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J.A.N.E. Award Presentation

100 Predictors of the Best Outcomes Following Minimally Invasive Surgery for Grade 1 Lumbar Spondylolisthesis

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Introduction: The factors driving the best outcomes following minimally invasive surgery (MIS) for grade 1 lumbar spondylolisthesis are not clearly elucidated. This study investigates the factors that drive the best 24-month patient reported outcomes (PRO) following MIS lumbar spondylolisthesis surgery.

Methods: 310 patients from the Quality Outcomes Database (QOD) Lumbar Spondylolisthesis Module underwent surgery for degenerative grade 1 lumbar spondylolisthesis utilizing MIS techniques. Surgeries were classified as MIS if any of the following were involved: MIS laminectomy, MIS pedicle screws, MIS interbody grafts, or percutaneous screws. Baseline and 24-month follow-up parameters were collected. PROs included the Oswestry Disability Index (ODI), numeric rating scale (NRS) Back Pain, NRS Leg Pain, EuroQoL-5D (EQ-5D) Questionnaire, and North American Spine Society (NASS) Satisfaction Questionnaire. Multivariate models were constructed.

Results: The cohort included 233 (75.2%) fusions and 77 (24.8%) decompression only procedures. The mean age was 64.0±11.3 years. The cohort demonstrated significant improvement in ODI, NRS back pain, NRS leg pain, and EQ-5D at 24 months ($p<0.001$, all comparisons relative to baseline). In multivariate analyses, aside from baseline PRO values, only three factors were significantly associated with multiple PRO change scores: employment, independent ambulation at presentation, and the addition of fusion to surgery. Employment was associated with superior postoperative ODI (OR=0.002;95%CI[0.0002-0.28]; $p=0.01$), NRS back pain (OR=0.39;95%CI [0.19-0.78]; $p=0.008$), and NASS satisfaction (OR=0.36;95%CI[0.18-0.68]; $p=0.002$). Independent ambulation was associated with superior NRS leg pain (OR=0.34;95%CI[0.12-0.91]; $p=0.03$) and EQ-5D (OR=1.11;95%CI[1.04-1.18]; $p<0.001$). The addition of a fusion was associated with superior NRS back pain (OR=0.41;95%CI [0.17-0.93]; $p=0.03$) and NASS satisfaction (OR=0.35;95%CI[0.17-0.73]; $p=0.005$). Education was also associated with superior outcomes for a single outcome, ODI (OR=0.002;95%CI[0.0002-0.13]; $p=0.004$).

Conclusion: Multiple factors influence outcomes following lumbar spondylolisthesis surgery. For MIS, preoperative active employment, higher education, independent ambulation at presentation, and fusion surgery were significant predictors of superior outcomes across the domains of disability, back pain, leg pain, quality of life, and satisfaction.

Mayfield Basic Science Award Presentation

101 Transplantation of Neural Precursors Derived from Spinal Progenitor Cells Improves Functional Recovery from Spinal Cord Injury by Reduced Inflammation via Inhibition of the Nuclear Factor Kappa-B Pathway in a Rat Model of Spinal Cord Injury

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Introduction: Traumatic spinal cord injury (SCI) triggers a chain of events that hinders recovery characterized by an inflammatory cascade leading to necrotic cell death at the core injury site with astrogliosis and apoptotic cell death in surrounding areas. Activation of the nuclear factor-kappa-B (NF- κ B) signaling pathway is associated with inflammation in SCI. Here, we elucidate the activation pattern of NF- κ B in SCI while investigating the effect of transplantation of spinal neural precursors (SPC-01) on its activity, related astrogliosis, and functional recovery in a rat model.

Methods: Using a balloon compression rat model of SCI, injury was induced at T8 and SPC-01 cells or saline was injected into the lesion 7-days post-injury. Rats were followed for functional recovery (Basso, Beattie, Bresnahan (BBB), Rotarod, Plantar Thermal Nociception, and Flat Beam tests) and sacrificed to retrieve spinal cord sections at multiple time points. The course of SPC-01 cells was determined by immunofluorescence response to stem cell and neuronal markers. NF- κ B activity, phosphorylated-p65, secretory levels of cytokines (e.g. TNF- α), extent of glial scarring, white and gray matter preservation, and cavity size were determined.

Results: Functional recovery was enhanced in SPC-01-treated rats as confirmed by BBB score. A bimodal activation pattern of the NF- κ B signaling pathway was seen, with peaks at 3- and 28-days. Transplantation of SPC-01 cells resulted in significant downregulation of TNF- α at 10- and 14-days and inhibition of NF- κ B activity at 28 days after SCI, mainly in gray matter. Transplanted rats exhibited gray matter preservation and reduced glial scar and cavity size. **Conclusion:** We demonstrate immunomodulatory properties of SPC-01 cells based on inhibition of the canonical NF- κ B pathway. This effect occurs prior to maturation of SPC-01 cells, implying that the observed results are due to paracrine mechanisms rather than cell replacement. Reduced inflammation may result in tissue sparing, reduced glial scar, and improved functional recovery.

Mayfield Clinical Science Award Presentation

102 Fusion and Opioid-sparing with the Use of Ketorolac in Posterior Thoracolumbar Spinal Fusions: A Prospective Double-blinded Randomized Placebo-Controlled Trial

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Introduction: Use of Ketorolac in spinal fusion is limited due to the risk of pseudarthrosis. Recent literature suggested that such an effect could be type- and dose-related. We sought to demonstrate that Ketorolac use was safe with significant opioid-sparing effect and non-inferior fusion rate.

Methods: This is a prospective, double-blinded, randomized placebo-controlled trial designed according to the 2013 SPIRIT Guidelines. It is a two-arm parallel design with a 1:1 randomization. Over a two-year period under 6 surgeons at two sites, consecutive patients who underwent elective 1-3 level minimally invasive thoracolumbar fusion were screened for inclusion/exclusion. Patients with fusion confounders were excluded. A centralized treatment allocation mechanism and Excel-generated block randomization were used. Patients received a 48-hour scheduled treatment of intravenous Ketorolac (15mg IV Q6H) or saline. We implemented a standardized analgesia regimen using a standardized order set. The primary outcome was fusion rate as evaluated XR/CT using the Suk criteria at 6/12 months by a blinded neuroradiologist. The secondary outcomes were morphine-equivalence (MME) in the first 48h postop and during the hospital stay, NSAIDs-specific perioperative complications, VAS, length of stay, and quality-of-life outcomes at 6/12 months. Univariate analysis was used with $p < 0.05$ considered significant. The sample size was estimated to be 600. This is an interim analysis to evaluate the safety and MME reduction.

Results: Sixty-nine patients were analyzed. Patient characteristics and operative data were comparable between the groups except EBL (Tables 1&2). No significant difference in fusion was found at 6-month (Table 3). There was a significant reduction in total/48-hour MME and length of stay for the Ketorolac group (Table 4). The only complication was a superficial hematoma in a ketorolac-assigned patient requiring evacuation.

Conclusion: Ketorolac demonstrated safety, a significant reduction in postoperative opioid use and length of stay when used as part of a multi-modal analgesics regimen after thoracolumbar fusion.

103 Long Term Costs of Maximum Non-Operative Treatments in Patients with Symptomatic Lumbar Stenosis or Spondylolisthesis that Ultimately Required Surgery: A Five Year Costs Analysis

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Introduction: The costs and utilization of long-term maximal non-operative therapy (MNT) can be substantial, and in the current era of bundled payments, the duration of conservative therapy trials should be reassessed. The purpose of this study is to characterize the utilization and costs of MNTs prior to spinal fusion surgery in patients with symptomatic lumbar stenosis or spondylolisthesis.

Methods: A large insurance database was queried for patients with symptomatic lumbar stenosis or spondylolisthesis undergoing index lumbar decompression and fusion procedures between 2007 and 2016. This database consists of 20.9 million covered lives and includes private/commercially insured and Medicare Advantage beneficiaries. Only patients with lumbar stenosis or spondylolisthesis and those continuously active within the insurance system for at least 5 years prior to the index operation were eligible.

Results: A total of 4,133 out of 497,822 (0.8%) eligible patients underwent 1, 2, or 3-level posterior lumbar instrumented fusion. 20.8% of patients were smokers, 44.5% had type II DM, and 38.2% were obese (BMI > 30 kg/m²). Patient maximal non-operative therapy (MNT) utilization was as follows: 66.7% used NSAIDs, 84.4% used opioids, 58.6% used muscle relaxants, 65.5% received LESI, 66.6% attended 21.1% presented to the ED, and 24.9% received chiropractor treatments. The total direct cost associated with all MNT prior to index spinal fusion was \$9,000,968; LESI comprised the largest portion of the total cost of MNT (\$4,094,646, 45.5%), followed by NSAIDs (\$1,624,217, 18.0%) and opioid costs (\$1,279,219, 14.2%). At the patient level, an average of \$4,010 per patient utilizing therapy was spent on MNT prior to index lumbar surgery.

Conclusion: Assuming minimal improvement in pain and functional disability after maximum non-operative therapies, the incremental cost effectiveness ratio (ICER) for MNT could be highly unfavorable. More effort is needed to identify patients earlier in the course of treatment that might benefit from surgery.

104 Enhanced Recovery After Surgery (ERAS): Implementation in Posterior Lumbar Fusion Surgery

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Introduction: Enhanced Recovery After Surgery (ERAS) is a multi-modal, evidence based approach to perioperative care that aims to prepare patients for and reduce the impact of surgery to facilitate quicker recovery. We instituted a comprehensive ERAS program that spanned our entire spine care continuum and report on outcomes in our posterior lumbar fusion (PLF) patients.

Methods: We report on our institutional outcomes of all PLF patients from 2013-2018 surrounding the implementation of our comprehensive spine ERAS program. Our program encompassed specific interventions geared towards standardizing care pathways including: pre-operative work-up and patient education, anesthesia protocols, surgical order sets, patient flow and nursing care process metrics, pain management, discharge disposition planning, and outcomes evaluation tools. Statistical analysis was performed on process measures, outcomes (LOS, readmission, return to ED, mortality), and complications in our patient cohort before and after ERAS implementation.

Results: 1137 patients underwent PLF during the study period with 601 patients receiving surgery prior to ERAS implementation and 536 patients post-ERAS. In terms of general outcomes, there was a statistically significant decrease in the LOS (4.45 to 4.15 days, $P = 0.034$) with an increasing proportion discharging with home health services or to rehab. Analysis of complications revealed significant decreases in blood transfusions (5.32% vs 0.37%, $P < 0.0001$) and pneumonia (PNA) (1% vs 0%, $P = 0.032$). In terms of process metrics, patients had significant reductions in foley reinsertion, time to PO pain control (9 to 6 hrs, $P = 0.009$), and time until rehab clearance (3.9 to 3.5 days, $P = 0.027$).

Conclusion: Implementation of spine surgery ERAS program led to decreased length of stay and significant decreases in blood transfusion and PNA, and improvements in ERAS-associated in-patient process metrics in patients undergoing PLF. These changes may reflect improved perioperative care coordination made possible by ERAS implantation.

105 An Analysis of Medicare Reimbursement Rates in Spine Surgery: 2000-2018

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Introduction: There is a paucity of data regarding financial trends for procedural reimbursements in spine surgery. A comprehensive understanding of such trends is important as continued progress is made to advance agreeable reimbursement models in spine surgery. The purpose of this study was to evaluate monetary trends in Medicare reimbursement rates for the 15 most common spinal surgery procedures from 2000 to 2018.

Methods: The National Surgery Quality Improvement Project (NSQIP) database (2016) was queried to determine the 15 most performed spine surgery procedures. Next, the Physician Fee Schedule Look-Up Tool from the Centers for Medicare & Medicaid Services was queried for each of the top 15 most utilized CPT codes in spine surgery, and reimbursement data was extracted. All monetary data was adjusted for inflation to 2018 US dollars (USD) utilizing changes to the consumer price index (CPI). The R-squared and both average annual and the total percentage change in reimbursement were calculated based on these adjusted trends for all included procedures.

Results: After adjusting for inflation, the average reimbursement for all procedures decreased by 25.8% from 2000 to 2018. The greatest mean decrease was seen in anterior cervical arthrodesis (-32.1%), while the smallest mean decrease was in vertebral body excision (-13.3%). From 2000 to 2018, the adjusted reimbursement rate for all included procedures decreased by an average of 1.7% each year, with an average R-squared value of 0.69. (Table 1)

Conclusion: This is the first study to evaluate trends in procedural Medicare reimbursement for spine surgery. When adjusted for inflation, Medicare reimbursement for included procedures has steadily decreased from 2000 to 2018. Increased awareness and consideration of these trends will be important for policy-makers, hospitals, and surgeons in order to assure continued access to meaningful surgical spine care in the United States.

106 Burnout and Quality of Life in Spine Surgeons: Results of a Worldwide Survey

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Introduction: Burnout is a syndrome characterized by emotional exhaustion, depersonalization, and decreased sense of accomplishment that leads to decreased effectiveness at work. Our objective was to evaluate the prevalence of burnout and to assess the personal and professional characteristics associated with burnout in spine surgeons.

Methods: An electronic survey with members of AOSpine was performed in May 2018. The survey evaluated demographic variables, practice characteristics, burnout, and quality of life. English, Spanish and Portuguese versions of the Maslach Burnout Questionnaire and EQ5D were used to evaluate burnout and quality of life, respectively.

Results: A total of 818 surgeons from 87 countries answered the survey. Majority of respondents were male (93.4%), married (76.3%), had at least 1 child (74%), orthopedic surgeons (62.2%), with more than 10 years in practice (45.2%),

working between 40-60 hours per week(54.4%), and treating both adult and pediatric spinal pathologies(53.6%). The prevalence of burnout was 30.6%. High levels of emotional fatigue and depersonalization were observed in 18.1% and 23.2%, respectively; and low levels of personal fulfilment in 21%. Independent risk factors for burnout were currently being fellow/resident (A-OR=2.16,P=0.003), work more than 60 hours per week (A-OR = 1.46, P = 0.032), and not practicing in Latin America (A-OR:NA=2.79,E=1.62,ME= 1.45, Asia = 1.78). Higher levels of emotional fatigue (R = - 0.35, P < 0.0001), depersonalization (R = -0.21, P < 0.0001), and lower levels of personal fulfilment (R = 0.22, P < 0.0001) were associated with lower scores of quality of life in EQ5D.

Conclusion: Burnout is a common condition among spine surgeons worldwide. The overall prevalence was 30.6%, being lower in Latin America (26.2%) and higher in North America (48%). There is a significant association between burnout scores and decreased general quality of life. These results highlight the need for development of interventional programs to better identify, prevent and manage this condition among practicing spine surgeons.

107 The Impact of Older Age on Functional Recovery after Surgical Decompression for Degenerative Cervical Myelopathy: Results from an International, Multicentre, Prospective Dataset in 757 patients.

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Introduction: The role of surgery, and the effect on functional and quality of life (QOL) outcomes, in elderly patients with Degenerative Cervical Myelopathy (DCM) is controversial (1).

Methods: 107 patients over the age of 70 were identified from the 757 patients enrolled in the prospective, multi-centre AOSpine CSM North America and International studies. Functional status (mJOA) and QOL (SF-36) outcomes at 6, 12 and 24 months after surgery were compared with unadjusted univariate analysis and multiple linear regression (to model the effect of age without co-morbidities, smoking, number of operated levels, surgical approach or baseline mJOA).

Results: Baseline mJOA in the elderly group was significantly lower than the younger group (11.0[95%CI 10.4-11.5] vs 12.9[12.7-13.1]; p=<0.01). The unadjusted change in mJOA scores were similar in both groups at 6 months (2.30[1.71-2.88] vs 2.21[2.02 2.40]; p=0.75), 12 months (2.79[2.18-3.41] vs 2.50[2.29-2.70]; p=0.30) and 24 months (2.63[1.99 3.27] vs 2.71[2.51-2.92]; p=0.77). After covariate adjustment, the coefficient for change at 6 months in the elderly group was -0.84(p=<0.01), -0.74 at 12 months(p=<0.01) and -1.22 at 24 months(p=<0.01). Baseline SF-36 physical component summary was unchanged between groups, but the mean change was lower in the elderly group at 6 months, 12 months and 24 months (coefficient of change -3.02[p=<0.01], -1.16 at 12 months[p=0.27] and -3.65 at 24 months[p=<0.01]). SF-36 mental component scores were higher in the elderly group at baseline (43.0[40.6-45.5] vs 39.8[38.7-40.8]; p=0.02), were no different at 6 or 12 months, but were lower at 24 months (2.59[-0.028 5.47] vs 5.96[4.97 6.96]; p=0.01; coefficient of change -4.53, p=<0.01).

Conclusion: In this large prospective dataset, the elderly group demonstrated significantly worse functional and QOL recovery compared to the younger cohort after adjusting for the effect of co-morbidities, number of operated levels, surgical approach and baseline mJOA. Elderly patients undergoing surgery for DCM should therefore be counseled appropriately regarding expectations of surgery.

108 Predictors of Elbow Flexion Outcomes following Reconstructive Nerve Transfers for Brachial Plexus Injury: An analysis of 651 patients

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Introduction: Elbow flexion is perhaps the most important function to restore in the paralyzed upper extremity. There are a variety of reconstructive strategies, with nerve transfer procedures becoming more widely employed over the past decade. The goal of our study was to identify clinical predictors of elbow flexion recovery with a large cohort of patients with brachial plexus injury.

Methods: We retrospectively analyzed prospective data of 651 patients who suffered a brachial plexus injury resulting lost elbow flexion and subsequently underwent reconstructive nerve transfer at a single institution between 1995-2017 by an experienced surgeon. Outcomes in elbow flexion were classified as good (M4-5) or poor (M0-3). Multivariable logistic regression was performed to identify predictors of good outcome.

Results: A total of 651 patients were identified who underwent reconstructive surgery. 434 (66%) patients had a good outcome. Factors associated with a good outcome in our model were age (OR 0.96; P < 0.001), follow up time (OR 1.10; P<0.001), timing of surgery (OR 0.85; P< 0.001), injury location, Ulnar to biceps nerve transfer with (OR 6.52; P< 0.001) or without (OR 5.81; P = 0.003) median to brachialis transfer and intercostals to musculocutaneous nerve transfer(OR 2.54; P=0.009).

Conclusion: Loss of elbow flexion from brachial plexus injury can be repaired with good results in well selected patients regardless of injury type. Age, adequate follow up length, shorter interval before surgical exploration, injury location and surgical technique influence motor outcome.

109 Ambulation on POD#0 is Associated with Decreased Adverse Events After Elective Lumbar Spine Surgery: Analysis of the Michigan Spine Surgery Improvement Collaborative (MSSIC)

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Introduction: The Michigan Spine Surgery Improvement Collaborative (MSSIC) is a multicenter quality improvement collaborative.¹ Using the MSSIC database, we sought to identify the relationship between ambulation on the day of surgery (POD#0) and 90-day adverse events after lumbar surgery, specifically urinary retention (UR), urinary tract infection (UTI), ileus, readmission, surgical site infection (SSI), PE/DVT, and disposition to a rehab facility.

Methods: A total of 23295 lumbar surgery patients were analyzed. Multivariate logistic regression models were constructed, including variables on patient demographics, medical history, and surgical intensity. Matching was performed to account for unknown confounding variables.

Results: POD#0 ambulation was associated with decreased LOS (OR0.83, $p<0.001$), UR (OR0.73, $p=0.008$), UTI (OR0.52, $p=0.001$), ileus (OR0.52, $p<0.001$), 30-day (OR0.84, $p=0.035$) and 90-day (OR0.86, $p=0.009$) readmission, and rehab discharge (OR0.52, $p<0.001$). POD#0 ambulation after single-level decompression (6244 patients) decreased LOS (OR0.72, $p<0.001$), UR (OR0.73, $p=0.004$), UTI (OR0.43, $p=0.003$), and rehab discharge (OR0.18, $p<0.001$). Ambulation after multi-level decompression (5526 patients) was associated with decreased LOS (OR0.73, $p<0.001$), UR (OR0.75, $p=0.04$), ileus (OR0.60, $p=0.027$), and rehab discharge (OR0.44, $p<0.001$). Ambulation after single-level fusion (5790 patients) decreased LOS (OR0.85 $p<0.001$), 30-day readmission (OR0.77, $p=0.032$) and rehab discharge (OR0.65, $p=0.004$). Ambulation after multi-level fusion (5735 patients) decreased LOS (OR0.88, $p<0.001$), UTI (OR0.60, $p=0.003$), ileus (OR0.51, $p=0.02$), 30-day readmission (OR0.77, $p=0.032$), and rehab discharge (OR0.59, $p<0.001$). No change in rate of or DVT/PE was observed for patients who ambulated POD#0.

Conclusion: POD#0 ambulation is associated with a significantly decreased risk for several key adverse events after lumbar spine surgery. Decreasing the incidence of these outcomes would be associated with significant cost savings. As ambulation POD#0 is a modifiable factor in any patient's postoperative care following most spine surgery, it should be encouraged and incorporated into spine related enhanced recovery after surgery (ERAS) programs.

110 Assessing the Differences in Characteristics of Patients Lost to Follow-up at 2 years: Results from the Multi-Site Quality Outcomes Database (QOD) Study of Impact of Fusion on Outcomes of Grade 1 Spondylolisthesis

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Introduction: Loss to follow up has been shown to bias outcome assessment among studies utilizing clinical registries. Previous studies has investigated the reasons why patients are lost to follow up; however, little is known about characteristics of patients that are lost to follow up and how they compare to patients who are captured. Herein, we analyzed patients enrolled in a national surgical registry and compared the baseline characteristics of patients captured with those lost to follow up at 2 years.

Methods: We queried the Quality Outcomes Database for patients with grade 1 lumbar degenerative spondylolisthesis undergoing a surgical intervention between July 2014 and June 2016. Only those patients enrolled in a multi-side study investigating the impact of fusion on clinical and Patient Reported Outcomes (PROs) among patients with grade 1 spondylolisthesis were evaluated.

Results: Of the 608 patients undergoing enrolled in the study, 84% ($n=511$) were successfully followed for 2 years. Patients who were captured were more likely to be unemployed (50.5%, $n=258$ vs 40.2%, $n=39$, $p=0.04$) and at baseline had lower back-pain (VAS-BP 6.5 ± 2.7 vs 7.3 ± 2.4 , $p=0.021$), lower leg-pain (VAS-LP 6.4 ± 2.8 vs 7.3 ± 2.6 , $p=0.006$), lower ODI-score (45.86 ± 16.8 vs 51.04 ± 18.1 , $p=0.007$) and higher EQ-5D-score (0.54 ± 0.22 vs 0.41 ± 0.24 , $p=0.004$) but longer operative time (180.2 minutes ± 87.3 vs 157.8 ± 78 , $p=0.020$). Patients lost to follow-up were more likely to be smokers (16.5%, $n=16$ vs 10.6%, $n=54$, $p=0.032$) and have a history of depression (26.8%, $n=26$ vs 19%, $n=97$, $p=0.05$). Proportion of patients undergoing a fusion surgery did not differ between the two groups (78.4%, $n=134$ vs 80.5%, $n=504$).

Conclusion: To execute future, high-quality study, it is important to identify patients undergoing surgery for spondylolisthesis who might be lost to follow up after surgical intervention. In a large, prospective registry, we found that those who were lost to follow up were more likely to be smokers and depressed.

111 Use of Polyetheretherketone Interbody Devices for Multi-Level Anterior Cervical Discectomy and Fusion Results in a Three-Fold Higher Rate of Pseudarthrosis Compared to Structural Allograft

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Introduction: Common interbody graft options for anterior cervical discectomy and fusion (ACDF) include: 1) structural allograft and 2) polyetheretherketone (PEEK). PEEK has gained popularity due to its radiolucency and elastic modulus similar to bone. Use of PEEK devices results in higher billing than allograft, which may drive selection. A previous study

at our institution found a five-fold higher rate of pseudarthrosis with the use of PEEK devices as opposed to structural allograft in single-level ACDF. Here we follow up those findings with a report on the occurrence of pseudarthrosis of PEEK devices versus structural allograft in patients who underwent multi-level ACDF.

Methods: We retrospectively reviewed 62 consecutive patients who underwent a multi-level ACDF, with at least 1 year of radiographic follow-up. Age, sex, body mass index (BMI), tobacco use, pseudarthrosis, and re-operation rate for pseudarthrosis were collected. Data was analyzed with a Pearson's chi square test.

Results: Of 62 patients, 31 had PEEK implants, and 31 had structural allograft. There were no differences between age, sex, or BMI in the two groups. There were 20/31 (65%) patients with PEEK implants demonstrating radiographic evidence of pseudarthrosis, compared to 6/31 (19%) patients with structural allograft ($p < 0.001$, OR 7.58; CI: 2.39-24.06). Four patients with PEEK implants required re-operation for pseudarthrosis (13%), compared to 0 patients with allograft ($p = 0.014$). There was no difference in tobacco use between the PEEK and allograft groups ($p = 0.154$).

Conclusion: This study reinforces our previous findings on one-level ACDF outcomes, and suggests that the use of PEEK devices in multi-level ACDF also results in a high rate of radiographic pseudarthrosis and need for revision surgery. Surgeons should be aware of these results when deciding on interbody graft options, and reimbursement policies should reflect these discrepancies.

112 The Effect of Peri-Operative Adverse Events on Long-term Patient Reported Outcomes after Lumbar Spine Surgery

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Introduction: Peri-operative adverse events (AE) lead to patient disappointment, resource utilization, and increased healthcare costs. There is a paucity of data on how adverse events affect long-term patient reported outcomes (PRO). The purpose of this study is to examine peri-operative adverse events and their long-term impact on PROs after lumbar spine surgery.

Methods: 3556 consecutive patients undergoing elective spine surgery for degenerative lumbar spine disorders enrolled in the Canadian Spine Outcomes and Research Network (CSORN) prospective database were analyzed. Major and minor adverse events were defined using the validated Spine Adverse Events Severity system (SAVES). Outcomes at 3 and 12 months post-operatively for physical function (Owestry Disability Index (ODI) and SF-12 PCS), pain (visual analog scale (VAS) for leg and back pain) and mental quality of life (SF-12 MCS, and EQ5D).

Results: Adverse events occurred in 767 (21.6%) patients, 85 (2.4%) suffered major AEs, and 682 (19.2%) experienced minor AEs. Patients with major AEs had significantly worse post-operative ODI scores and did not reach minimum clinically important differences at 1 year (Baseline: no AE: 47.515.5, major: 48.214.8, vs. 1 year: no AE 25.519.5, major: 37.319.3, $p < 0.001$). On VAS leg and back, EQ5D, and SF12 PCS the 1 year PROs were significantly different between the major AE group and the no AE group (< 0.01) but these differences were small and unlikely clinically relevant. SF12 MCS scores were not significantly different between the major and no AE cohorts at 1 year. At 1 year post-operatively patients that faced a major AE had significantly lower rates of satisfaction (no AE: 83.5%, major: 71.6%, minor: 82.8%, $p < 0.01$).

Conclusion: Major adverse events during hospital admission after elective lumbar spine surgery lead to significantly worse long-term functional outcomes and lower rates of patient satisfaction. This information highlights the need to implement strategies aimed at reducing in-hospital adverse events.

113 The Influence of Cervical Spondylolisthesis on Clinical Presentation and Surgical Outcome in Patients with Degenerative Cervical Myelopathy: Analysis of a Multicenter Global Cohort of 458 Patients

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Introduction: Cervical Spondylolisthesis (CS) is common amongst patients with Degenerative Cervical Myelopathy (DCM). However, its impact on clinical presentation and surgical outcome have not been well-described. Herein, we compare patients with and without CS on MRI undergoing surgical treatment for DCM.

Methods: 458 MRIs from the AOSpine North America and International Studies were reviewed. CS was identified using MRIs. Patients with DCM were divided into two cohorts, those with CS and those without, and propensity matching was performed. Patient demographics, neurological and functional status at baseline and 2-year follow-up were compared.

Results: Compared to non-spondylolisthesis patients ($n=404$), CS patients ($n=54$) were 8.8 years older ($p < 0.0001$), presented with worse baseline neurological and function status (mJOA, $p=0.008$; Nurick, $p=0.008$; SF-36-PCS, $p=0.01$), more commonly presented with ligamentum flavum enlargement (81.5% vs 53.5%, $p < 0.0001$), were less commonly from Asia ($p=0.0002$), and tended to have more compressed levels ($p=0.052$) and lower prevalence of OPLL ($p=0.098$). There was no difference in sagittal alignment ($p=0.94$). Surgical approach varied between cohorts ($p=0.0002$), with posterior approaches favored in CS (61.1% vs 37.4%). CS patients also had more operated levels (4.3 ± 1.4 vs 3.6 ± 1.2 , $p=0.0002$), and tended to undergo longer operations (196.6 ± 89.2 min vs 177.2 ± 75.6 min, $p=0.087$). The mean improvement of neurological function was lower with CS [mJOA (1.5 ± 3.6 vs 2.8 ± 2.7 , $p=0.003$); Nurick (-0.8 ± 1.4 vs -1.5 ± 1.5 , $p=0.002$)], and CS was an independent predictor of worse mJOA recovery ratio at 2-years ($B=-0.190$,

$p < 0.0001$). After propensity matching, the mean improvement of neurological function was still lower in patients with CS [mJOA (1.5 $\pm$ 3.6 vs 3.2 $\pm$ 2.8, $p < 0.01$); Nurick (-0.8 $\pm$ 1.4 vs -1.4 $\pm$ 1.6, $p = 0.02$)].

Conclusion: CS patients are older and present with worse neurological and functional impairment. Furthermore, they receive surgery on more levels and more commonly from the posterior. CS may indicate a more advanced state of DCM pathology and is more likely to result in a suboptimal surgical outcome.

114 Analysis of the Hierarchical Condition Category (HCC) Score as a Predictor for Increased Risk for Complication and Resource Utilization Following Spine Surgeries

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Introduction: Readily-available preoperative patient predictors of high postoperative resource utilization following lumbar decompression (LD), lumbar fusion (LF), and cervical fusion (CF) have not been clearly established. We propose an automated, predictive model of resource utilization based on readily-available preoperative data identifying patients at higher risk for perioperative complications and resource utilization.

Methods: Preoperative Hierarchical Condition Category (HCC) Score, ASA Score, age, BMI, procedure time, 30-day readmission, reoperation, length of stay (LOS), opioid utilization (MME), and cost hospitalization were collected on spine surgery patients from January 2014 to May 2018. Linear regression was performed on LOS, procedure time, inpatient MME, discharge MME, and cost to identify predictors of HCC quartiles controlling for procedure type. Cost was excluded from multiple regression modeling and analyzed separately due to LOS co-linearity. Student's t-Test and Pearson's chi squared test were used to evaluate differences between surgical procedure types. Two-way ANOVA and Pearson's chi squared analysis was performed to compare postoperative outcomes stratified by HCC Score (Quartile 1 < 0.37 , Quartile 2 $> 0.37-0.70$, Quartile 3 $> 0.70-1.17$, and Quartile 4 $> 1.17-11.27$).

Results: 1,966 inpatient spine surgery cases were identified (551 LD, 592 LF, 823 CF). BMI, ASA, and 30-day readmission were similar across procedures (LD 30.6, 2.5, 3.6%; LF 30.6, 2.5, 4.7%; CF 30.2, 2.4, 3.9%; $p = .265$, $p = .061$, $p = .713$). Significant quartile predictors were identified based on clinical factors modeling ($R^2 = 0.074$) including LOS ($\beta = 4.57E-3$, $p < .0001$), operative time ($\beta = 8.14E-4$, $p < .03$), discharge MME ($\beta = -2.7E-4$, $p < .0002$) and modeling prioritizing cost ($\beta = 6.28E-6$, $p < .0001$) ($R^2 = 0.016$). Across surgical procedures HCC demonstrated significant positive association with 30-day readmission (OR=1.43, 95%CI=1.27-1.62, $p < .0001$) and reoperation (OR=2.08, 95%CI=1.47-2.95, $p < .0001$). LOS ($p < .0001$), duration of procedure ($p < .0001$), discharge MME ($p = .0003$), total cost ($p < .0001$), daily MME ($p = .039$), reoperation ($p < .0001$), and 30-day readmission rate ($p < .0001$) were significantly different between HCC quartiles.

Conclusion: HCC score may hold significant value as a universal preoperative predictor of postoperative resource utilization and may serve as a reproducible tool to target clinical interventions for high risk patients.

