td>
<td></td>
</tr>
<tr>
<td>Military tuck position (during surgery)</td>
<td>0°</td>
<td>30°</td>
<td></td>
</tr>
<tr>
<td>Final position (just after surgery)</td>
<td>0°</td>
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Please click on the "Disclosure" link for author/participant financial disclosure information.
Effect of rhBMP-2 on Lung Cancer Spine Metastasis in Rodents

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Introduction: Lung cancer is the second most prevalent cancer, and spinal metastases are found in 30-90% of patients with death attributed to cancer. Due to bony destruction caused by cervical metastases, surgical intervention is often required to restore spinal alignment and stability. Although highly efficacious for augmenting fusion, the use of rhBMP-2 in patients with a history of cancer is contraindicated due to the controversial question of tumor propagation. While some research suggests that BMP-2 may possess tumorigenic effects, other studies provide evidence that it may actually inhibit tumorigenesis. Current literature provides no consensus on the clinical effects of BMP on metastasis, especially for lung cancer. Direct intraosseous injection of cancer cells into the vertebral body allows for the opportunity to quantify the effects of a specific bone metastasis without interference from other metastases.

Methods: Forty-two athymic rats underwent transperitoneal exposure and injection of 5x10^4 luciferase-labeled A549 lung adenocarcinoma cells into the L5 vertebral body. Cells were pre-treated with vehicle control (Group A, n=17) or with 100ng/ml rhBMP-2 (Group B, n=25) for 3 days prior to implantation. At 4 weeks post implantation, in vivo bioluminescent imaging (BLI) was performed with the IVIS Spectrum Imaging system 10 minutes after intraperitoneal injection of 300mg/kg of Luciferin. Average radiance of signal was quantitated utilizing Living Image® software. Plain anteroposterior radiographs and microCT imaging were employed to establish and quantitate osteolysis at the 4-week time point. Histological analysis was also performed to further characterize pathologic changes in the vertebral body.

Results: Ten post-operative deaths resulted in 32 animals surviving to 4 weeks (n=14 Group A, n=18 Group B). At 4 weeks post-implantation, BLI showed focal signal in the L5 vertebral body in 13/14 animals in Group A and 16/18 in Group B. Average tumor burden as determined by BLI radiance measurement was 7.43x10^3 p/s/cm^2/sr (Group A) and 1.11x10^4 p/s/cm^2/sr (Group B) (Figure 1a). Radiographs and microCT demonstrated osteolysis in 100% of the 29 animals that showed focal signal on BLI. MicroCT quantification demonstrated significant bone loss in both groups compared to age-matched controls but no difference between the study groups (Figure 1b). Histological analysis also demonstrated tumor invasion in the L5 vertebral body as expected.

Conclusion: These findings provide a reliable in vivo model to study isolated spinal metastases from primary lung cancer. Additionally, the data support the notion that in vitro exposure to rhBMP-2 does not promote the growth and development of A549 lung cancer spine lesions. Subsequent exploitation of this model in which BMP is administered in a posterolateral fusion setting after the establishment of the cancer lesion will provide an even more clinically relevant scenario that will further develop the conclusions drawn from the current study.
Effect of rhBMP-2 on Lung Cancer Spine Metastasis in Rodents

Fig 1. (a) Average radiance measurement from bioluminescent imaging (BLI) demonstrating no difference between treatment groups. (b) MicroCT quantification of vertebral body bone mass demonstrating significant bone loss in both groups compared to age matched controls but no difference between groups.
Contiguous Spinal Instability Due to Tri-Phasic Kinematics from Underbody Blast Loading

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Dennis J. Maiman, MD, PhD, Milwaukee, Wisconsin

Introduction: Inferior-to-superior loading of cervical spine coupled with/without helmet contact with roof/interior structure of vehicle is a postulated injury mechanism from underbody blasts from IEDs. Using a custom vertical accelerator device, this study applied simulated underbody blast loads to human cadaver head-neck complexes to determine forces, kinematics, injuries, injury mechanisms and instability at contiguous levels.

Methods: Pretest BMD, X rays and CT of six head-T2 complexes were obtained. Disc and facet joints were graded (two surgeons). Specimens were prepared with retro-reflective targets at various levels. T2-T3 was fixed. C7-T1 joint was unconstrained. A six-axis load cell was attached at inferior end. An appropriate-size military-combat-helmet was used for each specimen, determined based on individual head size. Prepositioning: T1 was inferiorly oriented at 30-degrees from horizontal. Occipital condyles were anterior to cervico-thoracic disc (seven-degrees forward of vertical axis). These were based on mean position data from a study of military volunteers. Tests were conducted using a vertical accelerator capable of imparting high-acceleration, short-duration pulses to specimen's inferior end (Figure 1). Accelerometers, angular velocity and acoustic sensors, and strain gages were used on vertebrae. Tests were done at different velocities, applied sequentially such that low velocity initial baseline test was repeated in between two higher velocity tests. Roof structure of military vehicles was simulated at a distance of 0.13 m from top of helmet. Load cells recorded roof impact forces. High-speed videos were taken (5000 frames/second). X-rays and palpations were done in between tests. X-rays and CT were obtained following final test. Detailed dissection was performed.

Results: Age, stature, BMI: 55±9 years, 183±5 cm, 21±3 kg/m2. Impact pulses were within 10-millisecond rise-time. Kinematics, force and acceleration analysis demonstrated tri-phasic response: initial acceleration/compression wave transmitted from T2 to occipital condyles during launching phase, followed by extension kinematics of the column, and in final phase, additional (re) compression occurred from roof contact. Entire tri-phasic event occurred within 120-milliseconds. Forces during initial compressive wave transmission phase were similar in all specimens, while during final compression phase, roof-contacted specimens sustained significantly greater forces than non-contacted specimens (Figure 2). Injuries were consistent with vertical inferior to superior loading mechanisms, forces, moments and accelerations: vertebra fractures, anterior intrevertebral annulus disruptions and ligament tears, and facet injuries.

Conclusion: Tri-phasic response and inferior-to-superior loading is unique to military environments. Anterior, middle and posterior column injuries occurred in the third phase with helmet-head to roof contact associated with ‘buckling’ of cervical column, only possible through the local realign upward wave phenomenon to the entire fractured vertebra(e) cross section. Involvement of anterior column, disc and ligament injuries suggests: soft tissue-related injuries occur due to local segmental extensions during second phase of wave transmission. Roof contact during third phase of the response injured spine, leading to clinical instability at contiguous levels. These mechanistic features distinctly differ from neck injuries under civilian environments. Military neck injuries from underbody blast loads are unique, have complex tri-phasic phenomenon and involve additional contiguous segmental instability.
Contiguous Spinal Instability Due to Tri-Phasic Kinematics from Underbody Blast Loading

Please click on the “Disclosure” link for author/participant financial disclosure information.
Risk of Adjacent Segment Breakdown at the Cervico-Thoracic Junction: Where should We Stop?

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Alim Ramji, Baltimore, Maryland

Introduction: When performing multi-level cervical fusions, the surgeon often must decide whether or not to cross the cervicothoracic (CT) junction. Choosing C7 as the distal fusion level entails risk of symptomatic adjacent segment disease (ASD), which is perhaps increased by leaving a single motion segment between a fusion mass and the relatively rigid thoracic spine. In contrast, crossing the CT junction will eliminate motion segments and add levels to the attempted fusion. Currently, there is little data to guide this decision. The purpose of this study is to compare revision rates for distal ASD after multi-level fusions that end at C7 versus the upper thoracic spine.

Methods: We identified all adult (age >18 YO) patients who underwent a cervical fusion of at least 4 vertebral levels with the distal fusion level from C7-T3. Age at time of surgery and gender were recorded. Surgical approach (anterior, posterior, or combined anterior/posterior) was determined. Complications and reoperations were determined by chart review. Those who underwent distal extension of their fusion (Ext group) were compared to those that did not (No-Ext group) to identify potential risk factors for distal ASD. Chi-squared tests were utilized for nominal variables and Mann-Whitney tests were used for continuous variables. Relative risk (RR) and 95% confidence intervals (CI) were determined when statistically significant differences (p<0.05) were found in nominal variables.

Results: There were 140 patients identified for inclusion. The revision rate for distal ASD when fusions were stopped at C7 was 21%, compared to 2% when stopped in the upper thoracic spine (T1-3). This difference was statistically significant (p<0.001) with a relative risk of 12.0 (95% CI: 2.6-56.3) for stopping at C7. There was no difference in age or gender between the Ext and No-Ext groups (Table 1). There was a significant difference found in the surgical approach between groups, with those requiring extension having a higher rate of anterior surgery.

Conclusion: Multilevel cervical fusions that ended at C7 vertebrae resulted in revision surgery for distal ASD in 21%, which was over 10 times the rate of distal ASD when fusions ended in the upper thoracic spine. Interestingly, anterior operations were more often found to require surgery for distal ASD. When performing multilevel cervical fusions, anterior or posterior, consideration of initially fusing across the cervico-thoracic junction should be taken.