115 Surgery for Potentially Unstable Spinal Metastasis Reduces 90-Day-Admissions

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Introduction: The Spinal Instability Neoplastic Score (SINS) helps assess the need for surgery for spinal metastatic disease; however, for potentially unstable lesions (SINS 7-12) the benefit is unclear. The role of surgery is palliative to improve quality of life as prognosis is dictated by systemic disease. Therefore, allowing patients to return to daily life while limiting hospitalization is paramount. This study assesses the role of surgery in reducing 90-day-admission for potentially unstable spinal lesions.

Methods: Patients with lesions SINS 7-12 treated for spinal metastatic disease from 2010-2015 retrospectively assessed. Patients were grouped as no surgery or surgery prior to radiotherapy. 90-day-admissions rates after radiotherapy was assessed in each group, along with the impact of the following factors: high grade epidural spinal cord compression (ESCC), radiosensitivity, local control, development of fractures, and hypofractionation of radiation.

Results: 61 patients with SINS 7-12 were treated: 44 in no surgery and 17 in surgery prior to radiotherapy. 90-day-admission rates were higher in the nonsurgical group (54.5% vs. 5.9%, $p = 0.001$). Spine-pathology related admissions were 18.2% nonsurgical vs. 0% surgical groups. The 1 surgical admission was for ileus. Counterintuitively, ESCC was associated with lower admission (13.3% vs. 50.0%, $p = 0.012$); however, is explained as high ESCC correlated to greater likelihood for surgery (58.9% vs. 11.4%, $p < 0.001$). Local control did not impact 90-day-admission (48.6% vs. 29.2%, $p = 0.131$), nor did tumor radiosensitivity (45.5% vs. 35.8%, $p = 0.441$). The development of fractures had higher admission (100% vs 37.9%, $p = 0.033$). When controlling for above factors only surgery and development of fractures correlated to reduced 90-day-admission ($p = 0.019$ and $p = 0.040$). The nonsurgical group had greater fractures (6.82% vs. 0%).

Conclusion: Surgery for potentially unstable metastasis reduces 90-day-admission rates. Development of fractures increases 90-day-admission rates, likely due to pain. Local control does not reduce admission, showing that treatment should focus on quality of life rather than solely tumor control.

116 Teriparatide Treatment Improves Bone Quality in the Lumbar Spine Out of Proportion to DEXA Changes

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Introduction: Teriparatide has been used to improve bone quality when considering spinal fusion surgery in patients with osteoporosis. Hounsfield units (HU), a standardized measurement for radiodensity, can be obtained on routine computed tomography (CT) scans, while dual energy x-ray absorptiometry (DEXA) is the standard test for bone density. The objective of this study was to compare changes in bone quality in the lumbar spine between HU measurements and DEXA following Teriparatide treatment.

Methods: A retrospective chart review was performed from 1997 to 2018 across all campuses at our institution. We identified patients who had been treated with at least 6 months of Teriparatide with a CT scan and DEXA scan before and after therapy. HU were measured from L1-L4 with three measurements per vertebral body using previously reported methodology (Figure 1).

Results: Fifty two patients (46 women, six men) were identified for analysis with an average age of 66.5 years who underwent an average of 20.9 months of Teriparatide therapy. Average HU improvement throughout the lumbar spine (L1-L4) was from 109.8 to 133.9 [(p-value 0.039, 95% CI 1.2-46.1) Figure 2]. Each individual lumbar level also had an average improvement in HU but only L1 was statistically significant (L1 improved from 112.4 to 139.2 with a p-value of 0.013, 95% CI 5.6-46.9). Based on DEXA results, BMD (measured in g/cm²) in the lumbar spine improved from 0.84 to 0.93 [(p-value 0.044, 95% CI 0.003-0.2) Figure 3], while average femoral BMD only improved from 0.65 to 0.67 and was not statistically significant (p-value 0.43).

Conclusion: Teriparatide treatment improved BMD based on HU and DEXA in the lumbar spine, without a change in femoral BMD. The improvement in HU out of proportion to the DEXA results supports some surgeons' subjective sense that intraoperative bone quality following Teriparatide treatment is better than indicated by DEXA results.

117 Which patients undergoing ACDF are most appropriate for an ambulatory surgery center? A pilot study

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Introduction: Ambulatory surgery centers (ASCs) are becoming increasingly utilized for spine operations and represent an enormous opportunity for cost-saving. However, ASCs are under increasing scrutiny for profit-driven motives and inability to handle complications. Using a national inpatient cohort undergoing ACDF with short hospitalization as a surrogate for a potential ASC population, the current objectives were to: 1) outline factors that can delineate which patients are best suited for an ambulatory versus inpatient setting, and 2) describe potentially catastrophic complications.

Methods: Adults who underwent ACDF between 2011 and 2014 were identified in the National Surgical Quality Improvement Program (NSQIP) database. Inclusion criteria were: principal procedure ACDF (CPT 22551, 22552), elective, neurologic/orthopaedic surgeons, length of stay (LOS) 0/1 days, and discharged home. The primary outcome was presence of any complication. The secondary outcome was occurrence of potentially catastrophic complications. Univariate/multivariable logistic regression was completed.

Results: A total of 12,169 patients underwent elective ACDF with a LOS of 0/1 nights and were discharged home. A total of 179 (1.5%) patients experienced a complication. Univariate logistic regression revealed the following factors were significantly associated with a complication: age, Charlson comorbidity index (CCI), modified frailty index, ASA score, HTN, diabetes, COPD, cardiac intervention, TIA/CVA, abnormal labs (bilirubin, hematocrit, platelets, INR), and operative time >2hrs. The following factors remained significant after multivariable testing: CCI, ASA score, TIA/CVA, operative time. A total of 51 (0.4%) patients experienced potentially catastrophic complications.

Conclusion: Using a national inpatient database, the current results represent a preliminary, pilot analysis in selecting which patients may be safely treated in the ambulatory setting. The incidence of potentially catastrophic complication was 0.4%. Though not a true ambulatory population, by using patients who were discharged home with a short hospitalization, these results can be validated in spine-specific databases to further optimize selection of patients most appropriate for ASCs.

118 Residual Exposed Endplate Predicts High Grade Heterotopic Ossification in Cervical Disc Arthroplasty

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Introduction: Cervical disc arthroplasty (CDA) is an accepted motion sparing technology associated with favourable patient outcomes. However, heterotopic ossification (HO) is a complication of CDA that is poorly understood. From experience, we hypothesized that HO could be predicted by the amount of endplate left exposed after implantation. The purpose of this study was to examine this hypothesis in a consecutive cohort of our CDA patients.

Methods: A retrospective cohort study was performed on consecutive adult patients (>=18 years) who underwent 1- to 2-level CDA at our institution between 2002-2015 and had >1-year follow-up. The residual exposed endplate (REE) was determined by subtracting the distance between the anterior and posterior margins of the vertebral body by the diameter of the arthroplasty device on lateral radiographs. HO was determined using the McAfee classification. A

multivariable regression model was used to evaluate the relationship between REE and high-grade HO (McAfee grade 3 and 4).

Results: Forty-five patients underwent CDA during the study period. The mean age was 46 years (SD:9.5). Median follow-up was 29 months (IQR:42). Thirty-three patients (73%) underwent 1-level CDA. Nineteen (33%) developed high-grade HO. The mean REE for patients with high-grade HO was 0.9 mm larger compared to patients with low-grade HO ($p=0.02$). On univariate analysis, patients with $>2\text{mm}$ REE had higher odds of developing high-grade HO (OR 4.0, $p=0.02$). In the multivariable model, REE $>2\text{mm}$ remained significant in predicting the development of high-grade HO (OR 4.5 [95%CI 1.3-15.02], $p=0.01$). No significant relationship was observed between the type of artificial disc and the development of high-grade HO ($p=0.1$).

Conclusion: In our CDA series, patients with $>2\text{mm}$ of REE were at 4.5 times higher odds of developing high-grade HO, irrespective of device type. Maximizing the implant-endplate interface may help to reduce high-grade HO and preserve motion.

119 Drivers of Episode Payments for Non-Cervical Spinal Fusion

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Introduction: Because of alternative payment models (APMs) developed by Centers for Medicare & Medicaid Services, payments for spine surgery now follow Bundled Payments for Care Improvement models. The objective is to determine drivers of episode payments among different hospital payment quartiles

Methods: The Michigan Value Collaborative was retrospectively queried for 90-day episodes of care for non-cervical fusions. Hospitals were partitioned into four-equally sized quartiles based on episode payments.

Results: Of 10,168 non-cervical spinal fusions, 90-day episode payment averaged \$42,879. The difference of \$8,371 between the highest payment hospitals (\$47,124) and lowest payment hospitals (\$38,753) reached statistical significance (17.7% difference, $p<0.0001$). Index hospitalizations accounted for majority of payments: 73.3% in the first, 69.1% in the second, 63.8% in the third, and 62.5% in the fourth quartile. Between the highest- and lowest-quartile hospitals, the greatest variation was actually attributable to post-acute care (\$7,478 vs \$3,178, $p<0.0001$) followed by professional fees (\$7,675 vs \$5,836, $p<0.0001$), readmissions (\$2,497 vs \$1,307, $p=0.018$), and index hospitalizations (\$29,474 vs \$28,432, $p=0.019$). In other words, 51.4% of the total \$8,371 episode payment difference between the highest- and lowest-quartile hospitals derived from post-acute care followed by 22.0% in professional fees, 14.2% in readmissions, and 12.4% in index hospitalizations. Upon examining subcomponents of post-acute care payments, the largest difference between highest- and lowest-quartile hospitals was \$2,169 for inpatient rehab ($p=0.004$) followed by \$1,822 for skilled nursing facility ($p=0.007$), and \$785 for home health ($p=0.007$).

Conclusion: Post-acute care, namely rehabilitation service is the primary driver of variations in 90-day bundled payments for non-cervical fusions.

120 Retrospective Review of Immediate Restoration of Lordosis in Single-level Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF): A Comparison of Static and Expandable Interbody Cages

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Introduction: Sagittal alignment is becoming an increasingly important consideration in spine surgery. The literature is conflicted regarding the effect of MI-TLIF on sagittal parameters and the role of expandable cage technology. We aimed to compare the lordosis generated by static and expandable cages in order to determine if there is a benefit of expandable cages in minimally invasive TLIF (MI-TLIF) and determine what factors affect segmental lordosis and foraminal decompression.

Methods: Pre-operative regional lordosis(RL), segmental lordosis(SL), and posterior disc height (PDH) were compared to post-operative values in patients undergoing single-level MI-TLIF using expandable or static interbody cages. Patients were stratified based on pre-operative SL: low lordosis (<15 degrees), moderate lordosis (15-25 degrees), and high lordosis (>25 degrees). Regression analyses were conducted to determine factors associated with post-operative SL and PDH.

Results: 171 patients were included; 111 in the static and 60 in the expandable cohorts. Patients with low pre-operative lordosis experienced an increase in SL and maintained RL regardless of cage type. Those with moderate to high pre-operative lordosis experienced a decrease in SL and RL with the static cage but maintained SL and RL with the expandable cage. Although both cohorts showed an increase in PDH, the increase in the expandable cohort was significantly greater. Pre-operative SL was predictive of post-operative SL and pre-operative SL, pre-operative PDH and cage-type were predictive of post-operative PDH. Cage position was not related to postoperative SL or PDH.

Conclusion: Expandable cages showed favorable results in restoring posterior disc height and maintaining lordosis in the immediate post-operative period. Cage position did not impact the restoration of lordosis or posterior disc height. Pre-operative segmental lordosis was the most significant predictor of post-operative segmental lordosis. Thus, pre-operative radiographic parameters and goals of the surgery should be important considerations in surgical planning.

121 Posterior Cervical Fusion: Analysis of Revision Rate Related to Crossing the Cervicothoracic Junction

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Introduction: Posterior cervical fusion (PCF) is frequently used to treat cervical myelopathy, radiculopathy, and/or deformity. Constructs ending at the cervicothoracic junction may lead to adjacent segment disease, and debate exists regarding the need to cross the cervicothoracic junction due to paucity of published data.

Methods: A single-center retrospective review of all patients undergoing three-or-more level PCF by five spine surgeons after June 2011 with at least 6 months follow-up was conducted. Clinical outcomes were analyzed and compared based on caudal extent of instrumentation. Multivariate regression analysis of the primary outcome, need for revision surgery, and the secondary outcomes, procedure duration, estimated blood loss and hospital stay, was completed.

Results: 139 patients underwent PCF and met inclusion/exclusion criteria, with mean follow-up duration of 19 months. 55 (39.6%) of constructs ended at C6, 18 (12.9%) at C7, 37 (26.6%) at T1, and 29 (20.9%) at T2. 13 (9.4%) revisions were performed, 5 (3.6%) of which were related to pseudarthrosis or adjacent segment disease. 3 (5.5%) revisions were performed for constructs ending at C6, 1 (5.6%) at C7, 2 (5.4%) at T1, and none (0%) at T2 ($p=0.072$). Mean procedure duration was 211min at C6, 221min at C7, 236min at T1, and 337min at T2 ($p=0.00$). Mean estimated blood loss was 224cc at C6, 178cc at C7, 308cc at T1, and 575cc at T2 ($p=0.00$). Mean hospital stay was 9.5 days at C6, 6.4 days at C7, 4.9 days at T1, and 12.2 days at T2 ($p=0.944$).

Conclusion: Extension of PCF across the cervicothoracic junction trends towards lower revision rates without reaching statistical significance, but also leads to statistically significantly increased procedure duration and estimated blood loss. As such, decisions regarding the caudal extent of PCF constructs must weigh the risk of pseudarthrosis against the risk of longer procedures with higher blood loss on case-by-case basis.

122 Utility of Crossing the Cervicothoracic Junction During Laminectomy and Posterior Spinal Fusion Surgery for Cervical Spondylotic Myelopathy

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Introduction: In laminectomy and posterior spinal fusion (PSF) surgery for cervical spondylotic myelopathy (CSM), the evidence is unclear as to whether the lower instrumented vertebrae (LIV) should cross the cervicothoracic junction (CTJ). This study compares outcomes between those with and without LIV crossing the CTJ.

Methods: Adults undergoing PSF for CSM from May 2012 through July 2018 were identified. Patients were included who underwent PSF with sub-axial upper instrumented vertebrae and LIV between C6 and T2. Outcomes were compared.

Results: 114 patients were included: 67 who crossed the CTJ (crossed-CTJ) and 47 who did not cross the CTJ (not-crossed CTJ). Not-crossed CTJ had worse baseline visual analog scale (VAS) neck pain scores (5.5vs.3.8, $p=0.04$), but similar Nurick scores. Crossed-CTJ had higher preoperative C2-7 sagittal vertical axis (SVA) (34.3vs.26.8mm, $p=0.03$), but similar preoperative cervical lordosis (CL) and T1-slope. Postoperative SVA, CL, and T1-slope did not differ significantly. Crossed-CTJ were associated with increased blood loss (373.5vs.212.2 ml, $p=0.001$), longer operative times (217.4vs.172 min, $p<0.001$), but similar hospital stays (5.2vs.4.2days, $p=0.13$) and discharge dispositions (67.2%vs.66.0% to home, $p=0.89$). The reoperation rate was 4.4% overall. For crossed-CTJ, there was 1 reoperation (1.5%) for irrigation and debridement (I&D) and no cases of pseudarthrosis or hardware misplacement/failure requiring reoperation (0%). For not-crossed CTJ, there were 3 reoperations (6.4%) involving 2 I&Ds and a single reoperation for pseudarthrosis and hardware misplacement/failure (2.1%). The latter involved a C7 screw with nerve root impingement. At final follow-up, VAS neck pain and Nurick scores were similar. Final follow-up change scores (i.e., latest follow up value - baseline) for VAS neck, Nurick, CL, T1-slope, and SVA were similar. Mean follow-up was 13.5 months.

Conclusion: Crossed-CTJ were associated with greater blood loss and operative times, but no cases of pseudarthrosis or hardware misplacement/failure requiring reoperation. Both crossed-CTJ and not-crossed CTJ had similar neurological and radiological improvement.

200 Evaluation of Same Day Discharge Following Stand Alone Single Level Lateral Lumbar Interbody Fusion

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Introduction: Increasing evidence suggests safety of outpatient lateral interbody fusion (LLIF). Recently, our institution adopted "same-day" discharge criteria for patients undergoing a single level LLIF. The purpose of this exploratory study was to demonstrate the feasibility and safety of same day surgery for single level LLIF procedures.

Methods: Consecutive patients undergoing single level LLIF for a variety of indications were identified. Criteria for same day discharge were single level LLIF procedure without additional hardware, controlled post-operative pain and nausea, and no intra-operative complications. Patients being discharged "same day" (same as operative day) were identified retrospectively. Patients were analyzed for factors that may have contributed to outpatient versus inpatient hospital course.

Results: 9 patients were discharged same-day, while 5 were admitted for at least 22 hours. Average time until discharge for the same-day group was 2 hours and 41 minutes. Admitted patients were discharged on average 54.6 hours after admission. 10 criteria associated with pre-operative and operative course were analyzed. Notable differences between the cohorts include shorter operative time in the same-day group (1.17 hours vs 0.9 hours, $p=0.054$), and lower BMI (33.48 vs 28.9, $p=0.16$). Within the inpatient cohort, 4 patients were admitted due to significant post-operative pain, with one patient having both significant pain and nausea requiring additional management. One patient was primarily admitted for lack of social support preventing same day discharge. No patient experienced an adverse intra-operative or peri-operative complication.

Conclusion: Same-day discharge appears to be a feasible, safe, and effective approach for patients undergoing a single level lateral lumbar interbody fusion. While we were unable to determine any statistically significant pre-operative or intra-operative factor that may have contributed to patients requiring post-operative admission, we believe larger-scale analysis will be valuable in establishing criteria for planned outpatient LLIF and reducing surgical costs.

201 Perioperative and Postoperative Complications of Multi-level Minimally Invasive Transforaminal Lumbar Interbody Fusion for Spinal Degeneration in the Elderly

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Introduction: Elderly patients undergoing traditional open spinal surgery are considered having high complication risk.¹ 3 Perioperative and postoperative complications risks for the elderly undergoing minimally invasive (MIS) multi-level transforaminal lumbar interbody (MLTLIF) fusion are not well studied.⁴ 6 We sought to demonstrate that MIS MLTLIF can be safely performed in the elderly.

Methods: A retrospective analysis was performed on consecutive patients aged 70 or older who underwent ML (> 2 level) MIS TLIF at a single institution from 2013-2017. Patients were excluded if the surgery was performed for non-degenerative etiologies. Electronic Medical Records were analyzed for patient demographics, procedures, and perioperative and postoperative complications. Complications were defined as major or minor based on Carreon's classification.² Postoperative period was defined as 30 days after surgery and perioperative period was defined as the duration of hospitalization.

Results: One-hundred-fifty-four patients underwent MIS MLTIF. Their average age was 76.4 years (range 70-90). Patient demographics and perioperative characteristics are detailed in Table 1. We observed 13 major (8.44%) 74 minor (48.05%) complications (Table 2) with 67 patients (43.5%) experiencing at least one major or minor complication (Table 3). The 13 major complications included acute kidney injury (4/2.60%), wound seroma and/or hematoma (3/1.95%) requiring surgical evacuation, pneumonia (2/1.30%), pulmonary embolism (1/0.65%), epidural abscess (1/0.65%), respiratory distress (1/0.65%), and adjacent level fracture (1/0.65%). The primary minor complications which occurred were anemia requiring transfusion and urinary retention. There were no myocardial infarctions, hardware complications, major visceral, vascular, neural injuries, or death. The complication rate per fusion level is shown in table 4. Estimated blood loss for the number of levels fused is shown in Figure 1.

Conclusion: MIS MLTLIF can be performed in the elderly (70 years and older) with a major complication rate comparable to other MIS TLIF studies in the elderly^{4,7} and more favorable when compared to traditional open MLTLIF.^{2,3,8,9}

202 Clinical Efficacy, Accuracy, and Radiation Reduction Using Instrument Tracking and Ultra-low Radiation Imaging in Minimally Invasive Surgery

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Introduction: Image-guided surgery (IGS) reduces blood loss, morbidity, and pain associated with open spine surgery, but it is associated with a substantial increase in patient radiation, operating room time, and a change in surgeon workflow. The principle of ultra-low radiation imaging with image enhancement, coupled with simultaneous instrument tracking (ULRI-IE/IT) is an IGS principle that can be used to reduce procedural radiation exposure, increase surgeon accuracy, and reduce operative time; however, there is currently a lack of clinical data to support or refute this claim.

Methods: A randomized study was performed evaluate radiation exposure, accuracy, and operative time of ULRI-IE/IT compared to conventional fluoroscopy. Consecutive spine procedures involving multiple levels or left and right-sides were included so that each level could be randomized to either ULRI-IE/IT or standard c-arm fluoroscopy. Number of images taken, radiation, and time to perform each task with or without ULRI-IE/IT were recorded. Given that this was a limited trial, identical cases that did not utilize the technology had similar data recorded in order to supplement the control arm.

Results: Ten study patients and three control patients were enrolled in this trial. The tasks studied included skin marking, placement of an initial dilator, and instrument localization for hardware placement. Forty-one total levels had internal controls. Overall, ULRI-IE/IT resulted in radiation reduction of 86% ($p<0.001$), as well as an 80% overall reduction in localizing images ($p<0.001$). Overall time reduction was 74% ($p<0.001$). Cumulatively, ULRI-IE/IT resulted in 123 minutes of saved operating room time. Statistical significance was seen for each procedure type and each surgeon studied.

Conclusion: ULRI-IE/IT drastically reduced operating room radiation, x-rays required, and procedural time. To date, this is the first clinical study showing that IGS technology using ULRI-IE/IT can make a surgeon safer and more efficient in the OR without significantly impacting preoperative or intraoperative time.

203 Minimally Invasive Tethered Cord Release in the Pediatric Population

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Introduction: Minimally invasive spinal operations have become more prevalent in the past decade and indications are expanding. Tethered cord syndrome (TCS) refers to an abnormally low-lying conus medullaris. Most children present with symptoms such as chronic back pain, leg weakness, incontinence, or scoliosis. We present the first series of minimally invasive muscle sparing tethered cord release (TCR) in the pediatric population.

Methods: A retrospective review of the Texas Children's Hospital Neurosurgical database was conducted for patients that underwent surgical release of tethered cord between 2010 and 2017. Charts were reviewed to determine the source of TCS and if TCR was conducted in a minimally invasive fashion. To establish a cohort of control population, age-matched cases of open TCR were selected in the same time frame to match the number of MIS cases. Exclusion criteria were non-fatty filum sources of TCS. The length of stay, operative time, estimated blood loss (EBL), and post-operative complications were recorded.

Results: Eleven patients underwent tubular TCR and eleven age-matched patients who underwent open TCR were included in data analysis. The average age of patients in both MIS and open cohorts were 10.1 ± 4.6 years and 9.5 ± 4.5 years, respectively ($p = 0.61$). The most common presenting symptom was neurogenic bladder. There was no difference in the mean operative time. There was significantly lower average EBL in the MIS group when compared to the Open group (8.2 vs 16.8, $p = 0.04$). The MIS group was found to have a significantly shorter hospital length of stay compared to the open group (2.6 days vs 3.7 days, $p = 0.04$). There were no complications in either cohort.

Conclusion: Minimally invasive muscle-sparing TCR is a safe and effective operation. Our study shows promising data regarding shorter hospital length of stay while preserving natural anatomy and minimizing tissue trauma.

204 Early Surgical Outcome of Open Lumbar Discectomy versus Endoscopic Lumbar Discectomy

Muhammad U. Anwar MBBS, MS; Abdul Hameed

Introduction: Backache is the second most common problem presented to the primary health care providers. A severe lower backache radiating towards ipsilateral leg, in the distribution of spinal nerve involved, is known as Sciatica, and Lumbar Disc Herniation is an important cause of such a pain. Open Lumbar Discectomy has always been the procedure of choice for Lumbar Disc Herniation. However, the Endoscopic approach allows even smaller incisions and less tissue trauma, compared to the former. Despite its advantages, the application of Endoscopic Lumbar Discectomy has been a matter of controversy.

Methods: This study was a Randomized Control Trial, and conducted in Neurosurgery Department of Sir Ganga Ram Hospital Lahore, from 13 March 2017 to 13 March 2018. A sample size of 80 cases (2 groups, 40 in each) was included.

Results: The Wound Site Pain Score after Endoscopic Lumbar Discectomy was 1.33 ± 0.62 , while in patients of Open Discectomy, Pain Score was 4.03 ± 1.67 ($p=0.001$). Mean Hospital Stay was 1.53 ± 0.68 days in Endoscopic Lumbar Discectomy Group while it was 2.4 ± 1.24 days in Open Discectomy Group ($p=0.002$).

Conclusion: The results of Endoscopic Lumbar Discectomy are acceptable, safe and effective as compared to Open Lumbar Discectomy.

205 Impact of Lower Thoracic vs. Upper Lumbar UIV in MIS Correction of Adult Spinal Deformity

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Introduction: Selecting the UIV in the region of the thoracolumbar junction when using MIS for ASD correction may allow for greater feasibility in choosing the upper lumbar (UL) region. The impact of choosing the upper lumbar vs. lower thoracic spine for the UIV when correcting ASD via MIS techniques has not been well-elucidated.

Methods: Multicenter retrospective review of an adult spinal deformity database. Inclusion criteria were age ≥ 18 years, and one of the following: coronal cobb $> 20^\circ$, SVA $> 5\text{cm}$, PT $> 20^\circ$, pelvic incidence-lumbar lordosis $> 10^\circ$. Patients were treated with circumferential or hybrid minimally invasive techniques at ≥ 3 spinal levels, and had 2-year minimum follow-up. They were then divided by UIV location of L1-2 (UL) or T10-12 (LT).

Results: 112 patients met inclusion criteria (68 LT and 46 UL). The UL group was older (67.5 vs. 62.3 ; $p=0.015$), but preoperative spinopelvic parameters were similar, except for sacral slope, which was higher in the UL group (30.5 vs. 26.5 ; $p<0.001$). The percentage of patients with fixation crossing the lumbosacral junction was also similar (70.6% vs. 67.4% , $p=0.717$). Postop LL (41.4 vs. 37.3 ; $p=0.01$) and ? Cobb (-23.2 vs. -9.6 ; $p<0.001$) were greater in the LT group, but the remainder of postop spinopelvic parameters and changes, as well as HRQOLs were similar between groups. Reoperation rates were lower in the UL group (17.4% vs. 36.8% ; $p=0.025$), largely as a result of less frequent

radiographic failures (UL=10.9% vs. LT=26.5%; $p=0.042$); however, overall complication rates were not different (60.3% vs. 43.5%; $p=0.077$).

Conclusion: Choosing an upper lumbar vertebra for UIV when correcting ASD with MIS techniques results in lower reoperation rates than when extending fixation to the lower thoracic region. It was also associated with shorter operative times and less EBL. Extending fixation to the LT was associated with slightly higher LL and greater change in coronal Cobb, but this was not associated with better clinical outcomes compared to when the UIV was in the UL region.

206 Is Achieving Optimal Spinopelvic Parameters Necessary to Obtain Substantial Clinical Benefit: Analysis of Patients Who Underwent Circumferential MIS or Hybrid Surgery with Open Posterior Instrumentation

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Introduction: It has been proposed that achieving optimal spinopelvic alignment is needed to attain clinical improvement. This study assessed whether obtaining optimal spinopelvic alignment was necessary to achieve a minimal clinically important difference (MCID) or substantial clinical benefit (SCB).

Methods: Multicenter retrospective review. Inclusion criteria were age ≥ 18 years, and one of the following: coronal cobb $>20^\circ$, SVA $>5\text{cm}$, PT $>20^\circ$, PI-LL $>10^\circ$. Patients underwent circumferential MIS or hybrid surgery and had 2-year minimum follow-up. Based on optimal spinopelvic parameters (PI-LL $\pm 10^\circ$, PT $<20^\circ$, SVA $<5\text{cm}$), patients were divided into aligned (AL) or mal-aligned (MAL) groups. MCID and SCB were defined as a 12.8 and 18.5 ODI improvement, respectively.

Results: 153 patients were identified (74 AL and 149 MAL). Although baseline SVA was similar, PI-LL (9.9° vs 17.7° , $p=0.002$) and PT (19° vs 24.7° , $p=0.001$) significantly differed between AL and MAL groups, respectively (Table 1). As expected postoperatively, the AL and MAL groups differed significantly in PI-LL (-0.9° vs 13.1° , $p<0.001$), PT (14° vs 25.5° , $p=0.001$), SVA (11.8mm vs 48.3mm , $p<0.001$), respectively. There was no difference in the proportion of AL or MAL patients who achieved MCID (52.75 vs 61.1%, $p>0.05$) or SCB (40.5% vs 46.3%, $p>0.05$), respectively. On multivariate analysis controlling for surgical and demographic differences, achieving optimal spinopelvic parameters was not associated with achieving MCID (OR 0.645, 0.31-1.33, 95%CI) or SCB (OR 0.644, 0.31-1.35, 95%CI) ODI.

Conclusion: Achieving optimal spinopelvic alignment did not appear to be a predictor for obtaining a MCID or SCB. Since spinopelvic parameters are correlated with clinical outcomes, our findings suggest that other factors such as age may influence the radiographic thresholds (SVA, PT, PI-LL) needed to achieve meaningful improvement.

207 Does Extension Dysfunction Affect Postoperative Loss of Cervical Lordosis in Patients who Undergo Laminoplasty?

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Introduction: Recent studies have focused on the correlation between LCL after laminoplasty and T1 slope. These studies explain this correlation through the injury of the posterior neck muscular-ligament complex (PMLC); however, this muscle injury model could not explain the less kyphotic change in high T1s patients, as reported in some studies as controversy. We have focused on the PMLC constriction reservoir which was represented by extension function (EF).

Methods: We retrospectively analyzed 50 consecutive patients who underwent open-door laminoplasty (>1 -year follow-up). EF is defined as extension C2-7 Cobb's angle (CA) minus neutral C2-7 CA (Ext CA - CA). LCL is defined as follow-up CA minus preoperative CA [CA (FU) - CA (PRE)], and significant kyphotic change was defined as LCL $<-10^\circ$.

Results: The distribution of LCL was -3.70 ± 7.98 and the significant kyphotic change occurred in 20% of the patients (10/50). EF, C2-7 sagittal vertical axis (PRE), and C2 slope (PRE) were found to be risk factors for LCL by multiple linear regression analysis. The receiver operating characteristic curve analysis revealed that EF could predict the significant kyphotic change well than previously known risk factors. The cutoff value of EF was 14° . No significant kyphotic change occurred at EF $=14^\circ$. Upon limiting the number of patients with preoperative straight curvature ($n=28$), there is also no significant kyphotic change occurred in any patient whose EF was $=14^\circ$.

Conclusion: In our study sample, we found that there is no relation between T1 slope and LCL. We have identified a new factor, EF, that could predict LCL after laminoplasty. No significant kyphotic changes after laminoplasty extension particularly when the EF was $=14^\circ$.

208 Influence of Prosthesis Design on the Relationship Between Preoperative and Postoperative Flexion-Extension ROM After Cervical Disc Arthroplasty

Avinash G. Patwardhan PhD; Saeed Khayatzadeh PhD; Robert M. Havey

Introduction: Biomechanical goals of cervical disc arthroplasty are to: (1) restore physiologic motion, and (2) maintain stability at the index segment. In a patient with limited mobility at the index segment disc arthroplasty should restore normal physiologic motion. Conversely, if a motion segment is hypermobile, the prosthesis should restore stability by eliminating hypermobility. We investigated the influence of prosthesis design on the relationship between preoperative

and postoperative FE-ROM after cervical disc replacement using fixed-core, mobile-core, and restrained compressible-core prostheses.

Methods: Sixty-Five C5-C6 and C6-C7 motion segments were tested using identical methodology. The flexion-extension motions of cervical segments before and after disc replacement were investigated using 5 different cervical disc prostheses classified into 3 design groups: Fixed-Core (N=33); Mobile-Core (N=16); and Restrained Compressible-Core (N=16).

Results: Fixed-Core and Mobile-Core: FE-ROM after disc replacement was positively correlated with preoperative FE-ROM ($p<0.05$) (Figure 1a-b). Preoperative FE-ROM ranged from 5 to 20 degrees; whereas, motion after disc replacement was as high as 24 degrees. Restrained Compressible-Core: FE-ROM after disc replacement was not correlated with preoperative FE-ROM ($R^2=0.17$, $p=0.12$) (Figure 1c). Preoperative FE-ROM ranged from 5 to 21 degrees; whereas, motion after disc replacement ranged 8 to 17 degrees.

Conclusion: We observed that disc replacement using either a fixed-core or moving-core design yielded postoperative FE-ROM that was positively and significantly correlated with preoperative FE-ROM ($p<0.05$). Arthroplasty with the mobile-core prosthesis allowed segmental motions far exceeding the physiologic range; with 6/16 implanted segments yielding motions of 20 degrees or greater. Following disc arthroplasty using a restrained compressible-core prosthesis, segments with limited mobility had physiologic ROM whereas hypermobile segments showed more controlled postoperative motion. These results suggest that a restrained compressible-core prosthesis that provides progressive resistance to angular motion like the natural anatomy, can better achieve both goals of restoring physiologic motion without sacrificing stability.

209 Indirect Decompression of Lumbar Spinal Stenosis Following Minimally Invasive Transforaminal Lumbar Interbody Fusion

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Introduction: Minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) is increasingly utilized in the treatment of degenerative conditions of the lumbar spine. The restoration of disc height and lumbar sagittal alignment following MIS-TLIF provides indirect decompression of the neuroforamina, however its effects on central canal stenosis are not well characterized. We aim to evaluate clinical outcomes and radiologic variables of sagittal segmental alignment and central canal dimensions in patients with concurrent lumbar spinal stenosis undergoing MIS-TLIF.

Methods: We conducted a retrospective review of MIS-TLIFs performed between 2014 and 2018. We identified patients who had both preoperative and postoperative upright lateral radiographs and magnetic resonance imaging (MRI) of the lumbar spine. MRI scans were analyzed for changes in central canal dimensions. Radiographic measurements included disc and neuroforaminal height, segmental lordosis, and spondylolisthesis.

Results: Of the 74 consecutive patients who underwent 81 MIS-TLIFs, we identified 18 patients with 20 levels of intervention (Age 58.3 ± 9.1 years, Mean $\pm$ SD; 66.7% Female), predominantly L4/5 (65%). Expandable interbody devices were utilized in 50% cases. No additional central canal decompression was performed beyond the limited facetectomy to access the disc space. Follow-up duration after surgery was 26.5 ± 11.3 months. Patient-reported clinical outcomes were significantly improved postoperatively. The anteroposterior dural sac diameter increased from 9.9 ± 0.6 mm (Mean $\pm$ SEM) preoperatively to 13.2 ± 0.5 mm postoperatively ($P<0.001$). Transverse dural sac diameter increased from 12.2 ± 0.6 mm to 16.5 ± 0.6 mm ($P<0.001$). There was a significant reduction in spondylolisthesis. The percentage offset of one vertebra over its adjacent segment decreased from $12.4\pm 2.4\%$ to $6.3\pm 1\%$ ($P<0.01$). Patients experienced significant increases in segmental disc height and lordosis, but neuroforaminal height was not significantly increased. Similar changes were observed within and between static and expandable cage subgroups; however, the magnitudes of disc height and segmental lordosis correction were greater with expandable cages.

Conclusion: MIS-TLIF results in successful indirect decompression of the central spinal canal, without additional posterior decompressive procedures.

210 Percutaneous Transforaminal Lumbar Interbody Fusion with an Expandable Cage Through Kambin's Triangle: Initial Results and Feasibility

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Introduction: Minimally-invasive transforaminal lumbar interbody fusion (MIS-TLIF) is a common procedure in lumbar spine fusion. Typically, a medial facetectomy is performed, allowing access to the intervertebral disc, and allowing the insertion of a cage. Percutaneous access to the disc through Kambin's triangle obviates the need for a medial facetectomy and is thus hypothesized to decrease patient morbidity and pain. Most authors have described the use of static cages through this approach or the use of a porous allograft-containment mesh. In this paper, we describe the clinical outcomes and feasibility of percutaneous TLIF with an expandable cage through Kambin's triangle.

Methods: A retrospective review of patients undergoing percutaneous TLIF via Kambin's triangle with an expandable cage was performed. Demographic information, pre- and postoperative radiographic factors, perioperative data, and complications were recorded.

Results: Five total patients (1 male) were included in this study. Average age was 62.8 ± 9.8 years, and average BMI was 31.6 ± 7.1 kg/m². Average preoperative spondylolisthesis, anterior and posterior disc height, canal area and

diameter, and left and right neuroforaminal area was 7.4+/-5.2mm, 8.4+/-1.6mm, 7.3+/-0.9mm, 1.3+/-0.47cm², 11.5+/-6.0mm, 2.0+/-0.5mm, 0.8+/-0.2mm, respectively. On average, there was 4.1+/-2.7mm, 5.1+/-2.8mm, 1.9+/-1.6mm correction of spondylolisthesis, anterior and posterior disc height, respectively. Average length of stay and blood loss was 1.8 days and 33cc, respectively. All patients experienced significant reduction in back and leg pain, and no patients experienced 30-day readmission.

Conclusion: Initial experiences have shown that percutaneous TLIF with an expandable cage through Kambin's triangle is a safe and clinically efficacious procedure for reducing lumbar spondylolisthesis and radiculopathy.

211 Novel Single Step MIS 3D NAV Thoracolumbosacral Pedicle Screw System: Workflow, Accuracy and Initial Clinical Experience

Franziska A. Schmidt

Introduction: Introduction: Single step 3D navigated thoracolumbosacral percutaneous pedicle screw systems were developed for minimally invasive spine surgery. The safety of the system has been previously reported, and we performed this study to report our initial clinical experience with this novel technique. We would like to evaluate a potential improvement of the workflow, the accuracy and a decrease in surgery time.

Methods: Material and Methods: The prospective case study was conducted on collected data from patients who underwent posterior pedicle screw fixation between October 2017 and April 2018. Viper prime system (DePuy Spine, Raynham, MA, USA) was used. Outcome measurements were obtained from intraoperative computerized tomography, including sagittal, axial and coronal reformatted images. The images were evaluated to determine pedicle wall penetration after surgery. We used a previously published grading system to assess the severity of the pedicle wall penetration. Severity was classified as grade 1 (<2 mm), grade 2 (2-4 mm), or grade 3 (>4 mm), and the directions were assessed as medial, cranial, caudal and lateral.

Results: Results: Our study includes 24 patients with a total number of 135 screws. Pedicle wall penetration occurred in 14 screws (10 %). Other variables such as sex, age and number of operated levels did not influence screw placement accuracy. Grade 1 breaches occurred in 4 screws (3 %) and grade 2 breaches occurred in 10 screws (7 %). Lateral breaches were observed more often than medial breaches. The accuracy rate in our study was 90 %. The median time per screw was 2.45 minutes. No revision surgery was needed and no complications occurred.

Conclusion: Conclusion: We conclude that the thoracolumbosacral pedicle system is a safe, accurate and efficient tool in minimally invasive spine surgery. Our accuracy rate is comparable to that found in the literature. We experienced an improvement in workflow and effectiveness with this one-step technique.

212 Sacroiliac Joint Fusion Outcomes at 2 Years: Triangular vs. Screw Fixation

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Introduction: Sacroiliac (SI) joint dysfunction is the primary cause of back pain in 15-30% of patients, and SI joint fusion has been shown to ameliorate this problem. The two minimally invasive fusion systems currently available on the market are the TriCor screw implant system (Zimmer Biomet Spine, Inc.) and iFuse triangular implant system (SI-Bone, Inc.). This study compares the cost utility of these two systems at two years.

Methods: 47 consecutive patients meeting NASS diagnostic and treatment guidelines for SI joint fusion were prospectively enrolled and followed for up to two years by a single surgeon. Randomization was prevented by insurance constraints. Oswestry disability index (ODI), visual analogue pain scale (VAS) for back and leg, and EQ5D scores were collected at each post-operative visit.

Results: 40 patients underwent arthrodesis with either triangular (n = 25) or screw fixation (n = 15). Mean age was 52 years (range 35-80 years) and 60% of patients were female. Mean ODI scores improved from 60 (+/- 2.4 SEM) at baseline to 32 (+/- 4.0 SEM) at 24 months. Likewise, mean VAS for back and leg pain improved from 6 (+/- 0.3 SEM) to 2 (+/- 0.5 SEM) and 5 (+/- 0.5 SEM) to 1 (+/- 0.3 SEM), respectively. EQ-5D time trade-off (TTO) index scores improved from 0.70 (+/- 0.0095 SEM) at baseline to 0.78 (+/- 0.014 SEM) at 24 months. Mean operative time was lower with the triangular implant system (83 min +/- 5.4 SEM) compared to the screw implant system (105 min +/- 4.80 SEM) with a hardware cost savings of \$495 per patient.

Conclusion: Both screw and triangular systems result in similar decrease in disability and improvement in quality of life at 24 months after SI joint arthrodesis, but the cost and operative time with the triangular implant system was lower in our institutional experience.

213 Vertebral Endplate Changes Observed by CT: Prevalence and Associations with Clinical Outcomes 3 years after Lumbar Discectomy With or Without an Annular Closure Device

Mark Arts MD, PhD; Adisa Kursumovic; Dharmin Nanda; Peter Vajkoczy MD

Introduction: Lumbar discectomy is the most common spine surgery, but patients are not usually examined for osseous changes by computed tomography (CT). The prevalence of endplate changes (EPCs) and associations with treatment outcomes are unclear. A randomized controlled trial of an annular closure device (ACD) provided the opportunity to evaluate EPCs through annual CT.

Methods: Lumbar disc herniation patients with large annular defects (= 6 mm width) were treated with discectomy alone (Control; n=283) or discectomy supplemented with an ACD (n=267). CT imaging and patient reported outcomes

were assessed pre-op and annually post-op. Success was defined as ≥ 20 points improvement for the visual analog scale (VAS) for back or leg pain or ≥ 15 points for Oswestry Disability Index (ODI). Two independent radiologists reviewed each CT for EPCs, with disagreements adjudicated by a third.

Results: At baseline, 15.1% (42/279) of Control and 18.0% (47/261) of ACD patients had prevalent EPCs ($p=0.4$). The 3-year prevalence of EPCs in Control and ACD patients was 48.6% (108/222) and 94.7% (232/245), respectively ($p<0.0001$). EPCs in the ACD group were not associated with device complications ($p=0.4$). Significantly more symptomatic reherniations occurred in Control patients with EPCs compared to those without EPCs (40.8% vs. 23.2%; $p=0.003$), but this was not the case among ACD patients (16.1% with EPCs vs. 26.7% without; $p=0.29$). Overall, symptomatic reherniations were reduced by 50% in the ACD vs. Control groups ($p<0.0001$). EPCs did not affect the probability of successful improvements in ODI or VAS scores in either group ($p>0.05$).

Conclusion: There was a high prevalence of EPCs among Control patients and a significantly higher presence in ACD patients. Despite the higher rate EPCs observed on CT, symptomatic reherniations and associated reoperations were significantly reduced in ACD patients and the presence of EPCs did not affect clinical outcomes in either group.

214 The incidence of Postoperative Epidural Hematoma after Minimally Invasive Lumbar Decompression - A Single Institution Retrospective Review of 1000 Cases

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Introduction: Postoperative epidural hematoma (PEDH) after minimally invasive lumbar laminectomy (MILL) can lead to significant morbidity and healthcare cost. The incidence is not well characterized in the literature as compared with traditional open techniques. Our aim was to define the incidence of PEDH after MIS lumbar decompression procedures and suggest various reduction strategies.

Methods: A retrospective review of a prospectively collected database was queried from January 2013 to September 2018 for all patients that underwent a minimally invasive lumbar laminectomy or laminotomy, with or without discectomy, for which the goal was decompression alone. Charts were reviewed to see the operation type, use of a fibrin sealant and whether the patient developed a postoperative epidural hematoma. The incidence of PEDH was determined along with a subgroup analysis on the use of a fibrin sealant.

Results: 1,004 cases were identified and reviewed. The overall PEDH rate was 1.4% (14/1004). The rate of PEDH was less with fibrin sealant (0.7% (3/443) versus 2.0% (11/561), $p=0.085$). 78.5% (11/14) of cases involved at least a single level laminectomy. 21.4% (3/14) involved a laminotomy alone or with discectomy. 64.3% (9/14) of patients presented with a neurological deficit.

Conclusion: 1,004 cases were identified and reviewed. The overall PEDH rate was 1.4% (14/1004). The rate of PEDH with and without fibrin sealant were 0.7% (3/443) and 2.0% (11/561), respectively. 78.5% (11/14) of cases involved at least a single level laminectomy. 21.4% (3/14) involved a laminotomy alone or with discectomy. 64.3% (9/14) of patients presented with a neurological deficit.

215 A Comparison of Anterior Cervical Discectomy and Fusion Versus Fusion Combined with Artificial Disc Replacement for Treating Patients with 3-level Cervical Spondylotic Disease

Lee S. Bok; Jongho Ahn

Introduction: Multilevel anterior cervical discectomy and fusion (ACDF) is known to present complications including a high rate of pseudoarthrosis, adjacent segment degeneration and device related complications. The purpose of this study is to evaluate the efficacy and safety of 3-level hybrid surgery, which combines fusion and cervical disc replacement (CDR), compared to 3-level ACDF in patient with cervical spondylosis (CS) involving 3 levels.

Methods: From January 2012 to January 2016, 49 patients that underwent 3-level anterior cervical spine surgery were included in this study. These patients were divided into two groups; the 30 patients in the ACDF group underwent 3-level ACDF and the 19 patients in the HS group underwent combined surgery with fusion and TDR. Clinical outcomes were evaluated using the visual analogue scale (VAS) for the arm, the neck disability index (NDI), Odom criteria and postoperative complications. The cervical range of motion (ROM) was evaluated at routine postoperative intervals of 1, 6, 12, and 24 months. Additionally, the radiological change of adjacent segments and the fusion rate at last follow up were assessed

Results: Significant improvements in arm pain relief and functional outcome were observed in the ACDF and HS group. The NDI of patients in the HS group showed better improvement 6 months after surgery than that of the ACDF group. The ACDF group had a lower fusion rate, higher incidence of device related complications and radiological changes in adjacent segments compared with the HS group. The postoperative cervical ROM in the HS group was slightly decreased compared to the preoperative value but gradually recovered during the follow up periods. However, that of the ACDF group was significantly decreased and did not recover. Radiological changes in adjacent segments were more commonly observed in the ACDF group than the HS group.

Conclusion: The HS group was better than the ACDF group in terms of NDI, cervical ROM, fusion rate incidence of postoperative complications and adjacent segment degeneration.

216 The Selection Effect of Minimally Invasive Posterior Spinal Fusion on Surgical Site Infection

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Introduction: Posterior spinal fusion (PSF) can treat numerous spinal pathologies, but can be complicated by postoperative infections that sometimes require operative intervention. Minimally invasive surgery (MIS) may reduce postoperative infection risk, and the risk factors for infection after MIS PSF may differ from the risk factors after open PSF.

Methods: We retrospectively analyzed all PSF procedures performed at our institution from 2000 to 2015. PSF procedures were identified using Current Procedural Terminology codes. Data was collected on patients' clinical characteristics, procedural factors, and antimicrobial management, and multivariable analysis identified factors independently associated with the outcomes of interest.

Results: We identified 4046 PSF patients, of whom 567 underwent an MIS procedure. MIS procedures were associated with a lower rate of infection (3.0% v. 5.4%, $p=0.0183$), and of gram-negative infection specifically (0.4% v. 1.4%, $p=0.0161$). MIS patients had an equivalent rate of 30-day readmissions (MIS 6.35% v. open 6.84%), but fewer infections requiring washout ($p=0.0008$, 0.88% v. 3.34%), and a trend toward fewer infections requiring hardware removal ($p=0.058$, 0.00% v. 0.69%) and any reoperation within 30-days ($p=0.0518$, 5.47% v. 7.88%). On multivariable analysis, selection for an MIS procedure was independently associated with fusing fewer levels ($p<0.001$, OR=0.45), having non-cervical surgery ($p<0.001$, OR=0.05), and having fewer comorbid diagnoses ($p=0.030$, OR=0.94). On multivariable analysis, MIS procedures were not independently associated with a difference in odds of infection, washout, or hardware removal. Among MIS patients, having a staged procedure was associated with gram-negative infections ($p=0.009$, OR=44.82), and infection leading to reoperation was associated with both staged procedures ($p=0.002$, OR=6.43) and cervical surgery ($p=0.008$ OR=10.46).

Conclusion: Patients undergoing MIS procedures are a distinct subset of PSF patients. They have lower rates of infections, but this may be due to a selection effect. The factors that predict infection-related complications among MIS patients are distinct from non-MIS patients.

217 Risk of Clinical Adjacent Segment Pathology Risk through 7 years Postop is Reduced Following Cervical Disc Arthroplasty Compared to Anterior Cervical Discectomy and Fusion

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Introduction: Cervical disc arthroplasty (CDA) is hypothesized to protect against adjacent segment pathology (ASP). Radiographic ASP (rASP) is often reported in favor of CDA, but the clinical effects (cASP) of this remain unclear. Adjacent level surgeries are the clearest clinical indicator of ASP, and the focus of this analysis.

Methods: ASP data were collected through 7 years in a prospective, randomized, controlled clinical trial comparing CDA to ACDF at one or two contiguous levels. Post-hoc analyses was performed including Kaplan-Meier survival curves for adjacent level surgery compared using the log-rank test, and cox regression was used to assess the impact of treatment on the relative risk of adjacent level surgery.

Results: Follow-up rate for this analysis was 74.6%. A secondary surgery performed at one or both adjacent levels was almost 3.5 times higher in 1-level ACDF (14.8%) compared to 1-level CDA (4.3%) and more than 2.5 times higher for 2-level ACDF (12.4%) compared to two-level CDA (4.9%). The probability of adjacent level surgery using Kaplan-Meier was significantly higher for ACDF ($p<0.0001$). The estimated rate of adjacent level surgery per 100 persons per year was 2.5 for ACDF and 0.7 for CDA ($p < 0.0001$). Treatment was a significant baseline predictor of adjacent level surgery, with a patient treated with ACDF being 3.9 times more likely to undergo adjacent level surgery than one treated with CDA ($p = 0.0001$).

Conclusion: The risk of adjacent segment surgery is significantly greater when treated with ACDF vs CDA through 7 years. The high quality data, and statistically significant differences provide compelling evidence that CDA should be a preferred treatment option compared to ACDF for the appropriately indicated patient.

218 How Well Does Indirect Decompression Work? Factors Affecting the Need for Additional Posterior Direct Decompression after Anterior or Lateral Interbody Fusion

Daehyun Park; Dean Chou MD; Praveen V. Mummaneni MD; Caleb S. Edwards BA

Introduction: To evaluate factors are associated with the need for additional posterior direct decompressive surgery after anterior or lateral interbody fusion(ALIF/LLIF).

Methods: 86 patients who underwent ALIF/LLIF for degenerative lumbar spine conditions were enrolled. Patient related factors (age, sex, number of treated lumbar segments, visual analogue scale(VAS) of leg and back pain), procedure related factors (cage height, cage angulation) and radiologic assessment (preoperative/postoperative disc height(DH), foramen height(FH), foramen area(FA), central canal diameter, degree of facet joint degeneration(FD)) were analyzed.

Results: Out of 86 patients, 62 patients underwent additional direct posterior decompression and in 24 patients, no posterior decompression was done. There were no significant differences between groups for age, sex, preoperative VAS of back pain, cage height, cage angulation, preoperative DH, FH, FA and central canal diameter($p>0.05$). Additional direct decompression group showed statistically difference ($p<0.01$) in numbers of treated segments (1.93), preoperative VAS of leg pain (7.9), postoperative DH improvement (61.3%), postoperative FH improvement (21.5%), postoperative FA improvement (24.1%), cage height-preoperative DH(5.32mm) and degree of FD compared with without posterior decompression group (1.49,6.1,96.2%,32.1%,36.9%, 7.45mm).

Conclusion: In selected patients, indirect decompression without direct decompression may be an option in treating radiculopathy. However, radiographic parameters should be defined to determine which candidate would be ideal for indirect decompression only.

219 Minimally Invasive Surgery for the Treatment of Traumatic Monosegmental Thoracolumbar Burst Fractures: Clinical and Radiological Outcomes of 144 Patients with 6-years Follow Up Comparing Two Groups With or Without Intermediate Screw.

Antonino Raco; Sokol Trungu MD; Stefano Forcato; Antonio Scollato; Marco Cimatti MD, PhD; Massimo Miscusi MD, PhD

Introduction: This was a retrospective study of the clinical and radiological outcomes of traumatic thoracolumbar (TL) burst fractures. Traumatic TL fractures are the most common vertebral fractures, especially at the TL junction (T10-L2). Minimally invasive surgery (MIS) is a valuable treatment option for traumatic TL burst fractures.

Methods: The clinical outcomes and radiological parameters (Cobb angle, mid-sagittal index, and sagittal index) of 144 patients with traumatic monosegmental TL fractures treated with MIS were evaluated preoperatively, postoperatively, and after 3 and 6 years of follow-up. Patients were categorized into a non-intermediate screw group (nISG) and an intermediate screw group (ISG), and the groups were compared.

Results: There were 71 patients (49.3%) in the nISG and 73 patients (50.7%) in the ISG. The radiological parameters improved significantly more from the preoperative evaluation to the 6-year follow-up in the ISG than in the nISG ($P < 0.025$). There were no significant differences in the mean Oswestry Disability Index (ODI) and VAS scores at the 6-year follow-up between the ISG and the nISG: 15.6% (ISG) vs. 16.8% (nISG) for Oswestry Disability Index (ODI) ($P < 0.1$) and 2.2 (ISG) vs. 2.4 (nISG) for VAS ($P < 0.85$) ($P < 0.73$).

Conclusion: MIS showed good clinical outcomes 6 years after surgery in both the ISG and the nISG. The additional intermediate screw significantly improved radiological parameters but not clinical outcomes.

220 Assessing the Difference in Clinical and Radiological Outcomes between Expandable Cage and Non-Expandable Cage among Patients Undergoing MIS-TLIF: A Systematic Review and Meta-Analysis

Mohammed A. Alvi MD; Shyam Kurian BS; Waseem Wahood MS; Anshit Goyal MBBS; Benjamin D. Elder MD, PhD; Mohamad Bydon MD

Introduction: Minimally Invasive Transforaminal Interbody Fusion (MIS-TLIF) has been shown to have excellent outcomes for surgical management of degenerative disc disease and other pathologies. However, one disadvantage of the technique is the challenge in addressing coronal imbalance and restoring lumbar lordosis and sagittal alignment. Use of expandable cages in MIS-TLIF has been hypothesized to circumvent this disadvantage. Literature comparing the clinical and radiological outcomes of expandable cages and non-expandable cages in MIS-TLIF is sparse.

Methods: Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were used to conduct a systematic review and meta-analysis to compare the clinical and radiological outcomes of expandable cages and non-expandable cages in patients undergoing MIS-TLIF.

Results: A total of 12 studies (706 patients) were included in the meta-analysis. The mean increase in disc height was found to be significantly greater for non-expandable cages group than for expandable cages group (1.33mm, 95% CI: 1.28-1.38 vs 1.14 mm, 95% CI: 1.06-1.23; $p < 0.001$). We did not detect any significant difference in change in lumbar lordosis at last follow up between the two groups (non-expandable: 2.55, 95% CI: 2.22-2.88 vs expandable: 2.27, 95% CI: 1.80-2.75, $p = 0.34$). The mean change in segmental lordosis was found to be significantly higher for expandable cage group (5.04degrees, 95% CI: 3.89-6.20 vs 2.08degrees, 95% CI: 1.93-2.22, $p < 0.001$). Finally, we did not detect any significant difference in fusion rate (expandable: OR 0.75, 95% CI: 0.44-1.06 vs non-expandable 0.90, 95% CI: 0.86-0.95; $p = 0.33$), subsidence rate (expandable: 0.05, 95% CI: 0.00-0.09; non-expandable 0.08, 95% CI: 0.01-0.15, $p = 0.41$) or in reoperations (expandable: 0.02, 95% CI: 0.01-0.04 vs non-expandable: 0.01, 95% CI: 0.00-0.02, $p = 0.56$) at last follow up between the two groups.

Conclusion: Our results indicate that there may not be a significant difference in clinical and radiological parameters between expandable cages and non-expandable cages among patients undergoing MIS-TLIF, and it is unclear if the higher cost of the expandable cages is justified.

221 Comparing Post-operative Opioid Use After Endoscopic and Open Spine Surgery

Rajeev D. Sen MD; Zeinab Birjandian MD; Jason Barber MS; Lynn B. McGrath MD; Christoph P. Hofstetter MD, PhD

Introduction: Opioid addiction has become a national epidemic in the United States. More than 12 million people misuse prescription opioids and opioid abuse is the leading cause of drug overdose-related deaths in addition to adding tremendous cost to overall healthcare. While ESS has been shown to be a safe and effective alternative to open and MIS surgery for degenerative spine disease, its impact on opioid dependence has not been explored. The goal of this study was to compare post-operative opioid use in patients who underwent either endoscopic or open decompression for degenerative disease.

Methods: We conducted a retrospective analysis of 100 patients who underwent decompressive spine surgery for degenerative disease. Fifty cases were endoscopic and 50 were open. There were no instances of fusions. Pre- and post-operative opioid use data was gathered from the Washington State Department of Health portal, which documents

all prescriptions written and filled by each patient. Cumulative opioid use at 2 weeks, 6 months and 1 year after surgery were recorded in units of morphine equivalents.

Results: There was no significant difference between the endoscopic and open groups with regards to gender distribution, weight and BMI. The endoscopic group had a higher age (62 vs. 54; $p=0.021$) and less intra-operative blood loss (18.5 mL vs. 56.7 mL; $p<0.001$). The endoscopic group required fewer morphine equivalents in the inpatient setting (23.7 mEq vs. 77.6 mEq; $p=0.001$). After controlling for age and pre-operative opioid dependence, the endoscopic group required fewer morphine equivalents at the 2-week, 6-month and 1-year time points (344 mEq vs. 420 mEq; $p=0.001$).

Conclusion: In this retrospective study, we have found that endoscopic spine surgery for degenerative disease has a beneficial impact on opioid dependence by decreasing use at 2-weeks, 6-months and 12-months post-operatively when compared to equivalent cases of conventional open surgery.

222 Indirect Decompression Failure after Lateral Lumbar Interbody Fusion: Reported Failures and Predictive Factors; Systematic Review

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Introduction: In patients with symptomatic lumbar stenosis undergoing lateral transpsoas approach for lumbar interbody fusion (LLIF) surgery, it is not always clear when indirect decompression is sufficient in order to achieve symptom resolution. Indirect Decompression Failure (IDF), defined as "postoperative persistent symptoms of nerve compression with or without a second direct decompression surgery to reach adequate symptom resolution, is not widely reported. This information, however, is critical to better understand the indications, the potential and the limitations of indirect decompression. The purpose of this study was to systematically review the current literature on IDF after LLIF.

Methods: A literature search was performed on PubMed. We included randomized controlled trials (RCTs) and prospective, retrospective, case-control studies and case reports. Information on sample size, demographics, procedure, number and location of involved levels, follow-up time, and complications were extracted.

Results: After applying the exclusion criteria, we included 9 of the 268 screened articles that reported failure. 632 patients were screened in these articles and detailed information was provided. Average follow-up time was 21 months. Overall reported incidence of IDF was 9%.

Conclusion: Failures of decompression via LLIF are inconsistently reported and the incidence is approximately 9%. IDF failure in LLIF may be underreported or misinterpreted as a complication. We propose to include the term "IDF" as described in this manuscript to differentiate them from complications for future studies. A better understanding of why IDF occurs will allow surgeons to better plan surgical intervention and will avoid revision surgery.

223 Two-Level Cervical Disc Arthroplasty vs. Anterior Cervical Discectomy and Fusion: Ten-Year Outcomes of a Prospective, Randomized IDE Clinical Trials

Todd H. Lanman MD, FACS, FAANS; Matthew F. Gornet MD; J Kenneth Burkus MD; Randall Dryer; Jeffrey McConnell MD; Scott Hodges DO

Introduction: Long-term data from multiple Level-1 FDA IDE trials established cervical disc arthroplasty (CDA) as a proven alternative to anterior cervical discectomy and fusion (ACDF) for appropriately selected patients with single-level cervical degenerative disc disease (DDD). Long-term studies now also demonstrate the safety and efficacy of CDA at two contiguous levels. This paper reports the 10-year results of the Prestige LP FDA trial (clinicaltrials.gov: NCT00637156) comparing the safety and efficacy of CDA and ACDF.

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Methods: 397 patients with two-level radiculopathy and/or myelopathy between C3 and C7 were randomized and treated with investigational CDA ($n=209$) or control ACDF ($n=188$). The primary endpoint was Overall Success, a variable inclusive of 4 criteria: 1) Neck Disability Index (NDI) score ≤ 15 points 2) maintenance/improvement in neurological status 3) no serious adverse events 4) no additional surgery. Additional safety and effectiveness endpoints included neck and arm pain rating scales, SF-36, ROM, and adverse events (AE). Bayesian analyses were used to demonstrate non-inferiority and superiority of CDA to ACDF.

Results: Patient follow-up at 10 years was 86.0% for investigational and 84.9% for control patients. From 2 to 10 years postoperative, the rates of Overall Success, NDI and neck pain score improvements demonstrated statistical superiority for CDA over ACDF.

Conclusion: In selected patients, CDA with the Prestige LP Disc is at least as safe and effective as ACDF for symptomatic cervical DDD at 2 contiguous levels.

224 Subsidence Rates After Lateral Lumbar Interbody Fusion: A Systematic Review

Mohamed Macki MD, MPH; Paul Park MD; Victor W. Chang MD

Introduction: The evidence regarding the consequences of subsidence with lateral lumbar interbody fusion (LLIF) has been sparse. The objective of this study is to calculate the incidence of subsidence and reoperation for subsidence following LLIF. A secondary outcome examined the quantitative degree of subsidence by calculating the percent change in the height of the intervertebral space secondary to interbody subsidence at various postoperative follow up times.

Methods: Following the Meta-analysis (and Systematic Review) Of Observational Studies in Epidemiology (MOOSE) Guidelines, a systematic review searched for all cohort studies that focused on subsidence rates after LLIF, including Extreme Lateral Interbody Fusions (XLIF) and Direct Lateral Interbody Fusion (DLIF). Neoplastic, infectious, and/or metabolic indications for LLIF were similarly excluded as these pathologies may compromise bone quality and, thus, confound the rate of cage subsidence. Corpectomies were removed from the systematic review because 1) indications for removal of vertebral body typically reflect those excluded pathologies, and 2) subsidence refers to a different biomechanical process

Results: This systematic review identified a subsidence incidence with LLIF of 10.3% (N=141/ 1362 patients in 14 articles) and reoperation rate for subsidence of 2.7% (N=41/ 1470 patients in 16 articles). In the secondary outcome measure, the disc height decreased from 5.6% after 3 months, 6.0% after 6 months, 10.2% after 12 months, to 8.9% after 24 months ($p<.001$).

Conclusion: Subsidence after LLIF carries a non-negligible risk that may be incorporated in surgical consent discussions in selected patients.

225 Observations of Contralateral Facet Fusion in Minimally Invasive Transforaminal Lumbar Interbody Fusion (MIS-TLIF) for Spondylolisthesis

Lara W. Massie MD; Hesham M. Zakaria MD; Lonni Schultz PhD; Azam Basheer MD; Victor W. Chang MD

Introduction: Anecdotally, contralateral facet fusion (FF) has been observed after MIS-TLIF without posterior-lateral arthrodesis. Whether FF clinically affects patient reported outcomes (PROs) independently of IF after MIS-TLIF is unknown, and was the aim of this study.

Methods: Sixty-four patients were treated at 74 levels with MIS-TLIF for spondylolisthesis between 2014-2017. Arthrodesis using mesenchymal stem-cell-based allograft and autograft was limited to the intervertebral disc space. Each level was assessed using computed tomography (CT) at 6 and 12 months for IF and FF. ODI and NRS for leg/back pain (LP/BP) were collected before, at 6 months, and 1-year after surgery. Correlation between IF and FF (using chi-square test) and between IF, FF, and PROs (using two sample t-test) were analyzed.