### Table 1. Analysis of Risk Factors for Extension of Fusion

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<th>Gender</th>
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<th>No-Ext</th>
<th>p-value</th>
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<tr>
<td>Male</td>
<td>1</td>
<td>(12.5)</td>
<td>57</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
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<table>
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<th>Age</th>
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<tr>
<td>55.8 ± 11.9</td>
<td>11.9</td>
<td>59.6 ±</td>
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<th>No-Ext</th>
<th>p-value</th>
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</thead>
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<td>(62.5)</td>
<td>4</td>
</tr>
<tr>
<td>Posterior</td>
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<td>(37.5)</td>
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<tr>
<td>A/P</td>
<td>0</td>
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<td>16</td>
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Comparison of the Japanese Orthopaedic Association (JOA) Score and Modified JOA (mJOA) Score for the Assessment of Cervical Myelopathy

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Introduction: The Japanese Orthopaedic Association (JOA) score is widely used to assess the severity of clinical symptoms in the patients with cervical compressive myelopathy, particularly in eastern Asian countries. In contrast, modified versions of the JOA score are currently accepted as a standard tool for assessment in Western countries. The objective of the present study was to compare these scales and clarify their differences and interchangeability, as well as to verify their validity by comparing them to the other outcome measurements.

Methods: Five institutions participated in this prospective multicenter observational study. The JOA, modified JOA (mJOA) proposed by Benzel, and western type JOA proposed by Keller were recorded preoperatively and at three months postoperatively in patients with cervical compressive myelopathy who underwent decompression surgery. Patients reported outcome (PRO) measures including Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ), the Short Form-12 (SF-12) and the Neck Disability Index (NDI), were also recorded. The preoperative JOA score and its modifications were compared with each other and the PRO values. In the patients whose postoperative scores were available, the recovery rates were compared.

Results: Ninety-two patients were included. The correlation coefficients (Spearman’s ?) between the JOA and mJOA / western JOA was 0.87 / 0.92 respectively. All JOA scores and its modifications revealed statistically significant correlation with JOACMEQ QOL score, SF-12 physical component summary, and the NDI. The correlation coefficient of the recovery rate between the JOA and mJOA / western JOA was 0.74 / 0.77, respectively.

Conclusions: In the present study, the JOA score and its modifications showed good correlation with each other in terms of their total scores and recovery rates. Their validity of the scores was demonstrated by comparing these values to the PRO values.
Economic Considerations in the Management of Spine Fracture Patients with Ankylosing Spondylitis

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Introduction: Patients with ankylosing spondylitis (AS) are susceptible to unstable spine fractures even after low energy trauma, which can be potentially devastating with high complication rates. As a result, patients often require surgery with a prolonged hospital course. Knowledge of the associated costs with treatment of these injuries can help identify potential mechanisms of efficiency. This study evaluates the cost of care in AS patients with acute spine fractures and identifies risk factors for increasing expenditures.

Materials/Methods: A total of 21 patients diagnosed with AS and an associated spinal fracture presenting to our level I tertiary referral center were identified with an institutional database search and retrospectively reviewed from 1990 to 2014. Patients were classified amongst two groups based on definitive management - surgery versus nonoperative care. Patients’ clinical and demographic characteristics were collected (Table 1) in addition to itemized cost reports. The influence of specific variables on cost such as age, BMI, preoperative comorbidities, as well as surgical and medical complications were also assessed. Statistical Analysis Software version 9.3 was used for statistical analysis.

Results: Of the 21 patients (25 fractures) who met inclusion criteria, fifteen patients underwent surgical intervention while six were managed nonoperatively. There was no statistical difference between groups with regards to age, BMI, or Charlson comorbidity index, however, the operative group had a significantly higher incidence of neurologic dysfunction (p<0.0015). The fracture site was located in the cervical spine in 17 cases (68%), thoracic spine in 7 cases (28%), and lumbar spine in 1 case (4%). Medical complications were diagnosed in 12/15 (80%) of the operatively treated patients while no complications occurred in the nonoperative group. Notably, 6/10 (60%) operatively treated patients with cervical spine fractures suffered from respiratory failure and five of those six patients eventually required a tracheostomy. There were two complications that required reoperation, one surgical site infection and one epidural hematoma. Two mortalities, both operatively managed cervical spine fractures, occurred during admission after withdrawal of care. AS patients managed surgically resulted in nearly 10-fold increase in cost compared to those managed nonoperatively ($97,087 vs. $10,918 respectively). Furthermore, those requiring tracheostomy accrued nearly twice the costs of those who did not, $133,051 versus $73,106 respectively. Age, body mass index, respiratory failure, and days in the ICU were shown to be statistically significant risk factors for elevated costs. A diagnosis of respiratory failure resulted in an additional $34,620 per hospitalization while each additional ICU day led to an extra $1,014.

Conclusion: The data in this study suggest that AS patients with cervical spine fractures are associated with a high rate of respiratory failure requiring tracheostomy leading to increased complications and costs to the healthcare system. Surgeons, patients, and administrators must be made aware of the prognoses associated with such serious injuries.
Comprehensive Assessment of Traumatic Atlanto-Occipital Dissociation in Survivors at a Single Institution over 15 Years

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Introduction: Atlanto-occipital dissociations (AODs) are rare injuries that are associated with a high level of morbidity and mortality. Initial cervical spine immobilization followed by cranio-cervical arthrodesis has emerged as the treatment of choice. There is a paucity of literature on the impact of craniocervical arthrodesis for AOD in relation to 90 day morbidity and mortality, health related quality of life, and return to work. The aims of our study were to 1) determine 90 day morbidity and mortality 2) assess patient reported outcomes (PROs) and 3) determine return to work.

Methods: All spine CT traumagrams (5337), occurring over a 15-year period (1997-2012) at a level 1 trauma center were reviewed by a fellowship trained spine surgeon. Patients were included in our study if they met one of the following radiographic criteria: 1) basion-dens interval (BDI) > 10mm 2) basion-axial interval (BAI): anterior displacement > 12mm or posterior displacement > 4mm between the basion and posterior C2 line 3) condyle-C1 interval (CC1) > 2mm. The electronic medical record (EMR), for those with CT evidence of AOD, were retrospectively evaluated to determine patient demographics, record of AOD diagnosis, American Spinal Injury Association (ASIA) score, injury severity score (ISS), 90-day morbidity and mortality. Post-operative pain, disability, quality of life, and return to work were assessed via phone interview in the survivors. PROs measured included Euro-Qol-5D (EQ-5D), Neck Disability Index (NDI), numeric rating scale for neck pain (NRS-Neck) and arm pain (NRS-Arm).

Results: Thirty-one patients met radiographic criteria for AOD, eight of whom died and 23 survived. The mean age at time of injury was 36.5 ± 13.04 years with 14 (61%) males and 9 (39%) females. Twelve (52%) patients sustained a neurological deficit. Twenty-one (94.5%) patients underwent a posterior craniocervical arthrodesis, one (4.5%) underwent C1-C2 decompression and craniocervical arthrodesis, and one (4%) was treated with a halo. There were no intraoperative complications. Ninety day complications included: DVT (n=1), sepsis (n=5), UTI (n=5), and pneumonia (n=10). At 90 days, 5 (22%) patients experienced improvement in ASIA score; there were no new neurological deficits, no reoperations, and no mortalities. PROs were collected from 9 (39%) patients with a mean follow-up time of 4.40 ± 2.28 years. Mean EQ-5D, NDI, NRS-Neck, and NRS-arm were 0.73 ± 0.19, 30.89 ± 18.57, 2.33 ± 2.21, 2.00 ± 2.54, respectively. Of these 9 patients, 4 returned to work full time and 5 patients were disabled.

Conclusions: Craniocervical arthrodesis for the treatment of AOD is a relatively safe procedure with unexpectedly high patient reported outcomes and return to work for such a significant injury. The 90 day complication profile is representative of multisystem involvement with polytrauma. The most surprising aspect of our study was the relatively high health state, mild to moderate disability, and minimal pain experienced by these patients that have sustained significant injury with dramatic loss of motion following stabilization. There is somewhat of a disparity between the relatively good PROs and return to work which may be secondary to limitations caused by non-spine multitrauma injuries.
Immunogenicity of Human Induced Pluripotent Stem Cells-Derived Neural Stem Cells as a Cell Source for the Treatment of Spinal Cord Injury

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Background: Recent studies demonstrated the effectiveness of transplantation of human induced pluripotent stem cells-derived neural stem cells (hiPSC-NSCs) for rodent as well as non-human primate spinal cord injury (SCI) model. Since first-in-man trial will be allogeneic transplantation of hiPSC-NSCs taking advantage of iPS bank in CiRA, the evaluation of immunological property of hiPSC-NSCs is crucial. The purpose of this study is to evaluate immunogenicity and the degree of immune response of hiPSC-NSCs in vitro.

Materials and Methods: To investigate immunogenicity of hiPSC-NSCs, immune-related surface markers on hiPSC-NSCs were analyzed using flow cytometry. Effect of passage number of hiPSC-NSCs on immunogenicity was evaluated at the same time. Furthermore, to mimic an inflammatory environment or damaged tissues in vivo, hiPSC-NSCs were stimulated with IFN-β. IFN-β was added 48 hours prior to analysis using flow cytometry. Mixed lymphocyte reaction (MLR) was performed to evaluate the degree of immune response and immunomodulatory effect of hiPSC-NSCs in vitro. hiPSC-NSCs inactivated by irradiation were co-cultured with allogeneic lymphocyte and proliferation of lymphocyte was measured quantitatively by radioactivity counter. As a positive control, two human HLA incompatible lymphocytes were mixed. Human fetal neural stem cells were analyzed as a control in the same way. Effect of passage on immune response was also investigated. In addition, the correlation between the expression level of immune-related surface markers and MLR of hiPSC-NSCs was evaluated to elucidate their immunogenicity.