Results: At 6- and 12-months, IF was observed in 56% and 87%, and FF was present in 40% and 70% of levels. Overall fusion rate (IF, FF, or both) was 71% at 6-months and 90% at one year. Correlation between IF and FF became significant by one year (6-months ($p=0.436$), 12-months ($p=0.008$)). Significant improvements over all preoperative PROs were present at 6 months and 1 year, but these improvements were not affected by the presence or absence of FF, respectively, at 6 months: (ODI: -16.9 ± 18.8 vs -11.3 ± 20.8 , $p=0.483$, BP: -4.6 ± 3.1 vs -2.9 ± 3.1 , $p=0.155$, LP: -2.9 ± 2.4 vs -4.4 ± 3.8 , $p=0.188$), or at 1 year (ODI: -12.6 ± 17.8 vs -16.8 ± 23.8 , $p=0.655$, BP: -4.0 ± 2.9 vs -3.2 ± 3.4 , $p=0.599$, LP: -3.9 ± 2.8 vs -3.4 ± 4.7 , $p=0.774$). Successful IF at one year was correlated with improvement in leg pain (-4.4 ± 3.3 vs -0.5 ± 1.0 , $p=0.033$).

Conclusion: Fusion rate after MIS-TLIF for spondylolisthesis at 1 year was 90%. Development of FF is correlated with successful IF at 1 year and was observed in 70% after 1 year. Successful IF at 1 year correlates most strongly with a significant reduction in leg pain after MIS-TLIF for spondylolisthesis.

226 Technical and Clinical Feasibility of Autologous Bone Marrow Mesenchymal Stem Cells as Fusion Substrate for Minimally Invasive Transforaminal Interbody Fusion: A Single Institution Cohort Study

Alex M. Butler BA; Eleonora F. Spinazzi MD; Garrett P. Banks BS, MD; Alfred T. Ogden MD

Introduction: Spinal fusion is an effective surgical treatment for many spinal pathologies that commonly present with severe pain, and/or weakness. Although there is general consensus that utilization of an interbody graft with posterior instrumentation enhances arthrodesis, the choice of additional graft substrate remains an area of debate. Autologous bone marrow aspiration is a novel strategy which utilizes mesenchymal stem cells (MSC) to produce osteoblasts, which is hypothesized to promote fusion rates. This study aims at comparing the clinical course and outcomes of patients who underwent minimally invasive transforaminal lumbar interbody fusion (TLIF) with either MSC or morselized autologous bone graft (MABG) as fusion substrate.

Methods: A total of 24 consecutive patients that underwent a single-level TLIF, with 8 patients receiving MABG and 16 patients receiving MSC as fusion substrate. Patients were analyzed before and after their operation, and were evaluated for changes in pain score, disability (ODI) score, correction mismatch and degree of arthrodesis. Secondary endpoints included subsequent back surgery, and time to return to work and driving.

Results: The average age of patients in the cohort was 58.1 years old (59.5 years old in the MABG cohort, 56.5 years old in the MSC cohort), and the male-to-female ratio was 0.71 (0.82 in the MABG cohort and 0.59 in MSC cohort). An average reduction in ODI score of 15.71 was observed in the MABG cohort and 23.24 in the MSC cohort ($p = 0.4$). An

average reduction in pain score of 2.89 was observed in the MABG group and 3.45 in the MSC cohort ($p = 0.77$). Correction mismatch and degree of fusion were found to be equivalent between cohorts.

Conclusion: There was no statistically significant difference in degree of fusion, correction mismatch, pain score, and ODI score in patients who received MSC substrate as compared to those who received MABG.

227 Multi-level Minimally Invasive Lumbar Decompression: Clinical Efficacy and Durability

Hani Malone MD; Kavantissa M. Keppetipola; Ryan Khanna MD; Ricardo B. Fontes MD, PhD; John E. O'Toole MD, MS

Introduction: The efficacy of single-level minimally invasive lumbar decompression and/or microdiscectomy is well established. However, there is a paucity of clinical data supporting the use of minimally invasive (MIS) decompression in a single operation to address pathology at multiple lumbar levels.

Methods: A retrospective review of prospectively collected data from patients with symptomatic lumbar stenosis/disc herniations who underwent multi-level minimally invasive decompression/microdiscectomy was conducted. Patient reported outcome measures (ODI, VAS back/leg pain, SF-12, SRS-30) were collected before surgery and at 3 months, 6 months, 1 year, and 2 years postoperatively.

Results: During the enrollment period, 92 patients received multi-level MIS lumbar decompression/discectomy (69 two-level, 21 three-level, 2 four-level). Patient follow up was as follows: 3mo $n=78$ (85%), 6mo $n=53$ (58%), 1yr $n=40$ (43%), 2yr $n=22$ (24%). The mean age at surgery was 70, and 23 (25%) patients were women. Patient reported outcomes, reported as average change from preoperative baseline, were as follows: back pain -3.93 at 3mo, -2.51 at 1yr; leg pain -3.59 at 3mo, -3.24 at 1yr; ODI -12.97 at 3mo, -13.58 at 1yr; SF12-MCS 2.84 at 3mo, 0.24 at 1yr; SF12-PCS 6.93 at 3mo, 9.55 at 1yr; SRS-30 0.57 at 3mo, 0.62 at 1yr. Surgical complications occurred in 16 patients (17.2%) with 15 durotomies and 1 post-operative hematoma. There were no reoperations within a year.

Conclusion: The use of minimally invasive (MIS) techniques to perform lumbar decompression/discectomy at multiple levels was found to be both clinically effective and durable. MCID was surpassed for all patient reported outcome measures at all follow up time points, except for SF-12 MCS. A major limitation of this analysis is loss to long-term follow up, which we hope to improve as more patients in the cohort reach 1 and 2 year post-operative time points.

228 Lumbar Spine Revision Surgery Through Minimally Invasive Muscle Separating Approach

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Introduction: Re-operation on patients that underwent prior lumbar spinal surgery with or without fusion is always challenging. In addition to scarring which is often severe, the anatomical planes are nondistinct and risks of injury to nerve roots or CSF leak are considerable.

Methods: We have developed a technique in which revision surgery previously performed using midline incision is performed using paramedian bilateral minimally invasive inter muscular dissection technique using a plane within the sacrospinalis muscle. We have performed a total of twelve (12) procedures on seven (7) males and five (5) females. The ages ranged from 52 to 76. The indications were revision of laminectomy for unilateral radiculopathy and instability in five (5) patients who had two previous surgeries and seven (7) patients who had one.

Results: There were three (3) surgeries for construct failure and nine (9) with adjacent segment disease. In addition to decompression, all patients had instrumented fusion at one or more levels. There were no instances of CSF leak, no nerve root injuries and no patient required transfusion.

Conclusion: The technique utilizes a modified paramedian Wiltse approach that we have described previously and approaches the revision site by removing completely the lateral facets followed by medial facet. The facets are drilled to leave only thin shell of bone below the level of scar which is lifted with a microdiscectomy. This leads to normal epidural space and the pedicles. The nerve roots are mobilized as needed and the disc space is easily accessed. The details of the technique will be presented.

229 Kinematics of Cervical Disc Arthroplasty Above a Two-Level Fusion: Index Level and Adjacent Segments

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Introduction: In this clinical scenario, a surgeon considers a cervical disc arthroplasty (CDA) at C4-5 to treat adjacent segment disease (ASD) proximal to an existing C5-7 fusion, in hopes of reducing the risk of ASD at C3-4. We sought to evaluate any adverse effect the existing fusion might have on the motion of the CDA, and what effect this construct would have on the kinematics of the C3-4 segment.

Methods: Human cadaveric cervical spines (Occiput-T1) were tested (1) intact, (2) after lateral mass screws and rods across C5-C7, (3) after C4-C5 CDA (Medtronic Prestige; hybrid construct), and (4) after removing posterior rods across C5-C7 (standalone C4-C5 CDA). Two types of tests were run on each specimen: (i) Range of Motion (ROM) test measured segmental motions across all segments under $\pm 2.0\text{Nm}$ flexion-extension moments; and (ii) Increasing SVA test quantified segmental angular compensations necessitated by progressively increasing anterior head-offset (C0-T1 SVA) while maintaining horizontal gaze, using a previously reported experimental setup.

Results: ROM Test: Posterior fixation across C5-C7 yielded excellent immobilization with $<3.0^\circ$ average motion at each level. Stand-alone CDA at C4-C5 maintained segmental motion at C4-C5 when compared to the intact spine. In the

hybrid construct, the ROM of C4-C5 CDA was not adversely affected (Figure 1A). SVA Test: With increasing C0-T1 SVA, the C3-C7 segments flexed while C0-C2 segments extended. The contributions of adjacent C3-C4 and C4-C5 segments towards C3-C7 angular motion increased after C5-C7 fusion compared to intact (Figure 1B). C4-C5 CDA above the fusion did not adversely influence the kinematics at C3-C4 when compared to C5-C7 fusion. These trends were seen in all specimens tested.

Conclusion: Segments above a 2-level fusion are subjected to increased motion compensation in the presence of sagittal imbalance (excessive SVA). C4-5 CDA above a 2-level fusion may not adversely affect the kinematics of the adjacent C3-C4 segment.

230 Comparison of Perioperative Complications in Minimally Invasive Surgery and Traditional Open Surgery for Decompression and Fusion

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Introduction: Although traditional open surgery for decompression and fusion of lumbar pathology is efficacious, concerns exist regarding postoperative complications that may be mitigated by using minimally invasive surgery (MIS) techniques. The aim of this study was to review surgical outcomes in patients that underwent either lumbar interbody fusion or lumbar decompression and to characterize differences in complication rates between the conventional open approach and MIS.

Methods: A total of 1,435 adult patients who underwent lumbar spine surgery between 2013 and 2016 were included in this retrospective analysis. The differences between open-fusion, MIS-fusion, open-decompression, and MIS-decompression in 30-day readmission, 90-day readmission, revision rate, deep vein thrombosis, pulmonary embolism, urinary tract infection, pneumonia, pressure ulcer, blood transfusion, discharge to rehabilitation, and drain placement were analyzed.

Results: Patients that underwent traditional open lumbar decompression were more likely to develop a DVT (p-value=0.007) and to have a drain placed (p-value<0.00001) than those undergoing MIS decompression. Patients that underwent traditional open lumbar fusion compared to MIS fusion were also more likely to have a drain placed (p-value<0.0001) and require a blood transfusion (p-value=0.000239). Although the rate of revision is well described for traditional open approaches, the rate of revision in MIS remains poorly characterized. Both groups in this study had similar reoperation rates: fusion revision rate in open versus MIS was 0.126 compared to 0.089 (p-value=0.201) and decompression revision rate in open versus MIS was 0.119 compared to 0.115 (p-value=0.867).

Conclusion: MIS is comparable with traditional open spine surgery in terms of safety and efficacy in both lumbar spine decompression and fusion surgery. MIS techniques lead to improved complication rates including reduced rate of DVT for decompression and reduced transfusion rate for fusion. MIS surgery does not result in increased revision rate when compared to open approach. Randomized controlled trials are needed to better compare these two surgical techniques.

231 Clinical Outcomes Following Endoscopic vs. Minimally Invasive Unilateral Laminotomy in Patients with Moderate Degenerative Deformity

Lynn B. McGrath MD; Jason Barber MS; Rajeev D. Sen MD; Christoph P. Hofstetter MD, PhD

Introduction: Endoscopic unilateral laminotomy (EL) has recently been demonstrated to be an effective alternative to minimally invasive (MIS) and open laminectomy producing favorable patient outcomes while reducing complication rates and hospital length of stay. The ability of the endoscope to facilitate decompression of neural structures with minimal facet joint resection suggests EL may be a cost-effective method of addressing radicular pain in patients with primary degenerative scoliosis. The safety and efficacy of EL compared with MIS in treating these patients has not been studied.

Methods: A retrospective analysis of 45 consecutive patients with coronal deformity between 10o and 20o. All patients underwent either MIS (n=18) or endoscopic (n=27) unilateral laminotomies for foraminal decompression. Patient demographics, operative details, complications, pre- and post-operative Cobb angle, back and leg visual analog scales (VAS), and Oswestry Disability Index (ODI) were reviewed.

Results: Our patient cohort consisted of 45 patients with an average age of 62 years. There was no difference in average pre-op coronal deformity, VAS or ODI scores. Hospital length of stay for EL patients was significantly shorter than for MIS patients (0.7 days vs. 2.4 days, P<0.001). At one-year follow up EL patients were found to have a trend toward superior improvement in VAS back (2.20 vs. 2.56), VAS leg (1.30 vs. 2.5) and ODI (20.6 vs 23.7) scores when compared to the MIS cohort.

Conclusion: Endoscopic unilateral laminotomy is a safe and effective alternative to MIS laminotomy for addressing radicular pain in patients with coronal deformity secondary to degenerative scoliosis, demonstrating significantly shorter hospital length of stay and a trend toward superior functional outcomes.

232 Evaluating the Differences in 30-day Outcomes for Repeat Arthroplasty and Repeat Fusion Procedures in the Lumbar Spine: Insights from a National Registry

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Introduction: Lumbar fusion is one of the most common surgical procedures which is employed for management of degenerative disc disease of lumbar spine. Lumbar disc arthroplasty (LDA) is a less-common alternative. Long-term reoperation rate for lumbar fusion and LDA in the literature range from 5-6% and 4-6%, respectively. However, not much is known about surgical and clinical outcomes of revision procedures after lumbar fusion and arthroplasty.

Methods: We queried the National Surgical Quality Improvement Program (NSQIP) database for patients undergoing repeat lumbar fusion and arthroplasty procedures between 2012-2016. Patients with history of hybrid procedure (LDA plus fusion) at the index operation were excluded. Operative characteristics of each of these procedures were abstracted. Demographic characteristics, baseline clinical characteristics and 30-day clinical outcomes were compared between repeat fusion and arthroplasty procedures using univariate statistical analyses.

Results: A total of 55 revision LDA were identified, of which 5.5% (n=3) were arthroplasty removal alone, 34.5% (n=19) were revision arthroplasty and 60% (n=33) were hybrid procedures (arthroplasty plus fusion). A total of 670 repeat fusion procedures were identified of which. Patients undergoing repeat arthroplasty procedures were found to be younger (52 ± 14.2 vs 58.3 ± 14.4 , $p < 0.001$), less likely to have a device related complication (9.1% vs 22.5%, $p < 0.001$), and more likely to have a degenerative disease (61.8% vs 29.2%, $p < 0.001$). Repeat arthroplasty procedures were found to be more frequently performed as outpatient (12.7%, n=7 vs 1.6%, n=11, $p < 0.001$), were associated with longer operative time (208.2 ± 122 minutes vs 171.1 ± 110.4 minutes, $p = 0.027$). Length of stay, surgical site infection (SSI), readmission and reoperation rate did not differ between the two groups.

Conclusion: We found that repeat arthroplasty procedures are more likely to be performed due to re-emergence of degenerative symptoms, compared to repeat fusion procedures which are more likely to be performed for device related complications.

233 Foraminal and Cross-sectional Area Changes Following Oblique Lateral Interbody Fusion (OLIF) as measured by CT or MRI and the Need for Additional Posterior Decompression

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Introduction: OLIF has been purported to provide indirect decompression of nerve roots by increasing foraminal and axial area. We sought to evaluate the effect of OLIF on foraminal and axial area using CT and MRI and to evaluate the rate of subsequent posterior direct decompression.

Methods: A retrospective review of OLIF cohort was undertaken. Demographic information was obtained in addition to operative levels. Only patients with both pre- and post-operative CT or MRI were included. Foraminal and cross-sectional axial area were measured pre- and post-operatively. Operative levels incurring further posterior decompression were also recorded.

Results: A total of 76 operative levels from 33 patients were analyzed, with 19 of these levels being imaged both with CT and MRI. Nineteen of these patients were female (57.6%) with the average age being 67.6 ± 6.6 years old. Operative levels were stratified as follows: 7 L1-2, 19 L2-3, 25 L3-4, 22 L4-5, 3 L5-S1. Axial cross-section on CT was found to be significantly larger after OLIF (232.3 mm^2 v. 275.6 mm^2 ; $p = 0.048$). Foraminal height (15.9 mm^2 v. 18.5 mm^2 ; $p = 0.0027$) and foraminal area (106.3 mm^2 v. 146.6 mm^2 ; $p = 0.000016$) both had statistically significant increases on CT after OLIF. Concerning MRI, there was a significant difference in foraminal height (15.6 mm^2 v. 17.7 mm^2 ; $p = 0.035$); however, axial cross-section (132.9 mm^2 v. 158.9 mm^2 ; $p = 0.12$) and foraminal area (114.8 mm^2 v. 133.8 mm^2 ; $p = 0.096$) were not found to be significantly different. Posterior decompression was performed on twenty-seven levels after OLIF, primarily at L4-5.

Conclusion: Our results illustrate that OLIF is effective in indirectly decompressing neural elements, with nearly two-thirds of levels not requiring posterior decompression. OLIF resulted in increased foraminal area, foraminal height, and cross-sectional area by CT. MRI detected less changes than CT, and thus, may not be as accurate in measuring foraminal area and cross-sectional area as compared to CT.

234 Clinical Outcomes Following Endoscopic vs. Minimally Invasive Unilateral Laminotomy for Bilateral Decompression in Patients with Preoperative Spondylolisthesis

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Introduction: Endoscopic unilateral laminotomy (EL) for bilateral decompression has recently demonstrated favorable patient outcomes and reduced hospital length of stay when compared to minimally invasive (MIS) laminotomy in patients with lumbar spinal stenosis. The superior visualization afforded by the endoscopic approach enables the surgeon to minimize unnecessary destruction of osseoligamentous structures and thus may be especially suited to mitigating the risk of post-decompression instability in patients with preexisting spondylolisthesis. The safety and efficacy of the endoscopic approach compared with MIS in treating these patients has not been studied.

Methods: A retrospective analysis of 43 consecutive patients with preexisting Grade 1 spondylolisthesis undergoing either MIS (n=23) or endoscopic (n=20) unilateral laminotomies for bilateral decompression of lumbar spinal stenosis was performed. Patient demographics, operative details, complications, degree of pre- and post-operative spondylolisthesis, back and leg visual analog scales (VAS), and Oswestry Disability Index (ODI) were reviewed.

Results: Our patient cohort consisted of 43 patients with no significant difference in demographic characteristics. There was no difference in average pre-operative spondylolisthesis grade, VAS or ODI scores. Hospital length of stay for EL patients was significantly shorter than for MIS patients (0.7 days vs. 2.4 days, $P<0.001$). At one-year follow up EL patients were found to have a trend toward superior improvement in VAS back (2.12 vs. 3.39), VAS leg (0.88 vs. 2.08) and ODI (17.8 vs 27.0) scores when compared to the MIS cohort. No differences were found in post-operative spondylolisthesis grade at one-year follow up.

Conclusion: Endoscopic unilateral laminotomy for bilateral decompression in patients with lumbar spinal stenosis and preexisting Grade 1 spondylolisthesis is a safe and effective alternative to MIS laminotomy, demonstrating significantly shorter hospital length of stay and a trend toward superior functional outcomes at 1 year.

235 Modular Approach to Minimally Invasive Treatment of Spinal Deformity: Evolution of Non-Linear Thinking

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Introduction: Despite growing popularity of minimally invasive (MIS) approaches to spinal deformity surgery, optimal radiographic outcomes have remained challenging. Compared to open techniques, improvement in MIS outcomes is highly dependent on surgical and imaging tools, as well as strategic surgical planning. We provide an updated perspective on non-linear management of significant global sagittal malalignment in adult spinal deformity (ASD) to reflect changes in technique, improvements in technology, and a nuanced understanding of surgical workflow.

Methods: Our approach to ASD has evolved to increasingly utilize: (1) hyperlordotic anterior cages at L5/S1, (2) hyperlordotic lateral interbodies, (3) mini-open approaches to osteotomies. We have also adopted non-linear, modular approaches to surgical staging. Generally, Day 1: Posterior percutaneous instrumentation with mini-open osteotomies, anterior lumbar interbody fusion, Day 2: multi-level lateral interbody fusion, segmental fixation using computerized rod bending systems. We performed a retrospective review of consecutive spinal deformity cases representing our management paradigm with minimum 12 month follow up and compared to a historical cohort. Mal-alignment was defined as pelvic incidence to lumbar lordosis mismatch $>10^\circ$, or sagittal vertical axis $>50\text{mm}$.

Results: 63 patients who underwent minimally invasive approaches to ASD correction were identified, 37 with new techniques and 26 with older techniques. Mean age was 64 ± 8.4 , 68% were female. No significant differences existed between groups in gender, length of construct, preoperative radiographic values ($p>.07$); the modern cohort was older ($p=.045$) and more frequently underwent ACR ($p=.03$). Average radiographic correction in lumbar lordosis was higher in the modern cohort (24 vs 15° , $p=.03$); following surgery, more patients in the modern cohort achieved alignment goals than in the historical cohort (78% vs 44%, $p=0.03$).

Conclusion: Updated MIS techniques achieved optimal spinopelvic alignment in the majority of cases. By capitalizing from the individual benefits of differing surgical approaches, non-linear management of spinal deformity can potentially yield improved radiographic outcomes.

236 Assessing the Differences in 30-day Clinical and Surgical Outcomes Between Repeat Cervical Disc Arthroplasty and Repeat Cervical Fusion: Results from a National Surgical Registry

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Introduction: Anterior Cervical Discectomy and Fusion (ACDF) and Cervical Disc Arthroplasty (CDA) are two commonly employed procedures for surgical management for Cervical Spondylotic Myelopathy. However, reoperations after both these procedures are common; the rate ranges from 8-12% for ACDF and from 4-6% for CDA. Literature regarding outcomes for revision procedures after ACDF and CDA is sparse.

Methods: We queried the National Surgical Quality Improvement Program (NSQIP) for patients undergoing removal/repeat 1-2 level ACDF/Posterior Cervical Fusion (PCF) and CDA using CPT codes between 2012 and 2016. Patients with a history of hybrid procedure (ACDF/PCF and CDA) at the index operation were excluded. Demographic characteristics, baseline clinical characteristics, postoperative diagnosis and 30-day outcomes were compared between revision/removal ACDF and CDA.

Results: A total of 104 repeat cervical arthroplasty procedures were identified, of which 14.4% (n=15) were removal alone, 44.2% (n=32) were revision arthroplasty alone, 26% (n=27) were removal of arthroplasty and fusion and 15.3% (n=16) were repeat arthroplasty and fusion (hybrid procedure). A total of 670 1-2 level repeat fusion procedures were identified, of which 14.2% (n=95) were removal of instrumentation alone while 85.2% (n=575) were revision fusion; among revision fusion cases, 72% (n=414) were anterior, 18.4% (n=106) were posterior while 7.1% (n=41) were circumferential fusions. On univariate analysis, patients undergoing repeat arthroplasty procedures were younger (Mean age 48.7 ± 12.2 years vs 56.4 ± 10.5 , $p<0.001$), more likely to have a postoperative diagnosis of instrument related complication (21.2% vs 12.7%, $p<0.001$), had shorter operative time ($139.1\text{ minutes}\pm 78.9$ vs $181.2\text{ minutes}\pm 104.2$, $p<0.001$) and shorter LOS ($1.8\text{ days}\pm 1.9$ vs $3.3\text{ days}\pm 6.1$, $p=0.008$). Readmission rate was not found to be significantly different between the two groups (6.7%, n=7 vs 5.1%, n=34, $p=0.48$).

Conclusion: Our results indicate that while there may be difference in patient characteristics and indications for 1-2 level repeat arthroplasty procedures and revision fusions both can be performed safely with favorable 30 day outcomes.

237 Volumetric Analysis of Endoscopic Decompression for Lumbar Spinal Stenosis

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Introduction: Lumbar central stenosis can theoretically be decompressed with minimal bone removal via an endoscopic approach. Although multiple studies have demonstrated an adequate radiographic decompression, none have quantified the volume of bone removal after endoscopic decompression. The objective of our study was to quantify the 3D volume of bone that is removed from the lamina and facet joints during endoscopic decompression for lumbar central and lateral recess stenosis.

Methods: This retrospective study included adults with lumbar spinal stenosis who underwent endoscopic decompression of a single level or two non-contiguous lumbar levels. Central stenosis on MRI was graded preoperatively and postoperatively with the Schizas scale. A computer program was developed in MATLAB to semi-automatically perform a 3D volumetric analysis of preoperative and postoperative lumbar CT scans. The volumetric percentage of bone removal from the lamina and facet joints ipsilateral and contralateral to the side of approach were quantified.

Results: Nineteen patients with 21 lumbar levels were included in the study. Preoperatively, the number of levels with Schizas stenosis grades B, C, and D were 5, 12, and 4, respectively. Stenosis grades improved postoperatively to 17, 3, 1, and zero levels with grades A, B, C, and D, respectively. All levels improved by at least one stenosis grade. The volumetric percentage of laminar bone removed was 15.5% (95% C.I. 11.2-19.8%, $p < 0.001$) from the ipsilateral lamina and 8.8% (95% C.I. 5.7-11.8%, $p < 0.001$) from the contralateral lamina. The percentage of facet joint resection was 5.3% (95% C.I. 4.2-6.4%, $p < 0.001$) and 4.3% (95% CI 2.2-6.4%, $p < 0.001$) for the ipsilateral and contralateral facet joints, respectively.

Conclusion: Endoscopic lumbar decompression achieves improvement in the radiographic grade of lumbar central stenosis with minimal bone removal from the lamina and facet joints. Future prospective studies are needed to validate the findings of this study with associated clinical outcomes.

238 Comparison of Clinical Outcome and Spino-Pelvic Parameters Modifications Between Minimally Invasive and Conventional Open Posterior Lumbar Interbody Fusion for Treatment of High-Grade L5-S1 Isthmic Spondylolisthesis

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Introduction: According to Meyerding scale, high grade isthmic spondylolisthesis are those with more than 50% slippage. Surgery is indicated when lowback pain episodes becomes frequent and refractory to medical and physical management and radicular symptoms due to progressive foramina stenosis. The demonstration of segmental instability at dynamic X-rays is also an indication for surgical treatment. According to literature, in case of high degree slippage an adequately sized and interbody cage is a key factor to allow satisfactory restoration of segmental lordosis.

Methods: Two homogeneous groups of 14 patients with painful high-grade isthmic L5 spondylolisthesis (grade III or IV) were respectively operated by posterior minimally invasive interbody fusion (MISS group) and by conventional open interbody fusion (open group). Clinical evaluations were performed applying back and leg VAS, ODI and SF36. Spino-pelvic parameters, compared between 2 groups before and after operation, were: - slipping (%), lumbo-sacral angle, lumbar lordosis, sagittal vertical axis, sacral slope, pelvic tilt and pelvic incidence

Results: At follow-up (mean 18mo; range 12-24), improvement of slippage was $65\% \pm 5\%$ in the MISS group, and $62\% \pm 3\%$ in the open group, without significant differences ($p = 0.07$). Back and leg pain VAS scores, ODI and SF36 were significantly improved after surgery ($p = 0.037$), more significantly in MISS group at the discharge, but without difference between 2 groups ($p > 0.05$) three months follow-up. Modifications of pelvic measurements were recorded in both groups without differences: LSA and slip angle improved in all cases ($p < 0.05$), while PT decreased below 25 degrees in 9 (32%) cases (5 open and 4 MISS). Sagittal alignment on SVA was constantly observed.

Conclusion: Both surgical procedures seem to obtain good results in term of late clinical improvement and restoration of spino-pelvic balance, but MISS group showed significant better results in term of blood loss and length of bed-rest.

239 Transforaminal Percutaneous Endoscopic Foraminoplasty (TF-PELF) against Lumbar Foraminal Stenosis

Manabu Minami

Introduction: Study Design: A retrospective Study. With the introduction of endoscopic micro drill, the transforaminal percutaneous endoscopic technique is now more versatile for not only lumbar disc herniation but also lumbar canal stenosis (LCS), especially aka foraminal stenosis. We performed root decompression by foraminoplasty with so called outside-in technique.

Methods: The efficacy of TF-PELF is compared to other root decompression procedures against foraminal stenosis; microsurgical foraminotomy (microsurgical decompression group: medial approach and posterolateral approach) and decompression with fixation (fixation group: total facetectomy plus transforaminal interbody fusion w/ pedicle screw).

Results: Twenty-three patients of TF-PELF were nominated. There were 10 women and 13 men with an average age of 67.6-year-old (range: 31-90-year-old). The lesions were L3 in eleven, L4 in eight, and L5 in four cases. Average duration of procedure is 105.8 minutes and estimated blood loss was 5.4 mL. The procedures were performed under general anesthesia in 8 and local anesthesia in 15 patients. As an adverse event, two patients had temporary hyperesthesia of exiting nerve root. No other adverse event at all. Mean follow-up period was 332.1 days (range: 24-733 days), improvement ratio was 35.0 % by patient-reported modified JOA score, 43.0% and 59.6% by NRS of low back and leg pain, respectively. JOA, NRSs improvement ratio of fixation group (n=50) were 41.0, 37.0 and 63.2%, and of microsurgical decompression group (n=15) were 35.9, 32.8 and 57.0%, respectively.

Conclusion: In short time follow-up period, TF-PELF is enough effective and lesser invasive to pain relief against lumbar foraminal stenosis.

240 Anatomical and Radiographical Parameters in the Craniovertebral Junction to Predict Postoperative Dysphagia in Occipitocervical Fusion: O-EA Angle, O-C2 Angle, and C2-T Angle

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Introduction: Occipitocervical fusion is the gold standard stabilization technique for several pathologies involving craniovertebral junctions, including basilar invagination and neoplasm. However, its postoperative clinical course is often complicated by dysphagia (PD). Here, we sought to evaluate whether radiographical measurements such as O-EAa, O-C2a, C2-Ta, and nPAS (defined in the attached figure) could predict PD in this cohort.

Methods: Single-center, retrospective data review from 2010 to 2017 identified 67 patients who underwent spine surgery involving occipitocervical fusion procedures. Among those, 61 patients had more than one-year follow-up as well as adequate postoperative assessment of swallowing functions. Clinical records of those 61 patients were collected and statistically analyzed. 18 patients (29.5%, group (A)) were diagnosed with PD associated with occipitocervical fusion, who were compared with 43 patients without this complication (group (B)).

Results: There were no statistically significant differences in terms of baseline characteristics including age, sex, BMI, smoking, and co-morbidities or operative data such as estimated blood loss, operative time, and operated levels. While preoperative radiographical parameters were similar between the two groups, postoperative O-EAa ((A) 83.2° versus (B) 101.3°, $p < 0.01$) and nPAS ((A) 8.7 mm versus (B) 14.6 mm, $p < 0.01$) were different with statistical significance. Greater than 5° perioperative changes in O-EAa yielded a positive predictive value of 91.2% and negative predictive value of 83.2% (AUC=0.865) to predict PD. O-EAa had the highest inter-observer reliability (coefficient=0.967) amongst the three parameters. In a linear regression analysis, nPAS (mm) was found to be affected by O-EAa ($p = 0.02$) and sex ($p = 0.01$), but not by O-C2a or C2Ta in this fit model (R square = 0.43).

Conclusion: Perioperative changes in O-EAa and nPAS were associated with postoperative dysphagia. O-EAa was an independent predictor of nPAS and thus can predict postoperative dysphagia with good diagnostic accuracy and inter-observer reliability.

241 Timing of Decompression for Central Cord Syndrome: An Institutional Perspective

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Introduction: Decompressive surgical intervention has become a generally accepted and viable treatment methodology in the setting of CCS and radiographic evidence of spinal cord compression and/or instability. However, the optimal timeframe of surgical intervention for CCS remains controversial. A retrospective study of 39 central cord syndrome (CCS) patients was done to evaluate whether early (< 48 hours after the injury) versus late (> 48 hours after the injury) surgical decompressions surgeries was optimal for enhancing neurologic recovery in patients suffering from CCS.

Methods: Patients, undergoing either early or late surgical treatment methods, characteristics including pre-operative ASIA scores, post-operative ASIA scores, cause of injury, age, length of stay (LOS) in the hospital, bladder incontinence, ambulation, and type of surgery were analyzed to evaluate the potential benefits of early versus late surgical options.

Results: A total of 39 patients were diagnosed and treated surgically for CCS. Early surgical patients had a LOS that was 1.46 days longer than those in late surgery options. There were no significant results in the areas of ambulation and incontinence with regards to the surgical timing. Overall, early surgical patients progress in their motor recovery at an elevated rate and a 13% increase in their ASIA scores as compared to late surgical patients.

Conclusion: The data presented within this study supports that the optimal surgical timeframe for decompression surgeries in the setting of CCS is within the first 48 hours of the sustained injury.

242 The Impact of Hospital Transfer, Time to Surgical Treatment, and Acute Rehabilitation on Spinal Cord Injury Recovery: A Retrospective Cohort Analysis

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Introduction: Spinal cord injury (SCI) has an incidence of 54:1,000,000 people annually with 17,500 cases in the U.S. Our previous work utilizing the National Inpatient Sample (NIS) demonstrated that patients transferred to a tertiary referral center showed greater likelihood for non-routine disposition, increased length of stay and increased cost compared to directly admitted patients. However, these findings were limited by the NIS database. Subsequently, we evaluated patient outcomes during referral to an inpatient rehabilitation unit.

Methods: A single-center, retrospective cohort analysis of patients directly admitted within a tertiary SCI designated facility or external transferred from community hospitals during 2011-2017 was performed.

Results: A total of 188 patients (mean age 46.1 ± 18.6 years, 77.1% males) were identified with 80 directly admitted and 105 transferred from outside facilities. Admission American Spinal Injury Association (ASIA) impairment scores were: A (32.4%), B (14.9%), C (14.9%), D (33.5%), and E (1.1%). Surgical treatment was performed in 80 (97.6%) of directly admitted patients while surgery for transferred patients was performed at the referring facility in 47 (44.8%) cases. No difference in time to surgical treatment (1.7 ± 4.3 vs. 1.9 ± 3.8 days, $p=0.7$), rehab length of stay (32 ± 24 vs. 34 ± 22 days, $p=0.5$), surgical treatment ($p=0.5$), followup (27.8 ± 28.0 vs. 21.5 ± 23.3 days, $p=0.1$), or improvement in Functional Independence Measure (31.1 ± 16.3 vs. 30.3 ± 16.1 , $p=0.7$) was seen between directly admitted and transferred patients, respectively.

Conclusion: Patient outcomes after transfer were similar treatment outcomes at directly referred hospitals for patients undergoing SCI rehab. Both groups of patient showed substantial improvement in functional outcomes after acute rehabilitation, suggesting early, coordinated referral to such facilities is clinically impactful.

243 Impact of the Inclusion of C2 in Posterior Cervical Fusions for Cervical Myelopathy on Sagittal Cervical Alignment

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Introduction: The incidence of kyphosis following cervical laminectomy is approximately 20% and is higher in patients with a straight spine. Despite the use of posterior instrumentation and arthrodesis after decompression, loss of lordosis or even the development of kyphosis remains prevalent. Inadequate cervical lordosis and other measures of sagittal cervical alignment have been shown to correlate with disability and general healthy scores, as well as myelopathy severity. The role of C2 in the posterior tension band, which maintains sagittal alignment, differs from the subaxial spine as it is the insertion point for erector spinae muscles that play a critical role in maintaining posture.

Methods: This study compares the radiographic outcomes of sagittal balance between two cohorts of patients who underwent posterior cervical decompression and fusion for cervical myelopathy over a 12 year period at a single institution. Demographic and surgical characteristics were collected using the electronic medical record for patients undergoing posterior cervical fusions including the axis (AF) and those that were subaxial fusions (SAF). Radiographic measurements included pre- and post-operative C2-C7 lordosis (CL), C2-C7 sagittal vertical axis (SVA), and T1 slope (T1S).

Results: After review of the electronic medical records, 229 patients were identified as having posterior cervical fusion and decompression for treatment of myelopathy. 167 patients had AF, while 62 had SAF. Posterior cervical fusion results in loss of CL in both cohorts. While there was no statistical difference in postoperative CL, there was a significant increase in SVA ($p < 0.001$) and T1S ($p < 0.001$) with AF.

Conclusion: Posterior cervical fusion is a procedure that results in loss of CL, and based on the results from this study, the inclusion of the C2 into the fusion construct also results in increased sagittal balance, increasing the SVA and T1S.

244 Outpatient Anterior Cervical Discectomy and Fusion (ACDF) in the Ambulatory Surgery Center Setting: Safety Assessment for the Medicare Population

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Introduction: Several studies have demonstrated that ACDF surgery in the outpatient vs hospital setting provides improved efficiency, cost-effectiveness, and patient satisfaction without a compromise in safety or outcome. Recent anecdotal reports, however, have questioned whether outpatient ACDF surgery is safe in the >65 year old Medicare population. We set out to analyze our 3-year experience with Medicare ACDF surgery in a single ASC to determine its safety profile and report our patient population, peri-operative care protocol, and associated outcomes.

Methods: 119 consecutive patients >65 years of age (Medicare-eligible) who underwent either one, two, or three level ACDF in a single ASC from 2015 to 2018 were included. All patients were ASA grade 1-3 and observed for a minimum of 4hrs in PACU for perioperative complications prior to discharge. Data were collected on patient demographics, comorbidities, operative details, and all perioperative and 90-day morbidity.

Results: 119 consecutive Medicare-eligible patients were included; 97 (81.5%) were actively enrolled in Medicare, Table 1. Comorbidities did not differ between Medicare enrolled and Medicare eligible patients, Table 2. No patients (0%) required return to the operating room for intervention within the 4-hour PACU observation window. No patients (0%) required transfer from the ASC to the hospital setting. Peri-operative adverse events were reported in 2.4% of cases, all which resolved by 90-days after surgery, Table 3. The incidence of 90-day hospital re-admission was 1.7% (n=2), of which one patient (0.8%) required re-operation at the index level for deep infection. All-cause 90-day mortality was 0%.

Conclusion: An analysis of consecutive Medicare patients (ASA grade 1-3) who underwent one to three level ACDF in an ASC setting demonstrates that surgical complications occur at a low rate with a safety profile similar to both inpatient ACDF and to patients <65 years of age. In an effort to reduce cost and improve efficiency of care, surgeons can safely perform ACDF for the Medicare-population in an ASC environment utilizing patient selection criteria and peri-operative management similar to that reported here.

245 Artificial Discs in Cervical Disc Arthroplasty: A Network Meta-Analysis for Comparison of Long-term Outcomes

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Introduction: Cervical Disc Arthroplasty(CDA) is an alternative method of surgical interventional for Degenerative Disc Disease in cervical spine which was hypothesized to replace Anterior Cervical Discectomy and Fusion(ACDF). Although comparison of two techniques has been extensively studied in the literature, a thorough comparison of all artificial discs within each other has not been performed yet, except a few studies comparing only two types of discs. Herein, the objective of presented study is to evaluate outcomes of 7 FDA approved artificial discs and to compare the discs which are in use for long-term.

Methods: A comprehensive literature search for cervical arthroplasty including device name, spanning four databases, was conducted from inception through 2018, in English only. Outcomes of patients undergoing cervical arthroplasty with different cervical replacement devices are compared(effect size, ES). These outcomes are: heterotopic ossification(HO), adjacent segment disease(ASD), and reoperations.

Results: Eighty-four studies(n=7066) were included for analysis. Thirty-eight studies and 3408 patients belonged to Bryan; 13 studies and 1463 patients belonged to Mobi-C; 8 studies and 1001 patients belonged to Prestige-LP; 12 studies and 453 patients belonged to ProDisc-C; 13 studies and 741 patients belonged to Discover. Based on statistical analysis, comparing the incidence of Grade III/IV HO, there was significant variability between the five devices(p<0.001) with Prestige-LP(ES:0.23) and ProDisc-C(ES:0.38) of highest incidence rate. Overall rate of ASD was 17%(95%CI: 11% to 24%;p=0.005), with Discover having the lowest incidence rate of 5%. As for reoperations at 4 years of follow-up, the overall incidence rate was 2%(95%CI: 1% to 3%) with no variability between any device(p=0.22).

Conclusion: Our results show that surgical and clinical outcomes may differ among different CDA devices. These results are important for surgeons so that in addition to patient selection, providers are also aware of device specific nuances while making a decision to perform CDA.

246 Degenerative Cervical Myelopathy in North America, 2002-2014: A Silent Epidemic

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Introduction: Although degenerative cervical myelopathy (DCM) is purported to be the leading cause of spinal cord dysfunction globally, the population incidence of this clinicopathological entity remains poorly defined. We sought to determine the incidence and healthcare resource utilization of surgical DCM at the population level, and compare these to other common neurosurgical pathologies.

Methods: Patients who underwent surgery for DCM were identified from the HCUP National Inpatient Sample (NIS) for 2002 through 2014 using ICD-9-CM codes. We calculated overall and age- and sex-stratified incidences per 100,000 persons for each year using patient-specific discharge weights and population estimates from the U.S. Census Bureau. Trends for incidences were evaluated by joinpoint regression to determine the average annual percent change (AAPC). Incidences were also calculated for traumatic spinal cord injury (SCI) and three common neurosurgical procedures: evacuation of subdural hematoma (SDH) (including acute, subacute, and chronic), craniotomy for tumor (including primary and metastatic), and clipping or coiling of cerebral aneurysm.

Results: The overall incidence of surgical DCM rose from 10.3 per 100,000 in 2002 to 21.1 per 100,000 in 2014, representing an AAPC of 5.9%. The highest incidence (61.1/100,000) and growth rate (AAPC 7.4%) were seen in the 65- to 84-year old age group. Age-adjusted incidences and annual growth rates for DCM exceeded those of SCI (5.0/100,000; -0.5%), evacuation of SDH (8.2/100,000; 0.4%), craniotomy for brain tumor (14.2/100,000; 1.1%), and clipping or coiling of cerebral aneurysm (7.2/100,000; 2.4%) (Fig 1). Cumulative hospitalization charges and costs related to surgery for DCM in 2014 were \$1.14 billion and \$291 million, respectively (Fig 3).

Conclusion: DCM is a leading indication for operation on the central nervous system. The incidence of, and healthcare dollars spent on, surgery for DCM has steadily risen over the past decade owing both to an aging population and increasing recognition of the role of surgical management.

247 Surgical Outcomes for Elderly Patients with Degenerative Lumbar Spondylolisthesis

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Introduction: Two randomized control trials assessing outcomes following surgery for lumbar spinal stenosis and spondylolisthesis excluded patients who were older than 80 years. This study assesses outcomes for patients age >80 years following degenerative lumbar spondylolisthesis surgery.

Methods: This was an analysis of a prospective registry. 797 patients underwent surgery for grade 1 degenerative lumbar spondylolisthesis at twelve high-enrolling sites. Elderly patients were identified as age >80 years. Baseline variables were collected. 3-month readmission and cumulative reoperation rates, as well as Numeric rating scale (NRS) back pain, NRS leg pain, Oswestry Disability Index (ODI), EuroQoL-5D (EQ-5D), and the North American Spine Society (NASS) Satisfaction Questionnaire, were collected at baseline and 24 months.

Results: Thirty-seven (4.6%) patients were elderly (range:80-95 years). Elderly patients had less baseline NRS back pain (5.4 ± 3.3 vs. 6.8 ± 2.7 , $p=0.003$). Elderly patients received fewer fusions (43.2 vs. 81.7% , $p<0.001$). At 24 months, both the elderly and young cohorts improved significantly for NRS back and leg pain, ODI, and EQ-5D ($p<0.01$ for all comparisons). There was no difference in cumulative reoperation rate (elderly 10.8 vs. 7.9% , $p=0.74$) and 24-month satisfaction (elderly 72.0 vs. 83.8% NASS 1/2; $p=0.40$). In univariate analysis, there was a trend toward increased 3-month readmission rate in the elderly (10.8 vs. 3.8% , $p=0.10$). In multivariate analysis, elderly status was associated with an increased risk of 3-month readmission ($OR=3.8$; $95\%CI[1.03-14.1]$; $p=0.04$). However, elderly status was associated with similar adjusted outcomes for 24-month ODI, NRS back pain, NRS leg pain, EQ-5D, NASS satisfaction, and cumulative reoperation rate ($p>0.05$, all models).

Conclusion: Age >80 years was associated with an increased risk of readmission following lumbar spondylolisthesis surgery. However, elderly patients achieved similar reoperation rates and benefits for disability, back pain, leg pain, quality of life, and satisfaction as young patients. Regardless of age, both elderly and young cohorts achieved significant improvements in all patient-reported outcomes at 24 months.

248 The Impact of Certificate of Need (CON) Programs on the site of Surgical Care. Do CON Programs Constrain Growth in Ambulatory Surgery Centers (ASCs)?

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Introduction: Performing spine surgery in lower cost settings can reduce the cost of surgery by up to 65%. Private practice spine surgeons have primarily been responsible for partnering with private insurers to move common spine procedures (e.g. decompression, ACDF, ADR) to the ASC. A Certificate of Need program (CON) is a bureaucratic step requiring a non-trivial fee and approval from a state level board before an ASC can be opened. CON programs exist for ASC ownership in 24 states. Our hypothesis is that the 24 states with CON programs will have fewer procedures performed in outpatient settings (inclusive of ASC and hospital outpatient) as compared to hospital inpatient.

Methods: We used claims data from Truven MarketScan Databases to analyze 1,018,171 ACDF or decompression procedures performed between 2009 and 2015. A multinomial logistic regression was used with dependent variables for each site of service (hospital inpatient, hospital outpatient and ASC). The site of service was identified by Medicare Severity-Diagnosis Related Group (MS-DRG) or Current Procedural Terminology codes and we only used MS-DRG codes without complications/comorbidities or major complications/comorbidities. We also controlled for age and other patient diagnoses that could impact the site of service decision (e.g. morbid obesity, smoking) using ICD-9 codes.

Results: Risk ratio calculations revealed that patients in states with a CON program are 40% ($p<0.01$) less likely to have an ACDF in an ASC and 37% ($p<0.01$) less likely to have a decompression in an ASC. The effect was more pronounced in the hospital outpatient setting where patients were 46% ($p<0.01$) less likely to have a decompression and 93% ($p<0.01$) less likely to have an ACDF.

Conclusion: States with a CON program have fewer ACDF and decompression procedures performed in lower cost settings.

249 Reduction in Narcotic Use After Lumbar Decompression and Fusion in Patients with Symptomatic Lumbar Stenosis or Spondylolisthesis

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Introduction: Opioids are frequently used to manage pain in patients with symptomatic lumbar stenosis or spondylolisthesis. Prolonged opioid use can potentially lead to misuse, abuse, and dependence. The purpose of the study is to assess change in opioid use before and after lumbar decompression and fusion surgery for patients with symptomatic lumbar stenosis or spondylolisthesis.

Methods: An insurance database, including private/commercially insured and Medicare Advantage beneficiaries, was queried for patients with symptomatic lumbar stenosis or spondylolisthesis undergoing 1, 2, or 3-level index lumbar

decompression and fusion procedures between 2007-2016. Research records were searchable by International Classification of diseases diagnosis and procedure codes, and generic drug codes. Opioid use 6-months prior to index surgery through 2-years after surgery was assessed. The primary outcome was change in opioid use after index lumbar surgery. Multivariate regression analysis was used to investigate independent predictors of prolonged opioid use after lumbar fusion.

Results: A total of 13,257 patients were included. Overall, 7,656 (57.8%) patients had a history of opioid use prior to index surgery. Throughout the 6-month preoperative period, a total of 2,368,008 opioid pills were billed for, which averaged to 51.6 opioid pills per opioid user per month. When compared to pre-operative opioid use, patients billed fewer opioid medications after surgery (pre-op pill/patient/month: 51.6 vs. post-op pill/patient/month: 33.6). Obesity (OR 1.10, pre-operative narcotic use (OR 3.43), length of hospital stay (OR 1.02), and receiving treatment in the South (OR 1.18) or West (OR 1.26) were independently associated with prolonged (>1year) opioid use after index surgery.

Conclusion: This study suggests that surgery for symptomatic lumbar stenosis or spondylolisthesis may be associated with a reduction in opioid use. Future studies are needed to corroborate our findings.

250 Utility of Cervical Collars Following Cervical Fusion Surgery; Does it improve Fusion Rates or Outcomes? A Systematic Review.

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Introduction: Anterior and posterior cervical fusions constitute the most commonly performed cervical spine procedures. Postoperative cervical immobilization following ACDF has been purported to improve fusion rates and outcomes. There is a paucity in the strength of evidence to support its clinical benefit following cervical fusion procedures.

Methods: A Systematic review using PRISMA. An online search using Medline and Cochrane CENTRAL databases was used to query clinical trials evaluating cervical fusions with or without postoperative collar.

Results: The search strategy identified 899 articles in Medline and 65 articles in the Cochrane Central Register of Controlled Trials. From these articles, only 3 studies directly compared between collar and no collar use; and were low risk in all 7 domains for assessment of bias. The mean improvement NDI scores after using a cervical collar in comparison to not using a collar from each of the 3 resulting studies were extracted and combined. ANOVA was used to compare between overall improvement means based on time interval. Our analysis of the mean improvement scores and improvement over time intervals did not show a statistical significant difference between collar vs no collar.

Conclusion: The result of this systematic study provides sufficient evidence to conclude that postoperative cervical collar is not necessary following 1-2 level ACDF for degenerative cervical pathologies. In PCF patients, there is insufficient data to make a valid conclusion.

251 Machine Learning Analysis of Multiparametric Quantitative MRI to Develop a Diagnostic Model for Early Myelopathy

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Introduction: The clinical diagnosis of myelopathy can be challenging as the symptoms and signs can be subjective and diagnostic uncertainty is common. Anatomical MRI showing cord compression has poor specificity. MRI techniques that provide measures of demyelination, axonal injury, and atrophy may provide enhanced accuracy for cases with diagnostic uncertainty. We previously described a multiparametric quantitative MRI protocol for microstructure analysis of the spinal cord that shows clinical correlation in the setting of degenerative cervical myelopathy (DCM). We used the metrics from this MRI protocol to develop a diagnostic tool, comparing 5 statistical approaches for classification between healthy subjects and those with DCM.

Methods: 35 healthy subjects and 56 DCM patients were included in the analysis. All subjects were examined clinically followed by MRI scans in a 3T GE scanner acquiring T2-weighted (T2w) imaging, diffusion tensor imaging (DTI), magnetization transfer (MT), and T2*-weighted (T2*w) imaging covering C1-C7. Image analysis was performed on Spinal Cord Toolbox (SCT) to calculate SC cross-sectional area (CSA), fractional anisotropy (FA), MT ratio (MTR), and T2*w white to grey matter signal intensity ratio (T2*w WM/GM) in the cord and normalized for confounding variables. Statistical analysis was performed with R version 3.3. Diagnostic models were developed using subject characteristics and MRI data using 1) logistic regression (LR), 2) linear discriminant analysis (LDA), 3) principle component analysis followed by logistic regression (PCA-LR), 4) k-nearest neighbors (kNN) with various k values (3,5,7), and 5) a support vector machine (SVM) model. Estimates of diagnostic accuracy were reported as corrected area under receiver operating characteristic curves (AUC).

Results: All 5 models showed good diagnostic accuracy, with the SVM model showing the highest performance (AUC=95.6%), outperforming LR (93.6%), PCA-LR (89.0%), LDA (87.9%) and kNN (84.6%).

Conclusion: Multiparametric MRI techniques show promise as an accurate diagnostic tool for the detection of early myelopathy and aid surgical decision making.

252 Implementation Analysis for the First Six Months of an Enhanced Recovery After Surgery (ERAS) Protocol for Lumbar Spinal Fusion

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Introduction: Enhanced Recovery After Surgery (ERAS) programs would benefit spine surgery. We describe the results of our initial iteration of a "bottom-up" approach, in which implementation of selected interventions is entirely provider-driven and targets specific elements of enhanced recovery.

Methods: Beginning March 2018 at our institution, 57 patients undergoing posterior, one-to-three level, lumbar fusion surgery with any of three spine surgeons (MYW, ADL, GRM) received an intraoperative injection of liposomal bupivacaine, immediate postoperative infusion of one-gram intravenous acetaminophen, and daily postoperative visits from our multi-disciplinary ERAS team. Medical records were reviewed for the ERAS cohort and a comparison group of 40 patients who underwent the same procedures during the six months preceding implementation.

Results: Groups did not differ significantly between gender, age, or BMI (all $p > 0.05$). LOS was significantly shorter in the ERAS cohort compared to control (2.9 days vs. 3.8 days; $p = 0.01$). Patients in the ERAS group consumed significantly less oxycodone compared to the controls on POD0 (408.0 mg vs. 1094.7 mg; $p = 0.0004$), POD1 (1320.0 mg vs. 1708.4 mg; $p = 0.04$), and POD3 (1500.1 mg vs. 2105.4 mg; $p = 0.03$). Post-operative pain scores recorded by the physical/occupational therapy teams and nursing staff each day were lower in the ERAS cohort compared to control with POD1 achieving significance (4.2 vs. 6.0; $p = 0.006$). Total amount of meperidine (8.8 mg vs. 44.7 mg; $p = 0.003$) consumed was also significantly decreased in the ERAS group, as was ondansetron (2.8 mg vs. 6.0 mg; $p = 0.02$). Distance ambulated on each POD was farther in the ERAS cohort with POD1 (109.4 ft vs. 41.4 ft; $p = 0.002$) achieving significance.

Conclusion: ERAS patients consumed fewer pain medications, ambulated a greater distance, and had a shorter hospital stay compared to controls. This is the first in a series of systematic iterations designed to continually improve patient outcomes, maximize protocol compliance, and create the framework for future ERAS implementation strategies for lumbar fusion.

253 The Safety and Efficacy of Riluzole in Enhancing Clinical Outcomes in Patients undergoing surgery for Cervical Spondylotic Myelopathy: Results of the CSM-Protect Double-blinded, Multi-center Randomized Controlled Trial in 300 Patients

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Introduction: Cervical spondylotic myelopathy (CSM) is the most common cause of spinal cord dysfunction in adults. Surgical decompression improves clinical outcomes; however, many patients have residual disability. We hypothesized that adjuvant treatment with the sodium-glutamate blocker riluzole may be effective in enhancing surgical outcomes.

Methods: In this Phase 3 multi-center, placebo-controlled, double-blinded, randomized controlled trial (ClinicalTrials.gov NCT01257828), surgically naïve subjects undergoing operative decompression for moderately severe CSM (mJOA 8-14) received riluzole 50 mg bid for 14 days before surgery and 28 days after surgery, or placebo. The primary outcome was change in mJOA score at 6 months post-operatively. Subjects were followed up 6 months for the primary efficacy analysis and 12 months in total.

Results: 300 subjects were enrolled and 290 (141 riluzole and 149 placebo) received surgery. Subjects in both trial arms improved with regard to all endpoints. At 6-month and 12-month follow-up, there was no difference between riluzole and placebo regarding improvement in mJOA (2.45 and 2.82 in riluzole and placebo groups at 6 months, respectively, $p = 0.16$), Nurick grade, NDI, SF-36, EQ-5D, ASIA motor and sensory scores, pain, and grip strength. In a repeated measurement analysis, riluzole subjects showed greater 35-day reduction in neck pain (VAS) that was maintained at 6 and 12 months.

Conclusion: Adjuvant treatment with riluzole does not improve functional recovery because the effects of surgical decompression dominate the clinical picture. The potential effect of riluzole in reducing pain in surgically treated CSM patients merits further study.

254 Cost Analysis During Rehabilitation After Spinal Cord Injury: A Retrospective Cohort Analysis

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Introduction: Spinal cord injury (SCI) has an increased lifetime direct and indirect cost with the level and severity injury. Despite the potential for substantial improvement in function with acute rehabilitation, evaluation of the costs has not yet been performed. We utilized the Value Driven Outcome (VDO) database to evaluate the direct costs of rehabilitation after SCI.

Methods: A single-center, retrospective cost-analysis of patients treated at a tertiary SCI facility from 2011-2017 was performed.

Results: A total of 190 patients (mean age 46.1±18.6 years, 77.1% males) were identified. Admission American Spinal Injury Association (ASIA) impairment scores were: A (32.1%), B (14.7%), C (14.7%), D (33.2%), and E (1.1%). Surgical treatment was performed in 179 (94.2%) of cases. The majority of injuries were in the cervical spine (53.2%). A mean improvement of Functional Impairment Score of 30.7±16.2 was seen. Facility (86.5%) followed by pharmacy (9.2%), supplies (2.0%), lab (1.5%), and imaging (0.8%) categories accounted for the cost of care. Length of rehabilitation stay was an independent predictor of cost (odds ratio 1.56, 95% CI 1.21-2.0, p=0.001) after adjusting for injury level and severity. Length of stay was impactful in explaining variation in cost for different patients.

Conclusion: SCI continues to have a high upfront cost of care, with increased need for rehabilitation playing a key role in cost. Improving the efficacy of rehab in order to reduce length of stay may be impactful in reducing the cost of SCI.

255 Tubular Discectomy vs Conventional Microdiscectomy for the Treatment of Lumbar Disk Herniation: Long-term Results of a Randomized Controlled Trial

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Introduction: The standard surgical procedure for the treatment of lumbar disc herniation is open microdiscectomy. Minimal invasive discectomy with tubular retractors is hypothesized to cause less tissue damage and faster recovery. We previously reported our 1- and 2-year results, and found no better outcomes of tubular discectomy compared with open microdiscectomy. Studies with long-term follow up are required to determine if clinical outcomes are sustained and to assess specific long-term outcomes such as reoperation rate.

Methods: The study was designed as a double blind randomized controlled trial. 325 patients with a symptomatic lumbar disc herniation were randomly allocated to tubular discectomy (166 patients) or conventional microdiscectomy (159 patients). Main outcomes are the Roland-Morris Disability Questionnaire for Sciatica (RDQ), Visual Analog Scale for leg pain and low-back pain, self-perceived recovery and reoperation incidence. Data were collected during 5 years follow-up.

Results: There was no clinically significant difference between tubular discectomy and conventional microdiscectomy regarding the main clinical outcomes; RDQ scores at 5-years were 4.3 (95% CI 3.3 to 5.2) in the tubular discectomy group and 3.4 (95% CI 2.4 to 4.5) in the conventional microdiscectomy group. The mean difference of 0.9 (95% CI -0.6 to 2.2) was not significant. Mean differences for leg pain and back pain were 0.2 (95% CI -5.5 to 6.0) and 0.4 (95% CI -5.9 to 6.7), respectively. 77% of patients allocated to conventional discectomy reported good recovery of symptoms compared with 74% of patients allocated to tubular discectomy (p=0.79). The reoperation rate was 18% in the tubular discectomy group and 13% in the conventional discectomy group (p=0.29).

Conclusion: Long-term functional and clinical outcome did not differ between patients allocated to tubular discectomy and conventional microdiscectomy. Reoperations were more frequent in the tubular discectomy group, but the difference was not statistically significant.

256 Faster Fusion with stand-alone interbody 3-D Printed Porous Titanium Cervical Implants: Results of the EFFECT Trial

Mark Arts MD, PhD; Jasper Wolfs

Introduction: Anterior cervical discectomy to obtain fusion is a common procedure in cervical spine surgery. Presently, PEEK with (auto)graft is the golden standard for interbody fusion. We report on the clinical and quantitative radiological outcome of a prospective cohort of 3-D printed porous titanium implants. Data on PEEK with autograft (CASCADE Trial) served as a historical control group.

Methods: A prospective study of 49 patients with single level ACDF using 3-D printed porous titanium cervical implants (EIT) was performed. The clinical outcomes (NDI, VAS, Likert) and fusion rates were compared to 47 patients from the historical control group (PEEK with autograft). Dynamic X-rays at 3, 6 and 12 months (N=48) were analyzed using FXA (Aces GmbH) to determine RoM (in °) of the operated level and subsidence (in mm). Fusion was defined as ≥2 degrees of motion.

Results: The mean NDI improved from 30,5 preoperative to 22 at 3 months, to 19 at 12 months postoperatively. Both VAS arm and neck improved significantly after surgery. Perceived recovery showed 83% improvement after 3 months. The mean RoM after 3 months was 2,4° (SD1,5°), 2,3° (SD1,5°) after 6 months, decreasing to 1,6° (SD1,4°) after 12 months. Mean subsidence after 6 months was 1.0 mm compared to 1,6 mm in the PEEK group. The fusion rate at 3, 6 and 12 months was 61%, 51%, 73% respectively, compared to 26%, 51%, 63%, in the PEEK group.

Conclusion: Porous 3-D printed titanium cervical implants result in significant clinical improvement after surgery. The fusion rate is faster and better with less subsidence as compared to PEEK with autograft.

257 Thoracolumbar Evoked Potentials Reveal Persistent and Varied Local Cord Connectivity in Spinal Cord Injury

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Introduction: Evoked potentials have found wide adoption as a mechanism to test neuroconnectivity across spinal levels of interest intraoperatively, and as an objective measure of recovery after spinal injury. However, the potential of this technique to evaluate intrinsic spinal cord connectivity remains largely unexplored. As spinal cord stimulation is hypothesized to harness preserved intrinsic spinal circuitry to affect often-unprecedented functional recovery, a means of evaluating such connectivity is becoming increasingly necessary. In this study, we utilize lower extremity and pelvic floor spinal-evoked potentials in spinally injured subjects to evaluate intrinsic spinal connectivity.

Methods: Six uninjured controls and eight chronic American Spinal Injury Association Impairment Scale (AIS) A to D subjects underwent systematic thoracolumbar magnetic stimulation with a commercially available apparatus. Evoked potentials from the tibialis anterior, medial gastrocnemius, and pelvic floor were collected. Tested stimulation parameters included spinal level of stimulus (T10-L4), pulse intensity, pulse frequency, and pulse waveform (biphasic vs monophasic). Evoked potentials were then evaluated for key parameters including latency, amplitude, and waveform.

Results: Magnetic thoracolumbar stimulation in spinally-injured subjects and uninjured controls yielded consistent evoked potentials. In both spinally-injured subjects and controls, the evoked potential amplitude consistently increased with descending spinal level of stimulation. Biphasic stimulation consistently generated evoked potentials of greater amplitude than monophasic stimulation. Injured subjects produced evoked potentials of lower magnitude and higher latency as compared to the control population; the reduction in amplitude correlated with injury severity.

Conclusion: The demonstrated persistence of spinal-evoked potentials in spinally-injured test subjects is direct evidence of maintained intrinsic cord function, while the reduced magnitude and increased latency suggest suppression or atrophy of the spinal circuitry. With the present findings, it is now possible to design future investigations to test the efficacy of spinal cord stimulation in patients with varying degrees of evoked potential degradation.

258 A Meta-Analysis of Steroids in Acute Spinal Cord Injury: Efficacy and Safety

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Introduction: The current debate on the benefit of steroids in acute spinal cord injury (ASCI) has left many physicians confused about whether these medications are safe and effective for the management of their patients.

Methods: A literature search for relevant articles was conducted on PubMed, EMBASE and Cochrane Library from their establishment date through 02/18/18 for studies evaluating the utility of steroids alone in ASCI. Pooled effect estimates were calculated using the random-effects model.

Results: After removing 890 duplicates, 2,956 articles were screened, and ten articles were included in the meta-analysis: three randomized controlled trials (RCTs) and seven observational studies. No article was found on dexamethasone that met the inclusion criteria. Comparing ASCI patients who received methylprednisolone alone to patients who received no treatment or other therapeutic agents (tirilazad mesylate or granulocyte colony stimulating factor), results from the RCTs demonstrated the overall standardized mean difference for motor score was 0.42 (95%CI: -0.47, 1.31) and the pooled RR was 6.55 (95% CI =0.82, 52.6) for gastrointestinal related diseases; 0.97 (95% CI = 0.54, 1.77) for urinary tract infection; 2.01 (95% CI = 0.43, 9.40) for sepsis; and 0.99 (95% CI = 0.48, 2.03) for pneumonia. Results from observational studies demonstrated that the overall standardized mean difference for motor score was 0.66 (95%CI:-0.63, 1.95) and the pooled RR was 2.12 (95% CI =0.98, 4.61) for gastrointestinal related diseases; 1.00 (95% CI = 0.65, 1.53) for urinary tract infection; 1.41 (95% CI = 0.39, 5.17) for sepsis; and 2.74 (95% CI = 1.59, 4.73) for pneumonia.

Conclusion: In patients with ASCI, methylprednisolone in comparison with no treatment, placebo, or other therapeutic agents was not significantly associated with an improved motor score, improved urinary tract infection, worsened gastrointestinal related diseases, or worsened sepsis. The increased risk with pneumonia was only seen in observational studies and merits further investigation.

259 Neurological Recovery Following Traumatic Spinal Cord Injury: A Systematic Review and Meta-Analysis

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Introduction: Predicting neurologic recovery following traumatic spinal cord injury (TSCI) is a complex task. This study aims to summarize the current evidence on neurologic recovery following TSCI by use of a meta-analytical approach; and to identify injury, treatment and study variables with prognostic significance.

Methods: A literature search was performed, and studies reporting follow-up changes in AIS or Frankel or ASIA motor score (AMS) scales were included in meta-analysis. Proportion of patients with AIS/Frankel improvement, and point changes in AMS were calculated. The potential effect of severity, level and mechanism of injury, type of treatment, time and country of study, and follow-up duration was evaluated through meta-regression analysis.