Results: More than 80% of hiPSC-NSCs expressed HLA class I. Compared to hiPSC-NSCs passaged 3 times, hiPSC-NSCs passaged 7 times tended to express higher percentage of HLA class I although there were no statistical differences (88.6 ± 4.9% vs. 81.6 ± 2.2 p=0.26). IFN-β administration induced HLA class I expression in more than 99% of hiPSC-NSCs. On the other hand, less than 2% of hiPSC-NSCs expressed HLA class II or co-stimulatory molecules (CD40, CD80 and CD86) that play an important role in antigen presentation. The expression of HLA class II and co-stimulatory molecules did not increase even after the multiple passages. In MLR, proliferation of lymphocyte co-cultured with hiPSC-NSCs was significantly suppressed than that of a positive control. According to the multiple passages, activation of lymphocyte mixed with hiPSC-NSCs was reduced remarkably.

Conclusion: Immunological examination revealed that hiPSC-NSCs exhibited low immunogenicity, and that hiPSC-NSCs suppressed the lymphocyte proliferation in MLR, suggesting their immunomodulatory function. Interestingly, multiple passages of hiPSC-NSCs may also influence their immunogenicity.
ACDF with Total En Bloc Resection of Uncinate in Foraminal Stenosis of the Cervical Spine: Comparison with Conventional ACDF

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Seong-Hwan Moon, MD, Seoul, Korea, Republic of
Hwan-Mo Lee, MD, Seoul, Korea, Republic of
Jin-O Park, MD, Seoul, Korea, Republic of
Jeong Ho Seo, MD, Seoul, Korea, Republic of
Jin-Soo Kim, MD, Seoul, Korea, Republic of

Introduction: Foraminal stenosis is a cause of radiculopathy. To relieve the radiculopathy, ACDF is the most frequently performed procedure. No studies have been performed comparing ACDF with and without uncinate resection. Purpose of this study was to find out any differences in clinical outcomes of ACDF depending on uncinate resection or not.

Methods: 606 patients who underwent ACDF due to foraminal stenosis were included in this study. Minimum follow up was 2 years. ACDF due to soft disc herniation or myelopathy were excluded in this study. Group U was consisted of 275 patients who were performed uncinate resection and group N was consisted of 331 patients who were not performed uncinate resection. Total en bloc resection of uncinate was performed using osteotome. After resection of uncinate, we observed the nerve root and completely released any compression (Figure 1). Clinical outcomes were measured by preoperative and follow up neck pain visual analogue scale (VAS), arm pain VAS, neck disability index (NDI), and subjective improvement rate. Follow up was performed on postoperative 6 weeks, 3, 6, 9, 12, 18, and 24 months. Statistical analysis was performed by independent sample t-test and paired sample t-test.

Results: Neck pain VAS, arm pain VAS, NDI, and subjective improvement rate were all improved significantly after the surgery (at 6 week follow-up) in both groups and the outcomes were not changed during the follow up (3-24 month follow up). There were no significant differences between the two groups in overall clinical outcomes including neck pain VAS, NDI, subjective improvement rate. There were significant differences between the two groups in arm pain nearly at all times. Arm pain was significantly less in uncinate resection group at all times (Figure 2).

Conclusion: Overall clinical outcomes were significantly improved at 6 weeks after the ACDF depending on uncinate resection or not. After 6 weeks, there was no significant improvement. There were no significant differences between the two groups in terms of neck pain, NDI, and subjective improvement rate. However, arm pain was significantly less in uncinate resection group at all times.
Area Under the Curve: Analysis of Approach Related Recovery Time in 166 Operative Cervical Spondylotic Myelopathy Patients with 2-Year Follow-Up

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Christopher I. Shaffrey, MD, PhD, Charlottesville, Virginia
Han Jo Kim, MD, New York, New York
Paul M. Arnold, MD, Kansas City, New York
Shian Liu, BS, New York, New York
Justin K. Scheer, BS, Chicago, Illinois
Jens R. Chapman, MD, Seattle, New York
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Virginie C. Lafage, PhD, New York, New York
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Eric M. Massicotte, MD, MSc, FRCS(C), Toronto, Ontario, Canada
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Introduction: Much debate about post-operative outcomes regarding surgical approaches for cervical spondylotic myelopathy (CSM) exists in the literature with no clear evidence of superiority in long term follow-up. We propose a novel method for assessing the surgical recovery process by taking into account each patient's baseline and post-operative time points and analyzing the area under the curve (AUC) of their health related quality of life scores (HRQOLs), a proxy for recovery kinetics.