Results: 114 studies were included, reporting AIS/Frankel changes in 19,913 patients and AMS changes in 6,920 patients. The AIS/Frankel conversion rate ranged from 19.3% for grade A patients to 87.3% for grade C patients. Neurologic recovery was significantly different between all grades of SCI severity in the following order: C > B > D > A. Level of injury was a significant predictor of recovery; as recovery rates followed this pattern: lumbar > cervical & thoracolumbar > thoracic. Thoracic SCI and penetrating SCI were significantly more likely to result in complete injury. Penetrating TSCI had a significantly lower recovery rate compared to blunt injury. Studies with follow-up durations of 6 months or less reported significantly lower recovery rates for incomplete SCI compared to studies with long-term (3-5 years) follow-ups.

Conclusion: This meta-analysis provides an overall quantitative description of neurologic outcomes associated with TSCI. Moreover, it demonstrates how neurologic recovery after TSCI is significantly dependent on injury factors, i.e. severity, level, and mechanism of injury; but is not associated with type of treatment or country of origin. A minimum follow-up of 12 months is recommended for TSCI studies that include neurologically incomplete patients based on our results.

260 Novel Algorithm for the Surgical Management of Lumbar Adjacent-Segment Disease: Adding Modern Techniques to the Surgeon's Armamentarium

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Introduction: Adjacent-segment disease (ASD) is common following lumbar spinal fusion surgery. While the incidence of radiographic ASD is reported to be as high as 100%, the incidence of symptomatic ASD varies widely, with reports ranging from 0% to 27%. Revision posterior surgery with laminectomy and extension of instrumented fusion remains the mainstay of treatment. We propose a novel treatment algorithm, which aims to incorporate minimally invasive alternatives in order to maximize outcomes while minimizing morbidity.

Methods: We retrospectively reviewed a consecutive series of patients treated surgically for ASD by the senior author (MYW) from September 2007 to January 2018. A treatment algorithm based on this series was constructed. To assess the algorithm, patient demographics, surgical characteristics, and pre-operative/post-operative numeric pain scale (NPS) scores for back and leg pain were analyzed, as well as complication, pseudoarthrosis, and revision rates.

Results: Ninety patients undergoing surgery for 92 index cases of ASD were reviewed. Mean follow-up was 13.5 months. Patients underwent open extension of fusion (n=52), stand-alone lateral lumbar interbody fusion (LLIF) (n=28), endoscopic-assisted decompression +/- discectomy (n=4), or open decompression (n=8). Age, sex, number of previously fused levels, and number of levels of ASD did not vary significantly between groups. Hospital length of stay and EBL was greatest for open extension of fusion. Significant improvements in NPS scores were seen for back and leg pain following open extension of fusion ($p<0.001$, $p<0.001$) and LLIF ($p=0.01$, $p<0.001$). Significant improvement in NPS scores for leg pain ($p<0.001$) was observed in endoscopic-assisted decompression. Low rates of surgical complications and pseudoarthrosis were present in all groups. Endoscopic-assisted decompression was associated with the highest revision rate (50%).

Conclusion: Adjacent-segment disease is amenable to a multitude of surgical interventions given appropriate clinical and radiographic indications. Less invasive alternatives may help reduce surgical morbidity, EBL, and length of stay while providing favorable outcomes.

261 Systematic Review and Meta-Regression Analysis of 50,000 Thoracolumbar Pedicle Screws: What is the Accuracy Across the Current Methods of Insertion?

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Introduction: Pedicle Screws (PS) are used for stabilization and enhancing fusion in the spine, in a broad diversity of spinal pathologies, and techniques have been developed to decrease screw misplacement: Free-hand (FH) technique, fluoroscopy-assisted (FA), CT-image navigation (CTNav), and robot-assisted (RA). We aimed to investigate the current PS placement accuracy rates among the four techniques.

Methods: We performed a systematic review, including articles from 1990 to 2018, following the PRISMA statement, to study PS insertion accuracy in the spine. Information on demographic data, diagnosis, the accuracy of PS insertion, spinal levels, the method for screw insertion, and breach features were collected. We conducted a meta-analysis to determine the overall pooled rates of PS accuracy as a primary outcome, stratified by screw placement techniques. Potential factors were examined via meta-regression analyses.

Results: 78 studies (including 51,161 pedicle screws and 3,614 pedicle breaches) were included in this study. The overall pooled accuracy rates were 93.1% via the FH, 91.5% via the FA, 95.5% via CTNav, and 90.5% via the RA. CTNav exhibited a higher PS insertion accuracy compared to the FA and the RA ($p=.01$ and $.04$, respectively). The FH technique presented a positive correlation with thoracic pedicle breach compared to CTNav and the RA ($p<.01$ and $.02$, respectively). The FA technique displayed a higher patient revision rate than FH and CTNav ($p<.01$ and $.01$, respectively), and a higher number of screws revised in a second surgery compared to the FH ($p=.01$). Preoperative diagnosis, age, study design, approach, and the number of surgeons, did not significantly influence the accuracy rates.

Conclusion: Currently, CTNav provides higher accuracy and lower revision rates for PS placement over other techniques. CTNav and RA exhibited fewer breaches in the thoracic spine. The FA exhibited higher rates of revision surgery. Further comparative and standardized studies are required to support these findings.

262 The Effect of Relative Decrease in Blood Hemoglobin Levels on Perioperative Morbidity after Surgery for Metastatic Tumors of The Spine

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Introduction: Blood loss is a known complication of spinal tumor surgery. The purpose of this study is to investigate the effect of percentage change in hemoglobin concentration (dHb) on perioperative complications after surgery for metastatic spinal tumors.

Methods: Our institutional neurosurgical spine database was queried for the years 2012 through 2018 to identify adult patients who underwent surgery for metastatic tumors. dHb was defined as the percentage change between the preoperative hemoglobin level and the nadir hemoglobin in the first 72 postoperative hours. The effect of dHb on the occurrence of perioperative complications was assessed via regression analysis both as a continuous and categorical variable (less than or over 35% change).

Results: A total of 65 consecutive patients operated on between 2012 and 2018 were identified from our database. The average preoperative hemoglobin level for all patients was 12 g/dL (SD 1.8) and the average nadir hemoglobin was 9 g/dL (SD 1.7) this corresponded to a dHb of 24.2% (SD 12.5%). The overall complication rate was 49.2% for all patients. Evaluated as a continuous variable, increasing dHb significantly increased the odds of developing a complication, with an odds ratio of 1.05 (95% CI, 1.01–1.09; $p=0.025$). A dHb of over 35% was also found to significantly increase the risk of complication occurrence (OR 4.54; 95% CI, 1.11–18.48; $p=0.034$). No patient factor was associated with the risk of dHb of over 35%. However, increasing number of decompressed levels (OR 1.69; 95% CI, 1.01–2.83; $p=0.045$), as well as increasing number of fused levels (OR 1.29; 95% CI, 1.01–1.66; $p=0.045$) were found to significantly increase the risk of a dHb of over 35%.

Conclusion: A dHb of 35% or greater following surgery for metastatic tumors of the spine was significantly associated with postoperative complication development in this study.

263 Motion Capture Analysis Quantifies Trunk Control Deficits in Spinal Cord Injury

Yevgeniy Freyvert MD; Lorie A. Brinkman; Ruyi Huang; Jacob S. Nusynowitz; Hamid Ghasemi; Daniel C. Lu MD, PhD

Introduction: Prior to the advent of advanced therapeutic methods for spinal cord injury, rehabilitative research efforts primarily targeted recovery of limb function. With the enhanced recovery potential afforded by modalities such as spinal cord stimulation, there is now an opportunity to provide more effective comprehensive spinal cord injury rehabilitation. Trunk control is essential for quality of life, mobility, and balance, but is often overlooked in recent studies. In this investigation, we describe a novel application of motion capture techniques for assessing trunk function in patients with spinal cord injury.

Methods: Four uninjured controls and eight chronic American Spinal Injury Association Impairment Scale (AIS) A to D subjects with varying levels of injury underwent evaluation. Study subjects were outfitted with motion markers and performed trunk range of motion exercises under multi-perspective video monitoring. Concurrent EMG data was acquired from the rectus abdominis, external obliques, quadratus lumborum, and lumbar paraspinals. Data analysis to evaluate activation, range of motion, physical proportions, and stability was performed using SIMI motion analysis software and MATLAB.

Results: Range of motion was reliably reduced by an order of magnitude in the most severely injured subjects as compared to uninjured controls. The presence of detectable EMG activity in the trunk musculature correlated strongly with increased range of motion while the neurological level of injury did not significantly correlate with range of motion variation or stability. Injured subjects were noted to activate the upper extremity while moving and greater upper body to lower body physical proportions were associated with reduced stability.

Conclusion: Previous advanced rehabilitative research has addressed trunk function as a peripheral and subjective outcome measure. This study demonstrates the utility of motion capture in the objective evaluation of trunk function in patients with spinal cord injury and lays the groundwork for future research efforts to target trunk control in a structured manner.

264 The Effects of Preemptive Hypothermia on Neurophysiological and Functional Outcomes Following Iatrogenic Spinal Cord Impact Injury

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Introduction: Spinal cord injuries accounts for the majority of neurosurgical procedures in the United States. Furthermore, studies have demonstrated that iatrogenic spinal cord injuries (iSCI) are potential complications of these procedures. The incidence rate of iSCI varies from 0.57% to 5.93% depending on among other factors age (adult vs pediatric) and initial injury etiology (1) (2). Examples of these perioperative injuries include direct traumatic injury from instrumentation, unintentional compressive injury during deformity correction or indirectly injury of surrounding

vasculature. Outcomes vary from radicular pain to paraplegia or quadriplegia; moreover, in adolescent patients, impaired learning abilities (3) and depression have been documented (4).

Methods: Female Sprague Dawley rats were randomly divided into two groups: a hypothermia group (32°C) and a normothermia group (36°C). After anesthetizing the rats, a laminectomy was performed at T8. The group assigned to the iSCI was further contused with an Infinite Horizon impactor at 200 kdyn. After the contusion was performed, both groups received an iSCI. After 2 hours under hypothermia, the rats were rewarmed. The sham surgery group experienced the same procedures except the contusion. Locomotor scores and SSEPs were collected one day after the surgery and weekly for five weeks post surgery.

Results: After 35 days, the mean BBB score for the rats that underwent hypothermia was 11.6 (left hindleg). In contrast, the mean BBB score for the rats that were kept under normothermia was 4.3. A two sided t--test comparing the two groups yields a statistically significant difference between the two means of 7.2 points with a p-val=.02. For the hypothermic group, the mean peak-to-peak SSEP amplitude was significantly higher than the normothermic group (21.8 versus 9.3 uV, p-val<0.05) and mean latency was significantly lower (24.7 vs 26.3 ms, p-val<0.05).

Conclusion: Modest hypothermia before an iSCI improves functional and neurophysiological outcomes in Female Sprague Dawley rats.

265 Postoperative Intubation: A Significant Predictor of Morbidity and Severe Adverse Events in Patients Undergoing Elective Posterior Lumbar Fusion

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Introduction: This retrospective review analyzes the impact of immediate postoperative intubation on complication rate, severe adverse events, and death in elective posterior spinal fusions.

Methods: Patients undergoing elective posterior lumbar fusions were identified in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2006 to 2016. Patients who had disseminated cancer or epidural spinal abscess were excluded. Patients who remained intubated postoperatively were identified and compared to the remainder of the cohort. Multivariate analysis was used to ascertain the predictors of non-neurologic complications and postoperative thirty-day mortality following surgical intervention.

Results: 58,370 patients were included in the analysis. 55 patients (0.1%) remained intubated postoperatively. Significant differences between the patients who remained intubated (group 1) and those who were extubated (group 2) include age (65.3 vs 60.2), history of COPD (12.7% vs 4.9%), dependent functional status (10.9% vs 2.3%), mean operative time (8.1 hours vs 3.5 hours) and ASA class of 3 or greater. On multivariate regression analysis the significant predictors of failure to extubate were dependent functional status (OR 2.89 95% CI: 1.18-7.04, p=0.020), COPD (OR 2.6 95% CI: 1.13-6.10, p=0.025), ASA class of 3 or greater (OR 2.44 95% CI: 1.59-1.84, p=0.013). and operative time (OR 1.7 95% CI: 1.60 -1.84, p<0.001). Patients that remained intubated had a significantly higher risk of overall complications (OR 10.3 95% CI: 5.77-18.22, p<0.001), severe adverse events (OR 13.8 95% CI: 7.78-24.48, p<0.001), and death (OR 24.2 95% CI: 8.95-65.65, p<0.001).

Conclusion: Previous smaller studies have shown that patients who remain intubation postoperatively have more complications. This study highlights that on review of a large number of procedures (58,370) postoperative intubation is a robust independent predictor of morbidity (OR 10.3) and mortality (OR 24.2) in elective lumbar fusion patients and has a odds ratio greater than any other predictor.

266 Clinical Outcomes and Local Control Rates for Stereotactic Radiosurgery Following Surgery for Metastatic Spinal Tumors

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Introduction: Stereotactic radiosurgery (SRS) is increasingly being used in the multimodal management of patients with metastatic disease to the spine, but clinical outcomes and local recurrence rates after post-operative SRS remains unknown. We present data on post-operative SRS for spinal metastasis.

Methods: We identified 63 patients who underwent various types of decompressive spine surgery for metastases followed by SRS at our institution between 2012 and 2017. Demographic information, tumor histology, survival rates, recurrence rates, clinical outcomes and complications were recorded and analyzed.

Results: The mean age of patients in our cohort was 64 years (range 44-85 years), with 32% female and 68% male. The radiation dose was 18-Gy in 1 fraction using 6 MV photons with a 24-Gy boost to the gross tumor volume. The follow up period range was 3-84 months, with 3-weeks average time between surgery and SRS. Radiographic evaluation following SRS was every 3 months after treatment with CT or MRI. The 1- and 2-year survival rates were 57% and 38% respectively. Overall rate of local recurrence was 12.7% within the follow-up period. Multivariate analysis revealed tumor location (thoracic) and histology (lung carcinoma, colon adenocarcinoma, or melanoma) as significant prognostic factors for local control and overall survival. The surgical and medical complication rates were 14.3% and 19.0% respectively. The most common complication after SRS was an acute pain flare. The rate of hardware failure was 6.3%, with 3 patients developing procedure-related neurological deficits, but there were no cases of radiation myelopathy. There were no differences in local control if a patient had anterior column reconstruction or not.

Conclusion: SRS is an effective treatment modality following all types of surgery for metastases, not just separation surgery. SRS should be considered in the post-operative management for spinal metastases given the low side effect profile and low complications.

267 Penetrating Spinal Cord Injury in Civilians: Analysis of a National Database

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Introduction: Traumatic injuries are a major cause of morbidity and mortality in young people. Spinal trauma is common in polytrauma patients and spinal cord injury (SCI) is present in a subset of these patients. Penetrating SCI has been studied in military with blast and shrapnel injuries, civilian SCI is less studied, and their pathophysiology also varies given the general lower velocity of the projectiles. We sought to investigate civilian penetrating SCI in the U.S.

Methods: We queried the National (Nationwide) Inpatient Sample (NIS) for data regarding penetrating spinal cord injury from the last 10 years (2006 to 2015). The NIS includes data of 20% of discharged patients from U. S. hospitals. We analyzed trends of penetrating SCI its diagnosis, surgical management, length of stay and hospital costs. The data was processed in a statistical software.

Results: In the last ten years there has been a steady incidence of penetrating SCI with a mean of 6% (Range 4.6 to 7.2%) of all SCI patients. Of the patients with penetrating SCI only 17% of them underwent a surgical procedure, compared with 56% for non-penetrating SCI. Patients with penetrating SCI had a longer length of stay (23 days in average) compared to SCI (15 days). Hospital costs were higher for penetrating SCI, \$230 186 compared to \$192 022 for closed SCI.

Conclusion: Penetrating SCI represents 6% of all SCI patients in the NIS database. Patients who suffered a penetrating SCI have fewer surgical interventions for their injury however, their overall length of stay and hospital costs are larger compared to non-penetrating SCI. Further studies could help elucidate the difference in hospital costs between these two types of SCI.

268 Comparative Study of Percutaneous Pedicle Screw Fixation after Direct Decompression with Anterior Column Reconstruction for Thoracolumbar Burst Fracture

Seul-Kee Lee MD; Jung-Kil Lee MD; Jae Y. Kim

Introduction: This study aimed to compare the clinical and radiological results between anterior corpectomy and fusion technique versus posterior decompression with percutaneous pedicle screw fixation technique in the treatment of TLBFs.

Methods: A total of 46 patients (from 2002 to 2015) with TLBFs were included in this study. The inclusion criteria were single-level Magerl type A3 burst fracture of the thoracolumbar spine (T12 L2). These patients were divided into two groups: Group A (22 patients) was treated by anterior corpectomy with fusion, while Group B (24 patients) was treated by posterior decompression with percutaneous pedicle screw fixation (PPSF).

Results: The patients consisted of 17 males and 5 females in Group A and 13 males and 11 females in Group B. The average follow-up period was 44.9 months in Group A and 14.7 months in Group B. The corrections of kyphotic change were 6.4 degrees in Group A and 9.2 degrees in Group B. Among the patient with neurologic deficit, 11 of 15 patients in Group A and 20 of 23 patients in Group B demonstrated at least one ASIA grade improvement on the final observation. However, there was no significant difference between two groups ($p = .13$). In addition, a shorter mean operating time and less mean perioperative blood loss were observed in Group B than in Group A ($p < 0.01$ and $p < 0.01$, respectively; 167.3 minutes and 305.9 mL in Group A; 365 minutes and 1566.7 mL in Group B).

Conclusion: Spinal canal decompression via a small laminotomy followed by PPSF in the treatment of TLBFs with neurological deficits offers excellent biomechanical stability with clinical and radiological improvement. Furthermore, it can be a safe and effective surgical option with the advantages of less invasiveness for the treatment of TLBFs.

269 Ischemic Optic Neuropathy Following Spine Surgery: Case Series and Systematic Review of the Literature

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Introduction: Spine surgery remains one of the largest sources of perioperative vision loss due to ischemic optic neuropathy. Herein, we present our institutional case series supplemented with a systematic literature review to illustrate the prognosis and perioperative risk factors associated with this condition.

Methods: We reviewed all cases of perioperative ION diagnosed following spine surgery at our institution between 2000 and 2017. The chart review was supplemented with a systematic literature search of Medline, Embase, Scopus from inception to September 2017. Following this, we pooled our results to descriptively analyze demographic, perioperative and follow up data and evaluated risk factors for perioperative ION and visual prognosis. We also performed 1:4 matched case-control analysis for our institutional cases to evaluate risk factors.

Results: We identified 12 cases from our institution. A 1:4 matched case control analysis revealed fusion, higher number of operative levels, blood loss, and change in hemoglobin, hematocrit to be significantly associated with ION. Majority were diagnosed with PION (83%, 10/12) and had bilateral presentation (75%, 9/12). Literature review identified 182 cases from 42 studies. Posterior ischemic optic neuropathy (PION) was found in 58.7% (114/194) of cases, anterior ischemic optic neuropathy (AION) in 17% (33/19) and unspecified ION in 24% (47/194). Fusions were

the most common surgical intervention 86.5% (168/194). Mean operative time was 561+/-219 minutes. At follow up, only 34.5% (67/194) patients demonstrated improvement in either visual acuity, visual field or color vision. PION was associated with higher odds of severe visual deficit at immediate presentation (OR-6.45, CI-1.04-54.3, p=0.04) and last follow-up.

Conclusion: PION is the most common cause of vision loss following spine surgery and causes more severe visual deficits compared to AION. Prone spine surgery especially multi-level fusions with longer operative time, higher blood loss and intraoperative hypotension are most associated with the development of this devastating complication.

270 Thoracolumbar Junction Orientation: Its impact on Thoracic Kyphosis and Sagittal Alignment in both Asymptomatic Volunteers and Symptomatic Patients

Hong J. Moon MD, PhD; Munish C. Gupta MD

Introduction: The thoracolumbar junction (TLJ) has not been explored in regard to its contribution to sagittal alignment. The aim of this study is to define novel sagittal parameters of the TLJ and to assess their roles within sagittal alignment.

Methods: Included for cross-sectional, retrospective analysis were asymptomatic volunteers and symptomatic patients who had undergone operation for adult spinal deformity. Unique sagittal parameters of the TLJ were measured using the mid-line of the T12-L1 disc space: The TLJ orientation (TLJO); thoracolumbar tilt [TLT] and slope [TLS]. Thoracic kyphosis (TK; T5-12), C7-S1 sagittal vertical axis (SVA), lumbar lordosis (LL; L1-S1), sacral slope (SS), pelvic tilt (PT), and pelvic incidence (PI) were measured. Continuous variables were compared using the independent t-test. Pearson correlations examined relationships between the parameters in each group. The asymptomatic TK was calculated using the measurements of the asymptomatic volunteer's TLJO by linear regression.

Results: One hundred fifteen asymptomatic volunteers and 127 symptomatic patients were included. Only LL among the lumbopelvic parameters correlated with TK (asymptomatic volunteers: $r=-.42$; symptomatic patients: $r=-.40$). All the pelvic parameters have no direct correlation with TK in both groups. TLJO had stronger correlation with TK (asymptomatic volunteers: $r=-.68$ [TLS], $r=.41$ [TLT]; symptomatic patients: $r=-.56$ [TLS], $r=.44$ [TLT]) than the lumbopelvic parameters. TLS correlated with LL (asymptomatic volunteers: $r=.78$; symptomatic patients: $r=.73$). Most pelvic parameters correlated with TLJO except for PI. The asymptomatic TK was estimated by the derived formula: $20.847 + \text{TLS} \times (-1.198)$.

Conclusion: The TLJO integrates the status of the lumbopelvic sagittal parameters and simultaneously correlates to thoracic and global sagittal alignment.

271 Correlation of MR Diffusion Tensor Imaging Parameters with ASIA Score for Prognostication and Long-Term Outcomes

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Introduction: Conventional magnetic resonance imaging (MRI) is routinely used to demonstrate the anatomical site of spinal cord injury (SCI). However, quantitative and qualitative imaging parameters have limited use in predicting neurological outcomes. Currently, there are no reliable neuroimaging biomarkers to predict short- and long-term outcome after SCI.

Methods: A prospective cohort of 23 patients with SCI (19 cervical (CSCI) and 4 thoracic (TSCI)) between 2007-14 was included in the study. ASIA score was determined at the time of arrival and at one-year follow-up. Only 15 (12 CSCI and 3 TSCI) patients had one-year follow-up. Whole cord FA was determined at C1-2 following which C1=2 divided into upper/middle/lower segments and corresponding FA at each of these segments was calculated. Linear regression analysis was performed between FA and ASIA score at time of arrival and one-year follow-up.

Results: Regression analysis showed a positive but non-significant correlation ($P=0.095$) between FA and ASIA score for all patients (CSCI and TSCI) at the time of arrival. Additional regression analysis consisting of only CSCI patients showed a significant correlation ($P=0.008$) between FA and ASIA score at time of arrival as well as at one-year follow-up, significant correlation ($P=0.025$). Further, in case of CSCI patients, a significant correlation between FA at each of the segments (upper, middle, and lower) of C1-2 with ASIA score at time of arrival ($P=0.017$, $P=0.015$, and $P=0.002$ respectively).

Conclusion: FA can be used as a biomarker for determining recovery in SCI patients with injury at the cervical level. FA measured at lower portion of the C1-2 has a stronger correlation with ASIA at the time of injury. In thoracic patients, FA at the level of C1-2 might not be an accurate measurement due to distance from the level of injury.

272 Should Multi-level Posterior Cervical Fusions Involving C7 Cross the Cervico-Thoracic Junction? A Systematic Review and Meta-Analysis

Aya Akhras MBBS; Anshit Goyal MBBS; Waseem Wahood MS; Mohammed A. Alvi MD; Mohamad Bydon MD

Introduction: Current literature remains inconclusive as to whether multi-level posterior cervical fusions (PCFs) involving the C7 vertebra should cross into the thoracic spine (T1-T2) or not. The objective of this systematic review was to assess the differences in clinical outcomes, fusion and reoperation rates, between patients undergoing multi-level PCFs ending at C7 (not crossing Cervico-Thoracic Junction), and those up to T1-T2 (crossing the Cervico-Thoracic Junction).

Methods: PICO approach was used to query studies reporting outcomes for multi-level cervical fusions ending at C7 or T1 or T2 using a posterior or combined anterior and posterior approach were included. Meta-analysis was conducted comparing incidence of reoperation and fusion rate between patients receiving fusion ending at C7 to those undergoing fusion ending at T1-T2.

Results: Six articles and 530 patients were included in this review. Two studies were one arm studies, 4 studies were comparative studies. There were 305 (58%) patients in the non-crossing group, and 225(42%) patients in the crossing group. Between the 3 comparative studies that have recorded fusion rate, fusion rates are more likely to occur with crossing the CTJ than not crossing (OR: 2.75, 95% CI: 1.61-4.09, $p<0.001$). All four comparative studies recorded reoperations, which are less likely to occur with crossing the CTJ than not crossing (OR: 0.42, 95% CI: 0.25-0.73, $p=0.002$). As for indirect comparison analysis, fusion rate and reoperation rate were comparable between the two groups ($p=0.689$ and $p=0.714$, respectively).

Conclusion: For multi-level posterior or combined anterior and posterior cervical fusions, crossing the CTJ might be with a higher fusion and lower reoperation rate. Future studies will validate the findings of this study and elucidate further differences in clinical outcomes between the two surgical approaches.

273 Trends of Medicare Part B Utilization among Neurosurgeons

Rasheedat Zakare BA; Christine Park BS; Oren N. Gottfried MD

Introduction: Over the next decade, the Medicare-eligible population is expected to swell from 54 million to 80 million beneficiaries. Medical specialties which care for geriatric populations will derive an increasing proportion of their income from Medicare reimbursements and will need to predict where their burgeoning needs will be. The Physician and Other Supplier Public Use File (POSPUF) is a registry of all healthcare professionals who have filed for reimbursements of their services and procedures performed for Medicare beneficiaries. This is the first study to characterize and describe the patterns of Medicare Part B utilization by neurosurgeons.

Methods: This is a retrospective exploratory analysis of the 2015 POSPUF neurosurgery subset merged with physician demographics, population, and regional healthcare market data from publicly-available federal databases.

Results: : There were 4309 neurosurgeons making Medicare claims in 2015. The cohort was overwhelmingly male, urban, and working in large groups of >100 employees. There were a total of 2,170,183 non-medication claims made, 28.13% of which were procedural. Providers who offered fewer kinds of services but performed more of them received higher reimbursement returns, as did those who worked in areas where there were fewer healthcare facilities and in smaller practices ($p < 0.001$).

Conclusion: Our study reveals that there are demographics characteristics attributable to neurosurgeons who file Medicare claims and who receive higher Medicare reimbursement returns.

274 The Limited Influence of the Surgical Team Behavior on the Inpatient Experience: A Retrospective Multi-Hospital Analysis of HCAHPS Feedback

Rasheedat Zakare BA; Wes Dickson BSE; Alessandra Garcia PT, PHD; Tracy Cheng AB; Oren N. Gottfried MD

Introduction: The Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey ties patient satisfaction via the Overall Hospital Rating (OHR) to neurosurgeon reimbursement, but the survey covers several elements of the patient experience. This study investigated the factors which had the highest impact to receive a high (top-box) OHR score.

Methods: Retrospective cohort analysis ($n=1470$) of returned HCAHPS surveys from patients who were discharged between August 1, 2016 and January 31, 2018 from a neurosurgical or orthopedic spine service from our 3 hospitals. Multivariate logistic regression was run for predictors of top-box OHR.

Results: After adjusting for subspecialty and hospital, 7 of 17 survey items were found to be significant predictors of OHR, the top 3 were from discharge "Did you get information about what symptoms to look out for after you left?" (OR 5.93, 95% CI 2.52 13.94), nursing "Did nurses treat you with courtesy and respect?" (OR 3.86, 95% CI 2.28 6.52), and hospital environment "Were your room and bathroom kept clean?" (OR 2.86, 95% CI 1.96 4.17). Subgroup analysis by hospital revealed different OHR predictors within each subpopulation as well.

Conclusion: Drivers of OHR are multidimensional, vary significantly between hospitals and sometimes do not include any surgeon-related measures. Reimbursement for neurosurgical quality should depend on a more reliable measure.

275 Differences in Characteristics and Outcomes among Patients Undergoing Surgery for Spondylolisthesis at a Private vs Academic Institution: Analysis from the Multi-Site Quality Outcomes Database (QOD) Study on Outcomes of Impact of Fusion on Grade 1 So

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Introduction: Recent healthcare reforms introduced as per the Affordable Care Act (ACA) have emphasized on optimizing the "value" of healthcare which translates into maximizing patient outcomes while containing the cumulative

cost of the delivered care. The setting of healthcare delivery has been purported to have an impact on patient outcomes. In the current manuscript, we investigated the differences in outcomes of patients undergoing surgery for spondylolisthesis at a private medical center vs an academic hospital.

Methods: The Quality Outcomes Database (QOD) was queried for patients with grade 1 lumbar-spondylolisthesis included in the multi-site QOD study to investigate the impact of fusion on patient reported outcomes (PROs). Patients were divided into private setting and academic setting based on the administrative structure of the institution they received their care at. The outcomes of interest included Oswestry Disability Index (ODI) and the North-American-Spine-Society (NASS) Satisfaction-Scale (Satisfied= satisfaction index 1, not satisfied= satisfaction index 2-4).

Results: A total of 797 patients were included in the study, of which 40 % (n=318) patients were treated at an academic center and 60% (n=479) treated at a private center. Patients treated at an academic center were more likely to have private insurance (57.9%, n=184 vs 11.3%, n=237, p=0.046), more likely to be employed and working (45.3%, n=131 vs 36.7%, n=176, p=0.04), less likely to undergo fusion (75.2%, n=239 vs 83.3%, n=399, p=0.005) and MIS surgery (28.9%, n=92 vs 36.1%, n=173, p=0.053). On multivariable analysis, the type of institution was found to have no impact on 1-year and 2-year ODI (Academic vs Private: OR 0.70, 95% CI 0.46-1.05 and OR 0.80, 95% CI 0.53-1.2, respectively) and patient satisfaction at 1 and 2 years (OR 1.67, 95% CI 0.66-2.06 and OR 1.01, 95% CI 0.58-1.74 respectively).

Conclusion: Our results indicate that even though the baseline patient characteristics and operative characteristics may differ between private and academic centers, both are associated with equivalent clinical and surgical outcomes among patients undergoing surgery for spondylolisthesis.

276 Impact of Anterior Plating vs. Stand-Alone Cage on Rate of Fusion, Subsidence, and Adjacent Segment Disease in Single-Level Cervical Corpectomy for Spondylosis

Murray Echt MD; Michael Longo BA; Rafael D. Ramos MD; Yaroslav J. Gelfand MD; Jonathan P. Nakhla MD; Merritt D. Kinon MD; Reza Yassari MD

Introduction: The impact of anterior plating vs. stand-alone grafts in anterior cervical discectomy and fusion has been extensively studied, however the use of a plate in anterior cervical corpectomy and fusion has not been well described.

Methods: A chart review was performed for the dates of July, 2008 until June, 2018. Inclusion criteria was single-level corpectomy performed for spondylosis without posterior instrumentation. Subsidence was calculated by comparing the postoperative lateral x-ray films to those obtained during follow-up visits, an considered present if there was at least 3mm of settling into the end-plates. Rate of fusion, subsidence, and adjacent segment disease was compared using Pearson's Chi2 test (p-value <0.05 was considered significant).

Results: A total of 65 patients were identified with 38 constructs including anterior plating and 27 as stand-alone cages. Average age was 61.1 years-old, 55% were male, and average follow-up was 12.7 years. Patient demographics including medical comorbidities and type of graft used were similar. Overall fusion rate was 89.2% with no difference in fusion between plate and stand-alone, 88.9% vs. 89.5% respectively (p=0.94). The overall subsidence rate was 38.5% with a non-significant increase in subsidence for stand-alone cages, 40.7% vs. 36.8% (p=0.75). Adjacent segment disease had a non-significant increase with the use of anterior plating, 13.2% vs. 3.7% (p=0.19). Despite relatively high rate of subsidence there was only need for one revision surgery due to the development of osteomyelitis and epidural abscess in setting of endocarditis. There were only two complications including one C5 palsy that improved on follow-up and one return to the OR for evacuation of a neck hematoma.

Conclusion: In this study, we affirmed the null hypothesis that there is no significant radiographic or clinical difference in using an anterior plate vs. a stand-alone cage. A stand-alone graft construct may be considered for single-level cervical corpectomy for spondylosis.

277 The True Penalty of the Waiting Room: The Role of Wait Time in Patient Satisfaction in a Busy Spine Practice

Rasheedat Zakare BA; Wes Dickson BSE; Tracy Cheng AB; Oren N. Gottfried MD

Introduction: Most clinics collect routine data on performance metrics on physicians for outpatient visits; however, the relationship between them and the patient experience is vague. The aim of this study was to investigate the relationships between the Consumer Assessment of Healthcare Providers and Systems Clinician and Group Survey (CG-CAHPS) and new performance metrics in order to understand the determinants of patient satisfaction.

Methods: All spine surgeons in our academic health system were included and the following were retrospectively reviewed from a 15-month period: demographic data, average cycle times (time in minutes from check-in to check-out), waiting-room times (check-in to being roomed), in-room times (room placement to check-out), lead times (time in days from scheduling phone call to appointment), timely note closure, timely response to patient questions, and patient volume. Kruskal Wallis tests and univariate and multivariate mixed model regression were used to determine their relationships with patient-reported outcomes in global, access, and communication CGCAHPS scores.

Results: Twenty-two surgeons were included in the study. There were 27090 visits. Male gender and no fellowship were independently associated with higher satisfaction in global ratings (p<0.001) and communication (p<0.05). The average clinic visit cycle time was 85.17 ± 25.75 minutes. Increased wait times were associated with poor global (p=0.008), access (p=0), and communication scores (p=0.003) in both univariate and multivariate analyses. Waiting

room time also independently predicted 4 of the 6 individual communication questions. Every ten-minute increase in waiting time was associated with a 9.8% decrease in access scores. Increased in-room time was also an independent predictor of poor scores.

Conclusion: Excessive waiting room time affects not only access scores but also significantly colors other dimensions of the patient experience and impacts perceived communication between patients and doctors. This will help to target effective interventions to improve clinic efficiency and patient satisfaction.

278 Predicting Non-Routine Discharge After Elective Spine Surgery: External Validation of Machine Learning Algorithms Using Institutional Data

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Introduction: Non-routine discharge from elective spine surgery negatively impacts patient outcomes and increases healthcare costs. Preoperative prediction in this population could improve discharge planning as reimbursement for elective spine surgery transitions to bundled payments. We previously developed a machine learning algorithm from national data that predicts non-home discharge of patients undergoing elective spine surgery. Here we externally validate our algorithm in an independent institutional population of neurosurgical spine patients from a previously published Transitional Care Program (TCP) at an academic, tertiary care center.

Methods: Medical records from elective inpatient surgery for lumbar disc herniation or degeneration in the TCP program (2013-2015) were retrospectively reviewed. Variables included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) class, pre-operative functional status, number of fusion levels, co-morbidities, pre-operative laboratory values, and discharge disposition. The discrimination (c-statistic) and calibration of the previous algorithm was assessed in the independent sample. Algorithm validation was performed using Python 3.0 software.

Results: Overall, 144 patients underwent elective inpatient surgery for lumbar disc disorders with a non-home discharge rate of 10 (7%). Median age was 50 years (IQR 39-63) and 45.1% patients were female. The neural network algorithm generalized well to the institutional data with c-statistic 0.89, calibration slope 1.09 and calibration intercept - 0.08. This performance in the institutional cohort was comparable to performance in the derivation cohort and substantiates initial use of this algorithm in clinical practice. Prospective validation of this algorithm and comparison to other existing discharge prediction models is ongoing.

Conclusion: This institutional external validation of a previously developed machine learning algorithm suggests a reliable method for identifying lumbar disc disorder patients at risk for non-routine discharge. This tool can be used by multidisciplinary teams of case management and spine surgeons to strategically invest additional time and resources into post-operative plans for this population.

279 Correlation of Body Mass Index (BMI) and Global Sagittal Alignment with Anterior Correction Surgery in Adult Spinal Deformity

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Introduction: The influence of Body Mass Index (BMI) on global spinal alignment is scarcely known. Anterior surgery with the use of hyperlordotic cages (HLCs) helps in maximizing lumbar lordosis (LL) and correction of global sagittal parameters, such as sagittal vertical axis (SVA). No prior study investigated the effect of global correction on BMI. Therefore, authors hypothesized pre- to postoperative change in SVA correlates with the change in BMI in obese patients undergoing correction surgery with anterior approach.

Methods: All patients operated for de novo or iatrogenic flat back syndrome with a pre-operative BMI of more than 25 were included in this study. Pre- and postoperative standing stereographs were used to calculate sagittal parameters including SVA and LL. Demographics including BMI preop- and postoperatively at last follow up were collected. Unpaired and paired t-tests, and a linear regression were used for statistical analysis.

Results: Of total 74 patients with an average age of 59 years (SD $\pm$ 12), 48 patients with BMI of more than 25 and mean follow-up of 392 days (SD $\pm$ 441) were identified. Mean BMI was 31.1 (SD $\pm$ 4.5), mean pre-op SVA was 87.2mm (SD $\pm$ 60.3), and mean LL was 31.4° (SD $\pm$ 23.6°). Preoperative SVA was significantly correlated with preoperative BMI ($R^2=0.16$, $p=0.004$). Post-surgery, mean change in SVA was 45.9mm (SD $\pm$ 64.1), and mean change in LL was 20.4° (SD $\pm$ 17.5°). Mean change in BMI was 0.1 (SD $\pm$ 3.2) with 27 (56%) patients having a significant decrease in BMI. Postoperative change in SVA was directly correlated with change in BMI ($R^2=0.083$, $p=0.047$).

Conclusion: Anterior surgery with HLCs is efficacious to overpower the overall LL thereby achieving global sagittal correction. High BMI is associated with global malalignment; however, postoperative reduction in SVA is strongly correlated with the decrease in BMI.

280 The Effect of Best Practice Alerts in Electronic Medical Records for Low Back Pain Imaging

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Introduction: Guides presented by the ACP, NASS, ASA_PM, ACOEM, AANS, ACEP, AAPM&R state that imaging should not be obtained for low back pain unless there is unexplained weight loss, focal neurologic deficit, fever/recent

infection, osteoporosis, immunocompromise, history of trauma, or prolonged steroid use. However, many providers continue to obtain imaging for low back pain, which increases the cost of healthcare.

Methods: We implemented Practice Alerts in our electronic medical record system (EPIC) at Stanford from March 2015 to April 2017. We then reviewed the frequency of imaging orders and reasons for override.

Results: Overall, we saw 5176 encounters per month for low back pain at Stanford. There were 28 CTs per month, 85 MRIs, and 170 xrays per month. 473 alerts on average (13.7% of all imaging orders) triggered the alert. After the alert implementation, we saw a relative decrease of 9.6% of unindicated imaging ($P = 0.0193$). There was a significant decrease in MRI rate (1.8% vs 1.5%, $P = 0.003$), but not CT ($P = 0.88$) or xray ($P = 0.39$). Analysis revealed that 55% of overrides may be inappropriate (pain < 6 weeks, radicular symptoms only, patient request).

Conclusion: Overall, we show a small but significant decrease in imaging rate for low back pain after implementation of best practice alerts. There was a significant decrease in MRI use, but not xray. Further research and targeted education initiatives are needed to improve resource utilization.

281 Preoperative Disability Predicts Prolonged Hospital Stay Following Elective Lumbar Fusion Surgery

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Introduction: Prolonged length-of-stay (LOS) after surgery are associated with poor patient outcomes and increased health-care costs. Accurate prediction of LOS following elective lumbar fusion may help optimize the utilization of resources, and assist with framing physician and patient expectations. The goal of this study is to identify pre- and peri-operative predictors of prolonged LOS following elective posterior lumbar fusion

Methods: Data from 150 patients enrolled in a randomized controlled-trial evaluating safety and efficacy of intrathecal-morphine vs. placebo on postoperative pain following elective lumbar fusion was analyzed. The primary outcome was prolonged LOS defined as >5 days (75th percentile in this series). The influence of preoperative variables (including patient age, sex, ASA status, body mass index, Oswestry Disability Index (ODI), and visual analogue scale for pain) and perioperative variables (including number of level fused, surgery type, blood loss, length-of-surgery time and presence of perioperative adverse events) on the odds of prolonged LOS was assessed by a multivariable logistic regression model.

Results: The mean patient age was 62.0 years, and 64 (42.7%) patients were male. The median LOS was 4.0 days (IQR: 3.0), and 41 (27.3%) patients had LOS>5 days. Preoperatively, the mean ODI was 37.6 (SD: 13.6), and the mean VAS for pain was 54.3mm (SD: 22.0). Multivariable analysis showed preoperative ODI ($p=0.004$), age ($p=0.001$), length-of-surgery ($p=0.005$), and presence of perioperative adverse event ($p=0.005$) were independently associated with prolonged LOS. When dichotomized, patients with severe disability (ODI >40/50) had 4.4 times the odds of prolonged LOS compared to patients with mild/moderate disability ($p=0.002$). Preoperative pain was not found to be associated with prolonged LOS.

Conclusion: Four pre- and peri-operative predictors were found to be significantly associated with prolonged LOS following elective open posterior lumbar fusion. Preoperative disability measured by ODI is a novel modifiable risk factor that may benefit from targeted intervention before surgery.

282 Impact of Patient-Controlled Analgesia on Clinical Outcomes after Posterior Lumbar Spinal Fusion Surgery

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Introduction: Optimal post-operative pain control is critical after lumbar fusion surgery. However, there is significant variability in the use of intravenous opioid patient-controlled analgesia (PCA) and little data evaluating its utility compared to multimodal nurse-controlled analgesia (NCA) in this patient population.

Methods: A single institution retrospective review was conducted in patients receiving posterior lumbar fusion for degenerative pathology. Baseline demographics, treatment data, and clinical outcomes were collected. Patients were divided into two cohorts: those treated postoperatively with PCA and NCA. Post-operative numerical rating scale (NRS) pain scores, length of stay, and total opioid consumption were collected. Patients were stratified according to pre-operative opioid consumption as naïve, low (<60 morphine milligram equivalents (MME) daily), high (61-90 MME) or very high (>90 MME).

Results: 240 patients were identified: 62 and 178 in PCA and NCA groups, respectively. PCA patients had higher mean pre-operative opioid consumption compared to the NCA patients (49.2 vs 24.3 MME, $p=0.009$). After stratifying by preoperative opioid consumption, PCA patients had higher 72-hour opioid consumption in all groups. With opioid naïve patients, PCA was associated with higher post-operative mean NRS scores at 24 and 24-72 hours ($p=0.046$ and 0.023, respectively) despite higher opioid intake. In the Very High opioid consumption group (>90MME), PCA patients had increased maximal reported pain scores between 24-72 hours ($p=0.014$) and a greater rate of opioid-related adverse events per patient (0.86 vs 0.43, $p=0.046$). Pain control and adverse event rates were comparable between PCA and NCA in the middle groups (1-90 MME).

Conclusion: Postoperative PCA utilization is associated with significantly more opioid consumption and equal or worse post-operative pain scores compared to NCA after lumbar spinal fusion surgery, particularly in opioid naïve patients.

The increase opioid consumption in PCA patients may also lead to higher rates of opioid-related adverse events in a subset of patients.

283 Does the Height of Cervical Interbody Device Predict the Fusion and Quality of Life Outcomes after Anterior Cervical Fusion: A Regression Modeling Study

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Introduction: The optimal height of cervical interbody devices (cage) to achieve fusion and quality of life (QoL) outcomes in anterior cervical decompression and fusion (ACDF) remains controversial. We sought to determine whether cervical cage height is a predictor for fusion and QoL outcomes.

Methods: We retrospectively analyzed prospective data on consecutive patients who underwent ≥2 level ACDF using a horseshoe-shaped titanium cervical cage by multiple surgeons at a single institution from 1/2015 to 6/2016. We excluded patients =18-year-old or who had undergone prior ACDF at the same levels. We followed patients for =3 months postoperatively by XR/CT, clinic visits/phone interview. Data were collected on patient demographics, fusion levels, cage height, and width. The primary outcome, fusion, was determined by a radiologist using the Suk criteria. The secondary outcome was SF-12 at 6 months postoperatively. Multiple logistic regression was used to determine the predictors for cervical fusion. The sample size was estimated to be 500. $P < 0.007$ was considered significant.

Results: We studied 501 interspaces in 343 patients. Fifty patients had inadequate imaging or <3 months follow up. Patient demographics were shown in table 1. Overall fusion rate was 97.4% with a mean follow-up of 10.2 ± 6.9 months. There was no significant difference in fusion rate for cage heights or fusion levels (tables 2 and 3). There was no significant difference in SF-12 among cage heights (table 4). Multiple logistic regression analysis demonstrated an $\text{Exp}(\beta)$ for non-fusion of 4.1 (95%CI 1.6-10.7, $p=0.003$) for smokers and 4.5 (95% CI 1.6-12.3, $p=0.004$) for females. Cervical cage height was not a significant predictor for fusion. Using cage height as a predictor for fusion, post-hoc power was calculated to be 0.99.

Conclusion: Cervical cage heights did not significantly predict the fusion rate or QoL measures. This study demonstrated that sex and smoking status were significant predictors for cervical fusion.

284 Preoperative PHQ-2 Scoring Predicts Patient Satisfaction and Return to Work up to 1-Year After Lumbar Fusion: A 2-Year Analysis from the Michigan Spine Surgery Improvement Collaborative (MSSIC)

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Introduction: The Michigan Spine Surgery Improvement Collaborative (MSSIC) is a prospective, longitudinal, multicenter, quality improvement collaborative.¹ Using MSSIC, we sought to identify the relationship between a positive PHQ-2, which is predictive of depression, and patient satisfaction, return to work, and achieving ODI MCID up to 2-years after lumbar fusion.

Methods: A total of 8585 lumbar fusion patients were analyzed. Patient satisfaction was measured by the NASS patient satisfaction index. A positive PHQ-2 score is =3, which has a 82.9% sensitivity and 90.0% specificity in detecting major depressive disorder.² Multivariate logistic regression models were constructed; variables tested include age, gender, race, PMH, preoperative diagnosis (disc herniation, spondylolisthesis, etc), preoperative symptoms (axial pain, radicular pain, etc), severity of surgery, and preoperative opioid usage.

Results: Multivariate analysis was performed. Patients with a positive PHQ-2 score were less likely to be satisfied after lumbar fusion at 90-days (OR 0.93, $p < 0.001$), 1-year (OR 0.92, $p = 0.001$), and 2-years (OR 0.92, $p = 0.028$). A positive PHQ-2 was also associated with decreased likelihood of returning to work at 90-days (OR 0.76, $p < 0.001$), 1-year (OR 0.85, $p = 0.001$), and at 2-years (OR 0.82, $p = 0.031$). A positive PHQ-2 was predictive of failure to achieve ODI MCID at 90-days (OR 1.07, $p = 0.005$) but not at 1-year or 2-years after lumbar fusion.

Conclusion: A multivariate analysis from a large, multicenter, prospective database on lumbar fusion patients was performed. We find that PHQ-2, which is a simple and accurate screening tool for depression, predicts and inability to return to work and worse satisfaction up to 2-years after lumbar fusion. Depression is a treatable condition, and so in the same way that patients are medically optimized before surgery to decrease postoperative morbidity, then perhaps patients should have preoperative psychiatric optimization to improve postoperative functional outcomes.

285 Preventing Post Operative Urinary Retention (POUR) in Patients Undergoing Elective Lumbar Surgery: A Quality Improvement Project

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Introduction: The incidence of postoperative urinary retention (POUR) after elective lumbar spine surgery ranges from 8% to 38%. We implemented a quality improvement (QI) intervention to lower the POUR incidence in our institution and the associated morbidities.

Methods: The FADE (Focus, Analyze, Develop, and Execute) model was used. Retrospective charts reviews were conducted pre-intervention for consecutive lumbar surgeries conducted from 10/1/15 9/30/16 to determine our baseline POUR. We excluded kyphoplasty patients. Charts from POUR patients and literature were analyzed to

determine POUR risk factors and possible preventive measures. Multi-disciplinary work groups were conducted to develop a standardized protocol for the intervention. Multi-disciplinary meetings and education sessions were carried out to execute the intervention: catheterization protocol, ambulation day 0, Foley removal from OR on POD1, and prophylactic Flomax. We collected confounders (age, sex, diabetes, smoking, preoperative use of beta-blocker, history of preoperative urinary retention, duration of surgery and indwelling Foley upon return from OR). The primary outcome was POUR as determined by standardized definitions. Post-intervention data from consecutive lumbar surgeries were collected prospectively between 5/30/18-7/16/18 for our interim analysis. Sample size calculation was done for a power of 0.8 and an alpha of 0.05. Univariate analyses were used to evaluate the incidence of POUR pre- and post-intervention. $P < 0.05$ was considered significant. Multiple logistic regression will be used to determine significant predictors for POUR in our final analysis.

Results: There were 264 pre-intervention patients and 151 post-intervention patients. There were significant differences for confounders (tables 1, 2) groups differed significantly for smoking, diabetes, gender, duration of surgery, or pre-operative symptomatic urinary retention (Tables 1, 2). Our POUR rate decreased significantly from 7.6% to 3.3% and compliance measures improved significantly following the QI project implementation (table 3).

Conclusion: The implementation of our POUR prevention protocol significantly lowered our POUR rate following lumbar surgery.

286 Implications of Risk Adjustment for Physician Incentives in the Medicare Access and CHIP Reauthorization Act: Evidence from an Instrumental Variables Analysis of Patients with Low Back Pain

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Introduction: The Medicare Access and CHIP Reauthorization Act (MACRA) modifies physician compensation to account for patients' clinical outcomes and costs of care. If cost measures are not adequately adjusted to account for patient characteristics, physicians may be incentivized to avoid caring for costlier patients. We use a cohort of patients with newly diagnosed low back pain to estimate how successfully MACRA's total-per capita costs (TPCC) model accounts for patient risk profiles in the setting of a common and costly medical condition.

Methods: We estimate costs of care for patients with newly diagnosed low back pain and adjust these estimates for patient-level characteristics much the way MACRA's TPCC model will adjust cost measures to account for patient risk factors. We employ an instrumental variables approach to determine whether unobserved variables like pain severity confound a TPCC measure of costs.

Results: In our study population of 478,981 patients, we find that a TPCC approach to estimating costs of care is substantially biased by unobserved variables. Neurosurgeons are more likely to see patients who are at greater risk for having high costs of care, even after accounting for management decisions and for patient characteristics available in medical claims data. We find that a TPCC approach to estimating the costs of managing an episode of low back pain overestimates the costs of managing neurosurgical patients by approximately \$800 over 6 months, and underestimates the costs of managing less complicated patients.

Conclusion: MACRA's default approach to estimating costs of care is likely to penalize physicians who see a cohort of high-risk patients, even if the cost model is modified using standard risk-adjustment methods that account for patient comorbidities. Our work indicates that some physicians, particularly neurosurgeons, will face strong incentives to purposely choose healthier patients in the setting of low back pain if their management is being evaluated using a TPCC measure.

287 A Predictive Model and Nomogram for Predicting Return to Work at 3 Months After Cervical Spine Surgery: An Analysis from the Quality Outcome Database

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Introduction: Neck pain is one of the most common causes of work-loss due to disability. Due to recent changes in healthcare policies, return to work (RTW) has been increasingly prioritized by physicians and hospitals to optimize healthcare delivery. In this manuscript, we utilized a national spine registry to identify clinical factors associated with RTW at 3 months among patients undergoing a cervical spine surgery.

Methods: We queried the Quality-Outcomes-Database registry for preoperatively employed patients undergoing cervical spine surgery for degenerative spine disease. Multiple-imputations were used for missing values and multivariable (MV) logistic regression analysis was employed to identify factors associated with higher odds of returning to work. A nomogram was constructed using the results of the MV model.

Results: A total of 4689 patients were analyzed, of which 82.2 % (n=3854) returned to work at 3-months postoperatively. Among previously employed and working patients, 88.3% (n=3443) patients returned to work compared to 53.3% (n=411) among those who were employed but not working ($p < .001$). On MV-analysis we found that patients who were less likely to RTW were older (Age>56-65:OR 0.69, 95% CI= 0.57-0.85, $p < 0.001$;>65: OR 0.65, 95%CI= 0.43-0.97, $p = 0.02$), were employed but not working (OR 0.24, 95%CI: 0.20-0.29, $p < 0.001$), were employed part-time (OR 0.56, 95% CI=0.42-0.76, $p < 0.001$), had a heavy (OR 0.42, 95% CI: 0.32- 0.54, $p < 0.001$) or medium (OR 0.59,

95% CI:0.46-0.76, $p<0.001$) intensity occupation, had worker's compensation (OR0.38, 95%CI:0.28-0.53, $p<0.001$), had a higher NDI score at baseline (OR 0.60, 95%CI:0.51-0.70, $p=0.017$), more likely to present with myelopathy (OR 0.52,95%CI:0.42-0.63, $p<0.001$) and had more levels fused (3-5 levels:OR 0.46, 95%CI 0.35-0.61, $p<0.001$). We then constructed a nomogram to predict RTW which was found to have an area under the curve (AUC) of 0.812 and good validity.

Conclusion: The results from this study could help the surgeons identify at-risk patients so that preoperative expectations could more comprehensively be discussed.

288 Development of Clinical Prognostic Models for Postoperative Survival and Quality of Life in Patients with Metastatic Epidural Spinal Cord Compression Treated Surgically

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Introduction: Surgery is generally considered for patients with metastatic epidural spinal cord compression (MESCC) with at least three months of life expectancy. No existing clinical prognostic models (CPMs) are consistently used, and no CPMs predict quality of life (QoL). We aimed to develop the first CPMs of postoperative survival and QoL, using the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) [1,2] guidelines and based on the largest sample of prospective data of surgical patients with MESCC.

Methods: Using the TRIPOD guidelines, we created one-year survival and QoL CPMs using data from 258 patients (AOSpine North America (NA) MESCC study and Nottingham MESCC registry) using a Cox model, logistic regression and manual backward elimination. The outcome measure for CPMs of QoL was the minimal clinical important difference (MCID) in EQ-5D scores. Internal validation involved 200 bootstrap iterations; calibration and discrimination were evaluated.

Results: A higher SF-36 physical component score (PCS) was associated with longer survival (HR: 0.96) whereas primary tumor other than breast, thyroid, and prostate (unfavorable, e.g. lung, HR: 2.57; others, HR: 1.20), organ metastasis (HR: 1.51), male (HR: 1.58), and MESCC treated with radiotherapy preoperatively (HR: 1.53) were not (c-statistic: 0.69 [95% CI: 0.64-0.73]). Four factors were associated with the likelihood of achieving a MCID improvement in EQ-5D at 3 months: KPS <70% (OR: 2.50), living in NA (OR: 4.06), SF-36 PCS (OR: 0.95) and mental component (OR: 0.96) (c-statistic: 0.74 [95% CI: 0.68-0.79]). Calibration for both CPMs was very good.

Conclusion: We developed and internally validated the first CPMs of survival and QoL at 3 months postoperatively in patients with MESCC using the TRIPOD guidelines. A web-based calculator is available (<http://spine-met.com>) to assist clinical decision-making in this complex patient population.

289 Comparison of Inpatient versus Outpatient Single Level Anterior Cervical Discectomy and Fusion for Cervical Radiculopathy: Utilization, Safety and Economics from a National Perspective

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Introduction: Data is mounting to support the safety of single level Anterior Cervical Discectomy and Fusion (ACDF) in the outpatient setting. Moreover, emerging evidence suggests choosing the outpatient setting may represent a potential for cost-savings. This is largely from single center studies or state level databases, but there is a paucity of nationally representative data. Our aim is to evaluate the utilization, safety and economics of inpatient versus outpatient single level ACDF from a national perspective.

Methods: Adults undergoing single level ACDF between July 2003 and December 2014 for cervical radiculopathy were included from the MarketScan Commercial Claims and Encounters and Medicare Supplemental Databases. This national commercial health insurance claims database is representative of the largest segment of US healthcare users. Outcomes of interest consisted of utilization, adverse events, and total payments to the health provider for the index procedure and over a 30-day horizon. Propensity score matching balanced the groups on observed baseline covariates such as gender, age, comorbidities, region and insurance plan type.

Results: A total of 45,963 patients were included (24,282 classified as inpatients and 21,681 classified as outpatients). The proportion of cases classified as outpatient increased from 33.5% in 2003 to 66.6% by 2014. 30-day readmission rates were 3.22% in the outpatient cohort, which was significantly higher than the rate of 1.49% in the inpatient cohort ($p < 0.001$). Overall adverse events were not significantly higher in the outpatient cohort. Those in the outpatient cohort incurred payments of \$4,025 [95% CI: 3580, 4470; $p < 0.001$] less over a 30-day postoperative horizon than those in the inpatient cohort.

Conclusion: This large scale, nationally representative data suggests outpatient single level ACDF for cervical radiculopathy may represent a potential source of healthcare resource saving without increased risk when compared with inpatient ACDF for appropriately selected patients.

290 A Partial Least Squares Analysis of Functional Status, Disability, and Quality of Life after Surgical Decompression for Degenerative Cervical Myelopathy

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Introduction: Previous studies aimed at identifying predictors of clinical outcomes following surgical decompression for degenerative cervical myelopathy (DCM) are limited by multicollinearity among predictors, whereby the high degree of correlation between covariates precludes detection of potentially significant findings. We apply a data-driven method, partial least squares (PLS), to model multidimensional variance and dissociate distinct patient phenotypes that are associated with functional, disability, and QOL outcomes.

Methods: This was a post-hoc analysis of patients with DCM enrolled in the prospective, multi-center AOSpine CSM-NA/CSM-I studies. Baseline clinical covariates evaluated as predictors included demographic (e.g., age, sex, BMI, education, comorbidities), clinical presentation (e.g., symptoms, signs, duration of myelopathy, causative pathology), and surgical treatment (e.g., approach, number of levels, operative duration) characteristics. Outcomes evaluated included change in functional status (?mJOA), disability (?NDI), and QOL (?SF-36) at 2 years. PLS was used to derive latent variables (LVs) that relate specific clinical covariates with specific outcomes. Bootstrapping was used to estimate statistical significance.

Results: A total of 478 patients met eligibility criteria. PLS identified 3 significant LVs. LV1 (Fig 1) demonstrated that the patients with intrinsic hand muscle atrophy who were not treated with laminectomy alone had greater improvement in physical health-related QOL (SF-36 Physical Component Summary, Physical Functioning, Role Physical) at 2 years. For LV2 (Fig 2), the patient phenotype associated with lesser improvement in mJOA was dominated by respiratory, rheumatologic, and psychiatric comorbidities. Finally, LV3 (Fig 3) revealed that a phenotype of a patient with more severe myelopathy (lower mJOA) presenting with a history of gait impairment and exam findings of a broad-based, unstable gait was associated with poorer mental health-related QOL outcomes (SF-36 Mental Component Summary, Mental Health, Vitality, Social Functioning).

Conclusion: By applying a data-driven, multivariate approach, we identified robust associations between DCM clinical presentations and functional, disability, and QOL outcomes.

291 The Cost Effectiveness of Spine Clinic: An Analysis of 35,249 Patient Appointments and Subsequent Surgeries at a Single Academic Institution

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Introduction: hospital compensation remains an important driver for policy makers in practice groups, hospitals and even individual physician practice. While monetary incentive should never play a role in interfering with appropriate patient care, it is important to recognize the imminent nature compensation has on the current and future policies affecting the field of Orthopedic and Neurosurgical spinal surgery. The current study is the first to look specifically at the cost and revenues associated with spine clinic specifically and how the subsequent surgical appointments and factors may influence the overall cost structure of a practice.

Methods: All clinic visits to spine providers were identified at a single academic institution spanning the dates 6/1/2014-6/1/2018. Appropriate clinical and appointment related data were further collected. All subsequent related spinal procedures resulting from such visits were further identified through use of CPT billing codes. All payment information was calculated using medicare reimbursement values for CPT codes with the most recent (2018) conversion factor. Relevant clinical, surgical and cost structure data was collected for each patient.

Results: Clinic characteristics are shown in Table 1. A total of 35,249 clinic visits were identified over the four years studied. Of these, approximately 27.13 % of patients seen were new patients to each clinic. The conversion rate of new patient seen in clinic to subsequent surgery was approximately 19.63%. For these 19.63%, factors influencing the average cost of such procedures were modeled using appropriate regression models and are shown in Table 2. Procedures were further controlled for procedure difficulty and operative time and average opportunity costs of performing such procedures were modeled and shown in Table 3.

Conclusion: The current study is the first to look at the cost effectiveness of spine clinic. It is the authors belief that thoughtful use of above data can prove promising in making small, strategic changes to clinic operations, which could in turn lead to more efficient allocation of resources and overall better patient care.

292 Impact of Neurologic Deficits on Surgical Outcomes and HRQoL Following Treatment for Metastatic Epidural Spinal Cord Compression

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Introduction: A critical knowledge gap exists regarding the impact of neurologic deficits on surgical outcomes and health-related quality of life (HRQoL) in patients surgically treated for metastatic epidural spinal cord compression (MESCC). This study analyzes the impact of preoperative neurological status on postoperative outcomes.

Methods: Data were extracted from a multicenter international prospective cohort study (EPOS0, AO SPINE Knowledge Forum Tumor). Collected data included; patient demographics, overall survival, ASIA impairment scale, the Spinal Instability Neoplastic Score (SINS), perioperative complications, and HRQoL measures including the short form 36 version 2 (SF-36v2) and the spine oncology study group outcomes questionnaire (SOSGOQ2.0)

Results: A total of 239 patients were included. Higher SINS scores at baseline correlated $r_s = -0.20$ ($p = 0.002$) with lower ASIA scores. At 6 weeks post-treatment, 113 of 119 patients with ASIA E remained stable, 23 of 44 patients with ASIA D improved to ASIA E, and 6 of 11 patients with ASIA A-C at baseline improved to ASIA D or E. Patients with baseline ASIA scores of E or D survived ($p < 0.001$) longer than patients with ASIA A-C scores. At 6 weeks follow-up, better ASIA scores were associated with better scores on SF-36v2 and SOSGOQ items including; walking 100 yards ($p = 0.006$), leg weakness ($p < 0.001$), spine pain ($p = 0.048$), and bowel and bladder control ($p = 0.005$), and at 12 weeks, included walking 100 yards ($p = 0.039$), leg weakness ($p < 0.001$), activity level ($p = 0.006$), and working ability ($p = 0.043$). Postoperatively, patients with ASIA A-D experienced more urinary tract infections ($p < 0.001$) and wound drainage ($p = 0.003$) than those with ASIA E.

Conclusion: Patients with neurologic deficits due to MESCC have worse HRQoL, decreased overall survival, and increased risk of surgical complications. Nevertheless, surgery can result in stabilization or improvement in neurologic function which translates into better HRQoL. Postoperative care and follow-up is challenging for patients with neurologic deficits as they experience more postoperative complications.

294 The Impact of Breast Size on Sagittal Balance and Patient Reported Outcomes in a Retrospective Cohort of Elective Spine Surgery Patients

Lara W. Massie MD; Lonni Schultz PhD; Elizabeth N. Kuhn MD; Hesham M. Zakaria MD; Donna Tepper MD; Victor W. Chang MD

Introduction: The impact of sacro-pelvic parameters on surgical planning and clinical outcomes is well described in the literature. Breast tissue has been found to create a dynamic anterior torque on the thoracic spine. This factor has not been previously studied in patients undergoing elective lumbar surgery. This study evaluates the impact of breast size on radiographic sacro-pelvic parameters prior to surgery and patient reported outcomes (PROs) after surgery.

Methods: A retrospective review of patients who had both mammograms and standing scoliosis films, PRO data, and self-reported bra size (A, B, C, or D+) was performed. Patients were assessed for correlation between breast volume and sacro-pelvic parameters on full length radiographs or between breast volume and PROs (Numeric Rating Scale for leg and back pain (NRS), and Oswestry Disability Index (ODI) for lumbar disability). Self-reported bra size was also correlated with breast volumes.

Results: Breast volume of 1000cc correlated well with the cutoff between C and D cup size. No significant difference was found in pre-surgical levels of disability or pain related to breast size, but the ABC group experienced significantly more improvement than the D+ group in their disability: -28.4 ± 19.6 vs. -15.9 ± 18.3 ; $p = 0.001$, back pain: -3.9 ± 3.6 vs. -2.4 ± 3.2 ; $p = 0.019$, and leg pain: -4.9 ± 3.6 vs. -2.8 ± 4.0 ; $p = 0.004$. The ABC group was significantly more likely to reach the MCID for ODI than the D+ group (77% vs 46%, $p < 0.001$) after elective spine surgery. No significant associations between skeletal sacro-pelvic parameters and breast size were identified, though both groups did demonstrate increased pelvic tilt.