Methods: Post-hoc analysis of a prospective, multicenter database of patients with CSM. Inclusion criteria were: symptomatic CSM, age over 18, and 2 year follow-up with modified Japanese Orthopaedic Association (mJOA) and Neck Disability Index (NDI). Nurick grade was also assessed at baseline and 2 years and compared via chi-square. The anterior approach group (AAG, n=110) and posterior approach group (PAG, n=56) were compared at baseline, 6 months, 1 year, and 2 years for each HRQOL. This comparison was repeated with normalization, using the patient's baseline as the anchor, followed by an integration and comparison of AUC. Independent samples t-test was used to compare HRQOLs and AUC.

Results: 166 patients met inclusion criteria, with an average age of 56.4±11.9 years old (AAG 52.8 yrs, PAG 62.3 yrs, <0.001) and 41.0% female (n=68). Overall, Nurick demonstrated disability at baseline with a significant improvement at 2 years, p < 0.05 (Figure 1). Raw HRQOLs demonstrated a superior baseline and 2y post-operative outcome for the AAG, which was statistically significant for mJOA only (2y AAG 16.33 vs. PAG 14.98, p < 0.05). Normalization demonstrated superior outcomes for the AAG with NDI, however this was not significant, while normalized mJOA demonstrated a significantly superior outcome at 2 years for the PAG (Recovery Index: AAG 1.21 vs. PAG 1.32, p 0.03). AUC analysis showed significantly higher recovery kinetics for the PAG group at the 1 to 2 year interval only (AUC: AAG 28 vs. PAG 30, p 0.04).

Discussion: For the first time AUC analysis was applied to evaluating patients with CSM. Non-normalized HRQOLs demonstrated the AAG started higher and met better standards at all times points compared to the PAG. Normalized mJOA demonstrated the PAG actually did better at 2 years, while NDI suggested that the AAG did better, though this was not significant. AUC analysis further supported the superiority of the PAG, with statistical significance at 1 to 2 year time points, suggesting that patients who undergo the posterior approach may suffer less in the first two years of their post-operative course.
Area Under the Curve: Analysis of Approach Related Recovery Time in 166 Operative Cervical Spondylotic Myelopathy Patients with 2-Year Follow-Up

Figure 1.

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p-value: 0.006 0.009

Figure 2.

*Raw mJOA showed a significantly higher mJOA for the AAG at all time points (p < 0.05).
*Normalized mJOA showed a significantly higher recovery index at 2 years only for the PAG (p 0.03).
*AUC analysis showed significantly higher recovery kinetics for the PAG at the 1 to 2 year interval only (p 0.04).
Raw NDI, normalized NDI, and AUC analysis for NDI was not significantly different between the two groups.
Effect of Preoperative Sagittal Balance on Cervical Laminoplasty Outcomes in Elderly Patients Aged ≥65 Years

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Introduction: Sagittal imbalance increases with age. Also, previous studies have reported that the surgical effect of cervical laminoplasty can be affected by age. Because sagittal imbalance can affect quality of life, a higher proportion of those patients with sagittal imbalance may be one of the causes of poorer surgical outcomes in the elderly. The purpose of this study was to investigate the effect of preoperative sagittal balance on cervical laminoplasty outcomes in elderly patients aged ≥65 years.

Methods: We evaluated the cervical laminoplasty outcomes of 87 patients. Radiographic analysis included the measurement of cervical Cobb angles and range of motion (ROM) between C2 and C7 and the C7-sagittal vertical axis (SVA). Primary outcomes were Japanese Orthopedic Association (JOA) scores, the Short Form 36 (SF-36) Health Survey [physical and mental summary scores (PCS and MCS, respectively)], and the Neck Disability Index (NDI). The Wilcoxon signed rank test, the Mann-Whitney U test, and Spearman's rank correlation coefficient were used for statistical analysis.

Results: There were 56 men and 31 women with a mean age of 64 years (range, 30-89 years), and the mean follow-up period was 27 months (range, 12-84 months). The mean C7-SVA was 2.8 cm (?4.0 to 20 cm), which had a positive correlation with age (? = 0.36). The C7-SVA was >5 cm in 23 patients and ≤5cm in 64. Of the 46 patients aged ≥65 years, the C7-SVA was ≤5 cm in 28 and >5 cm in 18. The overall JOA recovery rates were 44% and 36%, respectively (p = 0.42). There were no significant differences in age, sex, C2/7 Cobb angle, and ROM between the two groups. Some of the preoperative scores were inferior in the imbalance group, although the difference was not significant. The postoperative NDI, PCS, and JOA scores were significantly poorer in patients with a C7-SVA of >5 cm than in those with a C7-SVA of ≤5 cm.

Conclusions: As expected, sagittal balance was positively correlated with age. Namely, C7-SVA was >5 cm in 18 of 46 patients aged ≥65 years. Among the patients aged ≥65 years, the presence of sagittal imbalance itself may have led to the poorer preoperative scores in those with a C7-SVA of >5 cm, independent of the degree of myelopathy. This was because some of the preoperative scores were inferior in these patients compared with those in patients with a C7-SVA of ≤5 cm, although the difference was not significant. In contrast, the difference in each outcome became clearer after surgery. Namely, many of the postoperative scores were markedly inferior in patients with a C7-SVA of >5 cm, which may indicate that the effect of surgical intervention itself on myelopathy could be affected by sagittal imbalance. Nonetheless, the influence of sagittal imbalance on surgical outcomes should be considered in elderly patients. Surgical outcomes after cervical laminoplasty can be affected by sagittal imbalance in patients aged ≥65 years.
Significance of Various Radiological Parameters to Predict Dysphagia and Dyspnea after Occipitocervical Fixation - Radiological Analysis

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Introduction: There has been little attention given to the relationship between the fixation angle of craniovertebral junction and swallowing physiology. This preliminary investigation evaluated the relationship between the subjective changes of swallowing function, diameter changes of oropharynx and various occipitocervical radiological parameters to assess which radiological parameter could be the best reference value to predict and avoid dysphagia after occipitocervical fixation.

Methods: Forty healthy asymptomatic volunteers, 20 males and 20 females, were collected in this study. None of the subjects had a history of cervical spine surgery, respiratory disease, temporomandibular joint disorders and cerebrovascular disease. Written and oral informed consent was obtained from subjects as per our institutional review board prior to videofluoroscopic examination.

The initial x-ray was taken in neutral position for reference, and the next x-ray was taken in a retracted position when subject feel difficulty on swallowing. And then, videofluoroscopic recording were made of each subject swallowing 20 ml boluses of liquid barium contrast. Videofluorographic swallowing study (VFSS) was performed in neutral comfortable position and retracted position which causes swallowing difficulty in each patient.

The pharyngeal transit time, valeculae retention, pharyngeal coating, piriformis sinus retention and aspiration were checked on the image checked in each different position. The dysphagia score was based on clinical findings such as foreign body sensation, residual sensation after swallowing, coughing, aspiration and swallowing difficulty.

We evaluated several radiological findings (OC1 angle, C12 angle, OC2 angle, C2-6 angle, oropharyngeal diameter (OD), mandible to C2 distance, McGregor line - C2 vertical axis angle (McC2A), McGregor line - C2 posterior body line (McPC2A), the difference of each value between neutral and retracted position and the percentile change of each value. Statistical analysis was carried out to identify which radiological parameter is significantly correlated with dysphagia using the SPSS software (v12.0).

Results: There was no correlation of %dn oropharyngeal space and dysphagia score with several radiological findings such as C12 angle, C26 angle and mandible to C2 distance (p=0.228). Percentile change of oropharyngeal space (neutral and retracted position) was negatively correlated with age (r=-0.477), R OC1A (r=-0.403) and R OC2A (r=-0.489). Percentile change of oropharyngeal space (neutral and retracted position) was significantly correlated with %dnOC2A (r=0.456), dnOC2A (r=0.47), dnOC1A (r=0.377), %dnMcC2A (r=0.344), %dnMcPC2A (r=0.328), symptom and radiologic score. (r=0.726, 0.4 respectively, p<0.01).

Total dysphagia score was significantly correlated with Percentile change of oropharyngeal space,%dnOC2A, dnOC2A, dnOC1A, dnMcC2A, %dnMcC2A, dMcPC2A and %dMcPC2A(p<0.05).

Conclusions: The findings of this study demonstrated dysphagia and oropharyngeal diameter is significantly related with the angle of upper cervical spine. These data support the finding that the angle of the craniovertebral junction (CVJ) has considerable impact on dysphagia after O-C fusion and C01 angle is more significantly related to dysphagia than C12 angle. Fixation angle of CVJ can be measured using OC2A, McC2A and McPC2A. Those angular parameters in neutral position can be reference value to avoid malalignment of CVJ. Mandible to C2 distance may not be a useful radiological parameter to predict dysphagia after CVJ fixation.
Comparison of Allograft and Polyetheretherketone (PEEK) Cage in Anterior Cervical Discectomy and Fusion (ACDF)

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Introduction: Structural allografts and PEEK cages are commonly used as interbody fusion devices in ACDF. The subsidence rates of these two spacers have not yet been directly compared. The primary aim of this study was to compare the subsidence rate of allograft and PEEK cage in ACDF. The secondary aim was to determine if the presence of subsidence affects the clinical outcome.

Methods: We reviewed 67 cases (117 levels) of ACDF with either structural allograft or PEEK cages. There were 85 levels (48 cases) with PEEK and 32 levels (19 cases) with allograft spacers. All surgeries were performed by a fellowship-trained spine surgeon from November 2005 to September 2012. Immediate post-operative and 6-month lateral cervical radiographs were evaluated for subsidence by measuring the anterior disc height and posterior disc height at each operative level. Subsidence was defined as a decrease in anterior or posterior disc heights > 1 mm. The subsidence rate between the two groups was compared using the chi-square to test for significance (?=0.05). NDI was recorded to evaluate clinical outcome of the subsidence (SG) and non-subsidence group (NSG). T-test was used to test for difference between the two groups (?=0.05).

Results: There was no statistically significant difference between subsidence rate of the PEEK group (54%; 46/685) and the allograft group (59%; 19/32) (p=0.69). Overall mean subsidence was 1.0± 1.3mm anteriorly and 1.2±1.2 mm posteriorly. The mean NDI improvement was 11.7 (from 47.1 to 35.4; average follow-up: 12 mos) for the SG and 14.0 (from 45.8 to 31.8; average follow-up: 13 mos) for the NSG (p=0.74).

Conclusions: The subsidence rate does not seem to be affected by the use of either PEEK or allograft as spacers in ACDF. Furthermore, subsidence alone does not seem to be predictive of clinical outcomes of ACDF.

***The FDA has not cleared the following pharmaceuticals/medical devices Lateral mass screws.
Does Preoperative T1 Slope affect Radiologic and Functional Outcomes following Cervical Laminoplasty?

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Changju Hwang, Seoul, Korea, Republic of
Choon-Sung Lee, MD, Seoul, Korea, Republic of
Dong-Ho Lee, MD, PhD, Seoul, Korea, Republic of

Introduction: T1 slope is an important parameter determining cervical sagittal alignment since it is positively correlated with cervical lordosis. Severe kyphosis of the cervical spine is one of the contraindications of laminoplasty; therefore, T1 slope could be an important factor that should be considered before laminoplasty. Some authors suggested postoperative loss of cervical lordosis was different by preoperative T1 slope. However, until now there has been no study about how preoperative T1 slope affect the sagittal balance of cervical spine and various functional outcomes following laminoplasty.

Materials and Methods: Seventy-six patients (M:F=50:26, mean age 65±9) who underwent cervical laminoplasty and were followed more than 2 years with available data were included. On the pre- and post-operative cervical lateral X-rays and standing 3-foot whole spine lateral X-rays, radiographic measurements were performed to analyze the following parameters: (1) C2-C7 sagittal vertical axis (C2-C7 SV A; distance between C2 plumb line and C7), (2) T1 slope, (3) C2-C7 lordosis, and (4) thoracic kyphosis. Visual analogue scale (VAS) of neck pain and arm pain, JOA, neck disability index (NDI), and SF-36 (PCS and MCS) were also investigated. The patients were divided into two groups by preoperative T1 slope: high T1 and low T1 group. Changes of clinical and radiological data between preoperative periods and final visits in each group were compared by paired t-test. The correlations between T1 slope and changes of radiological parameters were analyzed by Pearson correlation method.

Results: Overall, C2-C7 SVA increased from 21.2 to 24.5mm (p=0.004) and C2-C7 angle decreased from 13.9° to 10.3° (p=0.007) postoperatively. T1 slope did not show any differences postoperatively. Each group included 38 patients. The mean T1 slope was 32.1±4.6° in high T1 group and 22.1±4.0° in low T1 group. Preoperative C2-C7 lordosis was larger in high T1 group (19.1°) than in low T1 group (9.0°). However, postoperative changes in C2-C7 SVA and C2-C7 lordosis did not show any difference between both groups (Figure 1). Neurologic parameters and functional outcome except VAS of arm pain showed overall improvement in both groups although a few parameters did not reveal statistical significance (Table 1). However, neck pain increased postoperatively in both groups. Changes between preoperative period and final follow-up did not show differences between 2 groups in neck pain VAS (p=0.150), arm pain VAS (p=0.488), NDI (p=0.619) and SF-36 PCS (p=0.377).

Conclusions: C2-C7 SVA increased and C2-C7 lordosis decreased significantly in both groups following cervical laminoplasty. This means cervical sagittal balance is aggravated by laminoplasty. However, the degree of aggravation was not affected by preoperative T1 slope. Most neurologic parameters and functional outcomes showed overall improvement except neck pain. However, the degree of improvement was not much different by preoperative T1 slope.