Conclusion: Breast hypertrophy (D cup or larger) is significantly correlated with poorer functional outcome after elective lumbar spine surgery. No skeletal sacro-pelvic abnormalities were associated with breast hypertrophy, supporting the theory that breast hypertrophy leads to a dynamic sagittal imbalance.

295 Anterior Cervical Discectomy and Fusion: The Impact of Diabetes Mellitus on In-Hospital Complication Rates and Cost of Care

William Shuman; Sean N. Neifert BS; Daniel J. Snyder BS; Brian C. Deutsch BS; Jonathan S. Gal MD; Jeffrey Zimering MD; Robert J. Rothrock MD; John M. Caridi MD

Introduction: Anterior cervical discectomy and fusion (ACDF) is commonly used to treat degenerative disc disease and is associated with good outcomes and low complication rates. Diabetes mellitus (DM) is one of the most common comorbidities for patients undergoing ACDF, but the literature is equivocal about the impact it has on outcomes. As DM becomes increasingly prevalent, it is crucial to determine if it is a predictive risk factor for episode-based outcomes after ACDF procedures.

Methods: Patients at a single institution from 2006-2016 undergoing ACDF were compared on the basis of having a prior diagnosis of DM vs. no DM. The two cohorts were compared utilizing chi-square, Student's t-test, and multivariate logistic and linear regression.

Results: Data for 2,390 patients undergoing ACDF at a single institution from 2008 to 2016 was analyzed retrospectively. Patients with DM had a significantly higher proportion of American Society of Anesthesiologists (ASA) designations greater than two (62.0% vs. 22.6%, $p < 0.0001$) and Elixhauser Comorbidity Index levels greater than five (12.0% vs. 3.9%, $p < 0.0001$). Diabetic patients were more likely suffer from sepsis (0.6% vs. 0.1%, $p = 0.04$). All other complication rates were similar between the two groups. In multivariate analyses adjusting for age, sex, ASA status, and Elixhauser Comorbidity index score, diabetic patients had similar in-hospital complication rates to those without

diabetes. The direct cost of care was shown to be similar between the two groups after adjusting for patient, surgical, and hospital-related factors (-\$444.12, 95% CI -\$957.79 to \$69.55).

Conclusion: Patients with DM undergoing ACDF have similar outcomes and cost of care compared to non-diabetic patients.

296 The Association of Post-Operative Opioids with Pain Management and Doctor Communication Scores in Elective Lumbar Decompression Surgery Patients

Robert Winkelman BS; Jay M. Levin BA; Joseph E. Tanenbaum PhD; Dominic Pelle MD; Thomas Mroz; Michael P. Steinmetz MD

Introduction: Recent reforms implementing limits on opioid prescriptions for acute pain represent a unique challenge to surgeons when managing post-operative pain. To further complicate this matter, the relationship of post-operative opioids with measures of patient experience is not well known. The goal of the present study is to assess the association of post-operative opioids with patient evaluations of pain management and doctor communication following lumbar decompression.

Methods: A retrospective study was performed on patients who underwent lumbar decompression at a single institution from 1/1/2013 to 12/31/2015 and also completed the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey. Inpatient opioid dosing information was obtained from medication orders in the electronic medical record system. All opioids were converted into daily morphine equivalent dose (MED) for analysis.

Results: One hundred fifty-eight patients met the inclusion criteria for this study. The median [interquartile range] dosage of inpatient opioids was found to be 40.4 MED/day [24.6-52.4] with a median length of stay of 2 days [1-3]. For the HCAHPS question related to hospital staff responsiveness to patient pain, patients who recorded a top-box response were found to have an average daily inpatient opioid dose that was significantly less than patients who recorded a non-top-box response (-13.2 MED/day; 95% CI -24.2 to -3.05). No significant difference in the average daily inpatient opioid dose was observed between top-box and non-top-box respondents in analyses related to overall pain control or doctor communication measures.

Conclusion: In this study, the average daily inpatient opioid dose was significantly associated with the scores of only one of the five patient experience measures analyzed. These results imply that the dosing of inpatient opioids is not strongly associated with patient experience scores, and thus simply increasing the dose of inpatient opioids may not be expected to improve HCAHPS survey metrics.

297 National Adverse Event Profile After Lumbar Spine Surgery for Lumbar Degenerative Disease and Comparison of Complication Rate between Hospitals: A COSRN Registry Study

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Introduction: Most of the previous work investigating the rates of adverse events (AE) in spine surgery have been retrospective, with data collection from administrative databases, and often from single centers. To date, there have been no reports utilizing a rigorous and prospective analysis to capture adverse events in spine surgery on a national level or compare the rates of AEs between each center.

Methods: The incidence and severity of AEs after spinal surgery was captured using the Spine Adverse Events Severity system, version 2 (SAVES), in 14 spine centers from the Canadian Spine Outcomes and Research Network (COSRN) prospective registry. Data on consecutive patients undergoing elective spine surgery for degenerative conditions were collected prospectively and included demographic variables as well as medical and surgical AEs during hospital admission.

Results: A total of 3556 patients were enrolled in this cohort. As defined by SAVES, there were 85 (2.4%) patients with major AEs and 682 (19.2%) with minor AEs. There were no mortalities. There were 25 patients with major intraoperative AEs and 262 with minor intraoperative AEs. Post-operatively there were 61 patients with major AEs with a total of 80 major AEs and 84 minor AEs. Of the 487 patients with minor AEs post-operatively there were 698 total AEs. The rate of AEs varied by each hospital site. Of the 11 sites with more than 10 patients enrolled in the registry (3 sites had 10 or fewer patients enrolled) the average enrollment was 321 patients (range: 47-1237) per site. The rate of major AEs was consistent between sites (mean: 2.92.4%, range 0-9.1%). However, the rate of minor AEs varied widely between sites from 7.9-42.5% with a mean of 18.89.7% (site A: 25.5% B: 13.8% C: 21.3% D: 11.5% E: 7.9% F: 9.1% G: 18.7% H: 14.5% I: 20% J: 21.7% K: 42.5%).

Conclusion: This is the first study, to our knowledge to capture the adverse event profile on a nation level from multiple hospitals. The rate of major adverse events is consistent between each hospital but the reporting of minor events varies widely.

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

Jay M. Levin BA; Nicholas M. Rabah BS; Joseph E. Tanenbaum PhD; Thomas E. Mroz MD; Michael P. Steinmetz MD

Introduction: The Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey is used to measure patient experience and its scores influence reimbursement for hospital systems and spine surgeons in the

United States. While it is well-established that untreated depression is associated with worse patient-reported outcomes in cervical spine surgery, few studies have analyzed the association between depression and patient satisfaction for these patients. Therefore, we sought to investigate the association between preoperative depression and HCAHPS responses in patients undergoing cervical spine surgery.

Methods: Patients who underwent elective cervical spine surgery between 2013 and 2015 and completed an HCAHPS survey were included. Prospectively collected patient-reported outcomes including Patient Health Questionnaire (PHQ-9), EuroQol 5 Dimensions index (EQ-5D), and Visual Analog Scale for neck pain (VAS-NP) were collected for each patient. Preoperative PHQ-9 scores of greater than or equal to 10 (moderate to severe depression) defined our depressed cohort of patients. Demographic, surgical and other preoperative patient characteristics were also obtained.

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

Conclusion: In patients undergoing cervical spine surgery, preoperative depression was found to be associated with worse patient perception of doctor communication as measured by the HCAHPS survey. These results suggest that depression, a modifiable risk factor, may place patients at risk for having an unsatisfying experience communicating with their spine surgeon.

299 Quantifying the Unquantifiable: Using the Patient Satisfaction Index to Analyze the Impact of Opioids on Surgical Outcomes

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Introduction: In an effort to quantify the surgical outcomes of patients, patient reported outcomes measures (PROMs) have been used to quantify the unquantifiable. PROMs can be used to identify trends among subsets of patients, predict procedures and medications that suit them. This data can possibly be used to help identify opioid trends in spinal surgery.

Methods: The authors queried the Quality Outcomes Database (QOD) of a single practice for lumbar patients who underwent laminectomy and/or arthrodesis procedures. The baseline and 12 month Patient Reported Outcomes (PROs) were compiled for ODI, PSI, and Length of Stay (LOS).

Results: A total of 705 patients were identified in QOD. The patients who reported being the most satisfied with surgery had the greatest change in ODI score. Before surgery, 109 (15%) patients reported taking opioids. After 12 months, 88 of these patients reported no longer taking opioids, leaving 21 patients, who took opioids at the baseline that continued opioids at 12 months. However, 27 additional patients (of 578), who did not report taking opioids prior to surgery, reported taking them at 12 months. Of the 48 patients (6.8% of whole) still on opioids, 75% reported a satisfactory outcome, compared to an 85% satisfaction rate of all patients.

Conclusion: The apparent correlation between change in ODI and PSI suggests satisfaction indicates improvement. It appears that surgery allowed the majority of patients taking opioids at baseline to discontinue them by 12 months. Commonly, patients on opioids at 12 months would be considered a failure, yet 75% of this subset of patients are satisfied with their outcome and would have surgery again. Further investigations are needed to determine why the satisfaction rate of patients on opioids is generally similar to the rest of the population.

300 Predictors of Cost in Patients Undergoing Lumbar Spine Surgery

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Introduction: Identification of pre-operative patient risk factors is valuable and may allow payers to allocate additional resources towards modifiable patient specific risk factors, reducing potential cost-burden and untoward patient outcomes. In this retrospective analysis of lumbar spine patients, we evaluate the relationships between patient specific pre-operative risk factors and hospital cost, length of stay and readmissions.

Methods: This is a retrospective analysis of a prospectively collected database of 207 subjects that underwent lumbar spine surgery for degenerative conditions. Parametric and nonparametric statistical methods were used to determine the relationship between predictor variables and continuous, binary and multi-categorical outcome variables.

Results: Binary predictors: fusion surgery (\$15,430 vs \$2,277.79), presence of motor deficits (\$3,723.39 vs \$2623.92), spine symptom duration greater than 3 months (\$2,963.34 vs \$1858.62) and back pain dominant patients (\$8,877.51) compared to back equal to leg pain (\$6,708.33) and leg pain dominant (\$6,078.07) patients were associated with a statistically significant ($p<0.05$) increase in total hospital cost and LOS. Odds ratios were calculated for continuous predictors. The most notable results were for age, ASA grade and number of levels operated on. For every one-year increase in age the odds of discharge to home decreased by 5.6% ($p<0.001$) and 30-day readmission increased by 1.4% ($p<0.0173$). For every unit increase in ASA grade the odds of discharge to home decreased by 57.4% ($p<0.001$).

For every additional level operated on there was a 61% ($p<0.001$) increase in the odds of a 30-day readmission with a 15.8% ($p<0.001$) decrease in the odds of discharge to home.

Conclusion: As we move towards a value-based bundled payment model that forwards cost overruns to hospitals and physicians, identification of high-cost patients may allow for additional resource allocation towards high-risk patients, improved patient selection and reimbursement modifiers based on patient specific risk-factors.

301 Incidence and Risk Factors for 90-day Readmission Following Medical and Surgical Management of Spinal Epidural Abscess: A Multi-institutional Study

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Introduction: The incidence of spinal epidural abscess (SEA) is rising, yet there are few reports discussing readmission rates or predisposing factors for readmission after treatment. The aim of the present study is to determine the rate of 90-day readmission following medical and surgical treatment of SEA in an urban population and to identify patients at greater risk for readmission.

Methods: Neurosurgery records from two large urban institutions were reviewed to identify patients that were diagnosed with and treated for SEA. Patients that died during admission or were discharged to hospice were excluded from the study. Univariate analysis was performed using chi-square and Student's t-tests to identify independent variables predicting readmission with a p-value <0.10 . A multivariate logistic regression model controlled for age, body mass index (BMI), gender, and institution was used to determine significant predictors of readmission.

Results: Of 103 patients in our database with SEA, 97 patients met the inclusion criteria. Mean age was 57.1 (± 13.5) and 56 patients (57.7%) were male. The all-cause 90-day readmission rate was 37.1%. Infection (sepsis, osteomyelitis, persistent abscess, bacteremia) was the most common cause of readmission and accounted for 13 readmissions (36.1%). Neither pre-treatment Frankel grade ($p=0.12$) nor surgical versus medical management ($p=0.33$) were significantly associated with readmission. Multivariate analysis showed that immunocompromised status ($p=0.016$; OR 4.6 [95% CI 1.3-15.7]) and hepatic disease (chronic hepatitis or alcohol abuse) ($p=0.015$; OR 3.7 [95% CI 1.3-10.6]) were significantly associated with 90-day readmission.

Conclusion: Patients with hepatic disease and patients who were immunosuppressed demonstrated significantly increased odds of 90-day readmission after SEA treatment. These patients may require closer follow-up upon discharge to reduce overall morbidity and hospital costs associated with SEA. There was no significant difference in readmission rate between surgical and non-surgical patients.

302 Trends in 30 Day Unplanned Emergency Department Visits Following Elective Spine Surgery

Zachary Sanford; Andrew Broda BS; Justin Turcotte MBA; Chad Patton MD, MS

Introduction: Incidence of emergency department (ED) visits following elective spine surgery is largely unknown with episode-of-care costs and patient satisfaction potentially at risk following unplanned post-operative ED visits. We present rates of such visits following elective spine surgery at a single center in order to better allocate future preventative resources.

Methods: Retrospective review was conducted assessing outcomes of consecutively selected patients undergoing elective spine surgery at a single institution between July 2013 and June 2018. Patients were categorized either as inpatient (IP) or outpatient (OP) according to discharge status.

Results: 5823 patients (3600 IP, 2223 OP) were identified, of which 9.1% (528) returned within 30 days of discharge. Among the IP cohort 8.5% (494 encounters) returned with median time-to-presentation 10 days post-surgery compared to 2.9% (168 encounters) of OP cohort at 9 days. Visits occurred during weekday business-hours (38.7%), weekday after-hours (36.3%), and weekends (25.1%) with discharged to home observed in 51.7% (342) of encounters. Discharged following weekend surgery had higher rates of ED returns (14.1%) compared to surgeries performed on weekdays (11.0%). Spine-related reasons for return included uncontrolled pain (29%), wound-related (17%), and DVT or PE (5%) complaints. Other medical issues (49%) accounted for remaining encounters. Those returning to the ED evidenced significant increases in age ($p<.001$), incidence of African American race ($p=.019$), divorced or widowed marital status ($p=.041$), and ASA score ($p<.001$). Medicare recipients returned in significantly greater numbers as opposed to those with private insurance coverage ($p<.001$).

Conclusion: 30 day postoperative ED readmissions following spine surgery is higher for elective IP cases compared to OP analogues, many during normal business hours or were directly discharged to home, suggesting some visits may be avoidable with improved access to surgical and medical teams during the acute recovery period. Further risk-stratification is needed focusing on early follow-up access and management of post-operative pain.

303 Chronicity of Preoperative Opioid Usage Predicts Patient Satisfaction, Return to Work, and Achieving ODI MCID up to 2 Years After Lumbar Fusion: Analysis from the Michigan Spine Surgery Improvement Collaborative (MSSIC)

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Introduction: The Michigan Spine Surgery Improvement Collaborative (MSSIC) is a multicenter quality improvement collaborative.¹ Using the MSSIC database, we sought to identify the relationship between preoperative opioid usage and patient satisfaction, return to work, and achieving ODI MCID up to 2-years after lumbar fusion.

Methods: A total of 8693 lumbar fusion patients were analyzed. Patient satisfaction was measured by the NASS patient satisfaction index. Multivariate logistic regression models were constructed; variables tested include age, gender, race, PMH, and number of surgical levels. Preoperative opioid chronicity was defined as opioid naïve (no opioid usage), new opioid users (<6wks), recent opioid users (6wks–3mo), frequent opioid users (3mo–6mo), and chronic opioid users (>6mo).

Results: Multivariate analysis was performed. Comparisons were done to opioid naïve patients. Chronic opioid users were less likely to be satisfied with their procedure at 90-days (OR 0.95, $p<0.001$), 1-year (OR 0.90, $p<0.001$), and 2-years (OR 0.87, $p<0.001$) after surgery. New opioid users were more likely to achieve ODI MCID at 90-days (OR 1.25, $p<0.001$), 1-year (OR 1.15, $p<0.001$), and 2-years (OR 1.22, $p<0.002$) postoperatively. Recent opioid users were more likely to achieve ODI MCID at 2 years (OR 1.26, $p<0.001$). Chronic opioid users were less likely to achieve ODI MCID at 90-days (OR 0.89, $p<0.001$), 1-year (OR 0.87, $p=0.002$), and 2-years (OR 0.82, $p=0.004$). Chronic opioid users were also less likely to return to work at 90-days (OR 0.83, $p<0.001$).

Conclusion: A multivariate analysis on preoperative opioid usage from a large, multicenter, prospective database on lumbar fusion patients was performed. We found that, as compared to opioid naïve patients, 2-years postoperatively new opioid users were more likely to have a favorable outcome, while chronic opioid users were less likely to have a favorable outcome. Thus, preoperative opioid counseling is imperative to improve outcomes in spine surgery.

304 Correcting Patient-Reported Outcomes in the Age of the Opioid Crisis

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Introduction: Despite the inclusion of pain assessments in their questionnaires, none of the patient-reported outcomes (PRO) commonly used for spine surgery account for opioid use. Comparing PROs before and after surgery, between techniques, or between surgeons is therefore meaningless if there are differences in patients' opioid intake. Here we present a modified Oswestry Disability Index (mODI) that is opioid-adjusted.

Methods: We identified four criteria for the construction of a modified ODI score: 1) incorporation of daily morphine-equivalents; 2) a penalty for operating on patients taking opioids; 3) an increasing weight assigned to opioid use as follow-up time lengthens; and 4) equivalence to traditional ODI for patients taking no opioids. An equation was developed which satisfies these criteria, and it was then tested using multiple patient scenarios to ensure validity.

Results: The equation is shown in Figure 1 - c is a multiplier (1.0 before surgery, 1.2 at one month, 1.5 at three months, and 2.0 at one year after surgery), MED is the daily morphine equivalent dose, and P is a constant "opioid penalty" that is 30 before surgery and 60 at every time point after surgery. Table 1 lists the ODI, MED and mODI for three representative patients from the many scenarios tested during development.

Conclusion: The novel "mODI" metric we introduce here is the first PRO that allows for comparisons across patients taking differing amounts of opioids. For patients taking no opioids, mODI is equal to ODI. Patients with high preoperative opioid use have mODI scores that are worse than the baseline score at the one-year mark. Surgeons who make their patients opioid-free after surgery see improvements in mODI that exceed that of the traditional ODI score. We contend that findings in the PRO-based spine literature in recent years must be re-examined, given the lack of an opioid-adjusted PRO such as mODI.

305 Does Length of Stay Impact Likelihood of Unplanned Readmissions Following Spine Surgery? Insights from a National Surgical Registry

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Introduction: Postoperative length of stay has been recently prioritized as a way to drive down healthcare costs. However, studies have shown that decreasing length of stay might be associated with increase in adverse outcomes. In this project, we sought to investigate the impact of length of stay on 30-day readmission after 4 common spine procedures using a national registry

Methods: We queried the ACS-NSQIP 2012-2016 for patients undergoing four most commonly performed spinal procedures: ACDF, Lumbar Discectomy, Lumbar Laminectomy and posterior lumbar fusion (PLF). Patients were grouped based on their length of stay into 1) <3 days, 2) 3 days, and 3) > 3 days. Univariate analysis and multivariable logistic regression were performed to assess the impact of hospital length of stay on unplanned readmission after adjusting for an array of patient factors.

Results: A total of 91,102 patients, were included in the analysis. The median age of the study sample was 59 years with 50.5% males. Median length of stay varied by procedure: ACDF, Lumbar Discectomy: 1 day; Lumbar Laminectomy: 2 days, PLF: 3 days. Rate of unplanned readmission was 4.1% (3,678 patients) for all four spinal

procedures[ACDF: 3.0% (n=525), Lumbar Discectomy: 3.7% (n=377), Lumbar Laminectomy: 4.4%(n=714), PLF: 4.5% (n=2062)]. Overall, LOS > 3 days was associated with an increased likelihood for unplanned readmission(OR: 1.26; CI: 1.14-1.38, Ref: LOS=3 days) while LOS< 3 days did not confer an increased risk(OR: 0.95; CI: 0.87-1.04, Ref: LOS=3 days). Further analyzing by each procedure, LOS>3 days was associated with higher odds of readmission following Lumbar Laminectomy(OR: 1.3; CI: 1.03-1.61, Ref: LOS=3 days) and PLF(OR: 1.23; CI: 1.1-1.38, Ref: LOS=3 days). **Conclusion:** LOS>3 days following spine surgery might be associated with increased risk for unplanned 30-day readmissions, while a shorter length of stay appears to have no impact on odds of readmission.

306 Using Artificial Intelligence (AI) to Predict Postoperative Wound Infection: A Retrospective Cohort of 4,046 Posterior Spinal Fusions.

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Introduction: Machine Learning and Artificial Intelligence capabilities are growing immensely, allowing for more accurate analyses of big datasets. We used a trained deep neural network (DNN) to predict and evaluate risk factors for wound infections following posterior spinal fusion procedures.

Methods: 4046 posterior spinal fusion procedures were identified at our institution from 2000 to 2015. Demographic, clinical and surgical outcome data were collected for each patient. A DNN was trained (Figure 1) using a random subset of the patients (n=3034) and a test subset was set aside for later validation (n=1012). For each subject, 35 input variables (Table 1) were fed into the model with the output being post-operative infection. The model was initialized with randomized starting weights, after which all variables were input through a series of 9 layers. Upon completion of the 9th layer, model weights were recalibrated. This process was repeated 25 times (epochs) to ensure optimal calibration to training data. The remaining, previously unseen test subset was then fed into the model for validation and the receiver operator curve (ROC) was defined. The above steps were repeated 300 times for population data and overall model performance analysis. Stepwise multivariate regression was further used to identify actual model weights based on predictions.

Results: Median area under the curve (AUC) for our model was 0.787 with a mean AUC of 0.775 (95% CI [0.767,0.782]). A representative ROC is shown in Figure 2 from one of the above test sets. Table 2 shows a stepwise retrospective analysis of relative weights of the model in predicting infection. Similar results are displayed in Tables 3&4 for False Positives and False Negatives.

Conclusion: Machine learning models were able to predict wound infections moderately well based on the above variables. Artificial intelligence continues to provide promise towards advancing physician's ability to predict adverse surgical outcomes.

307 Predictors of 30-Day Morbidity and Mortality in Patients Undergoing C1-C2 Fusion for the Surgical Treatment of C2 Fractures

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Introduction: C2 vertebral body fractures account for more than 20% of all cervical spine fractures. The purpose of this study is to investigate and identify predictors of complications in patients undergoing C1-2 fusion for the treatment of C2 vertebral body fractures.

Methods: Adult patients undergoing surgery for the fracture of second vertebra were identified in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2006 to 2016, using ICD 9 and ICD 10 codes for this condition and CPT codes for posterior C1-C2 arthrodesis. Pre-operative lab values, demographic details, and comorbidities were reviewed. A multivariate analysis was used to identify the predictors of non-neurologic surgical complications and mortality within 30 days of surgical intervention.

Results: A total of 159 patients who underwent C1-C2 fusion for C2 vertebral body fractures were identified. Overall morbidity and mortality rates were 13.2% and 6.2%, respectively. After multivariate analysis hypoalbuminemia (Albumin <3.5 g/dL) was an independent significant predictor of 30-day post-operative complications (OR 4.7 95% CI: 1.5-14.7, p=0.008). Although age over 75 years and history of hemodialysis were significant predictors of 30-day mortality on univariate analysis, on multivariate regression there were no significant predictors that could be identified.

Conclusion: Pre-operative hypoalbuminemia is a significant predictor of non-neurologic complications in patients undergoing C1-2 fusion for second vertebral body fractures in patients requiring surgery.

308 Spine Surgery Patient-Related Factors and Outcomes Predict HCAHPS Self-Reported Overall Hospital Rating

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Introduction: Beginning in 2013, the Center for Medicare and Medicaid Services has tied a portion of hospitals' annual reimbursement to patients' responses on the Hospital Consumer Assessment and Healthcare Providers and Systems (HCAHPS) survey given to a random sample of inpatients after discharge. The present study aims to identify predictors of patients' rating their hospital as "top-box" (9 or 10 on a scale of 0 to 10).

Methods: Among patients undergoing spine surgery at a single institution from 2013 to 2017, a retrospective cohort analysis was performed comparing patients to who rated their overall hospital experience as "top-box" to those who did

not. Patient demographics, comorbidities, surgical/operative variables and perioperative outcomes were compared between groups. Controlling for patient demographics, as well as comorbidities and operative factors that differed significantly between high and low raters, a multivariate logistic regression was performed to determine predictors of a top-box hospital rating.

Results: 1,505 patients undergoing spine surgery who returned HCAHPS surveys were identified. Patients in the present study were 60.70 ± 12.88 years old and 50.23% were male. Patients who rated the hospital as top-box had higher mean HCAHPS scores than those who did not (53.30 ± 5.22 vs. 40.91 ± 11.044 , $p < 0.001$). On multivariate logistic regression, older age and (OR 1.01, $p = 0.011$) and cervical surgery (OR 1.55, $p = 0.002$) independently predicted a top-box HCAHPS score. Meanwhile a non-top-box hospital rating was predicted by ASA class IV (OR 0.23, $p = 0.014$), smoking within one preoperative year (OR 0.68, $p = 0.033$), non-elective surgery (OR 0.57, $p = 0.021$), and longer hospital length of stay predicted (OR 0.94, $p = 0.015$).

Conclusion: Among patients undergoing spine surgery, the present study identifies several factors present prior to surgery that independently predict patients rating of their hospital on HCAHPS.

309 A Two-Year Cost Analysis of Maximum Non-Operative Treatments in Patients with Symptomatic Lumbar Stenosis or Spondylolisthesis that Ultimately Required Surgery

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Introduction: A variety of non-operative therapies are attempted for pain management in patients with symptomatic lumbar stenosis or spondylolisthesis prior to surgery. The costs and utilization of MNT remains unknown. The purpose of this study is to characterize the utilization and costs of MNTs within 2-years prior to spinal fusion surgery in patients with symptomatic lumbar stenosis or spondylolisthesis.

Methods: A large insurance database was queried for patients with symptomatic lumbar stenosis or spondylolisthesis undergoing index 1, 2, or 3-level lumbar decompression and fusion procedures between 2007 and 2016. This database consists of 20.9 million covered lives and includes private/commercially insured and Medicare Advantage beneficiaries. The utilization of MNTs within 2 years prior to index surgery was assessed. "Utilization" was characterized by cost billed to the patient, prescriptions written, and number of units billed.

Results: A total of 27,877 out of 3,423,114 (0.8%) eligible patients underwent 1, 2, or 3-level posterior lumbar instrumented fusion. 17.6% of patients were smokers, 35.1% of patients had type II DM, and 24.8% were obese. Patient MNT utilization was as follows: 11,383 (40.8%) used NSAIDs, 19,770 (70.9%) used opioids, 12,414 (44.5%) used muscle relaxants, 14,422 (51.7%) received LESI, 11,156 (40.0%) attended PT/OT, 4,005 (14.4%) presented to the ED, and 4,042 (14.5%) received chiropractor treatments. The total direct cost associated with all MNTs prior to index spinal fusion was \$28,241,320. LESI comprised the largest portion of the total cost of MNT (\$15,296,941, 54.2%), followed by opioids (\$3,702,463, 13.1%) and NSAIDs (\$3,058,335, 10.8%). At the patient level, on average \$1,013.07 was spent on non-operative treatments prior to index lumbar surgery.

Conclusion: Opioids are the most used therapy in the preoperative period. Assuming minimal improvement in pain and functional disability after maximum non-operative therapies, the incremental cost effectiveness ratio (ICER) for MNT could be highly unfavorable.

310 Demographic Factors Associated with HCAHPS Reported Pain Management

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Introduction: Patient perception of pain control correlates with Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) quality of care domains and overall reported hospital experience. Prior studies have established links between pain control and factors such as race, ethnicity, gender, and socioeconomic status. In this study, we examine the relationship between HCAHPS responses pertinent to pain control and a variety of patient demographic variables.

Methods: 107,287 records for adult patients discharged between October 2015 and June 2017 from a university-affiliated tertiary hospital were included. We obtained all patient responses to HCAHPS pain management questions. 13,026 of included respondents answered at least one of the HCAHPS pain management questions. We then performed a systematic statistical analysis to evaluate interactions between demographic factor variables and responses to HCAHPS pain management questions.

Results: With respect to HCAHPS pain-domain responses, "Hispanic" and "Black or African American" respondents are more likely to report successful Pain Control when compared to "Not Hispanic" and "Caucasian/White", respectively (Odds Ratios 1.60, 1.22). Additionally, among female patients, "Black or African American" respondents are more likely to report positive Staff Helpfulness than "Caucasian/White" respondents (OR 1.38). Of note, "Hispanic" and "Black/African American" patients were each less likely to respond to the HCAHPS pain-domain questions (OR 2.03, 2.74).

Conclusion: Race/ethnicity and gender appear to affect both rate and type of response to HCAHPS pain-domain questions. Hispanic and Black/African American patients possibly underreport negative experiences. Demographic

biases in HCAHPS responses could potentially undermine the utility of this data to inform healthcare decision-making and practice.

311 Machine Learning and Time Series Motion Classification: Is it possible to write real-world, single sensor algorithms to detect the activities of daily living used in patient reported outcome questionnaires?

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Introduction: Clinical improvements in function are often measured using survey-based PROs (e.g. ODI) with questions about walking, sitting, standing, traveling (driving) and sleeping (lying down). However, survey data is time consuming for both the patient and clinician. Multiple sensor and rules-based algorithms have shown positive predictive values greater than 85% for ability for walking, jogging, sitting, and lying down in a laboratory setting. The purpose of the current study is to determine positive predictive value of activity in a real-world setting of a single wearable sensor containing an extremely high-end inertial measurement unit (IMU).

Methods: Three healthy volunteers wore a single navigation-grade IMU (SBG Systems Ellipse2-N) for 60 minutes in a real-world (outside) environment and asked to sit, stand, lie supine, drive and walk in an unscripted manner. Data were continuously recorded at 200Hz using a combinatorial supervised ML approach. A multinomial logistic regression (MLR) was first used to classify posture with results fed to a second layer of support-vector-machines (SVM). A classifier finalized the results in 1 second boundaries by rolling 5ms samples into a single vote. A 48-minute holdout data set was reserved for testing.

Results: 573,600 5ms data points were analyzed. After the two layers (MLR followed by SVM), accuracy was found to be 99.65% across all activities. Positive predictive values were 99.24% for walking, 99.67% for sitting, 99.8% for driving and 100% for both lying and standing.

Conclusion: The use of a high-end IMU and ML algorithms in this study to classify a subset of ODI activities in a real-world setting achieved greater accuracy than multiple sensors and rules-based algorithms reported in prior studies. This type of technology offers the potential for measured function to replace or supplement patient reported function focused on established patient-centric activities routinely considered reflective of health status.

312 Hospital Medicare Reimbursement Rates for Inpatient Episodes of Care in Spine Surgery

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Introduction: To address the feasibility of bundled reimbursement for spine, it is germane to evaluate current episodic-based reimbursement. As such, the purpose of this study was to evaluate Medicare reimbursement paid to hospitals for the 3 most common spine surgery admission types from 2011 to 2016.

Methods: The Inpatient Utilization and Payment Public Use File from the Centers for Medicare & Medicaid Services was queried. The file includes data for three Diagnostic Related Group (DRG) codes related to spine surgery; each was included for study. Extracted data from over 3,000 US hospitals included cost submitted by the hospital, amount paid by Medicare, and total payment for each admission. All data was adjusted for inflation to 2016 US dollars and averaged. The mean percent of the submitted cost covered by Medicare and the total percentage change for each variable throughout the study period were calculated. A student's t-test was utilized to compare variables with $p < .05$ indicating significance.

Results: The mean adjusted Medicare payment for non-cervical fusion decreased by 6.9% ($p < .001$), remained stable for cervical fusion, and increased by 3.4% ($p < .001$) for medical back admissions throughout the study. For all DRGs, the mean cost submitted by the hospital increased by 14.2% throughout the study ($p < .001$). Meanwhile, the mean amount paid by Medicare across all DRGs decreased by 4.2% ($p = .009$), while the mean percentage of the total submitted cost of admission covered by Medicare decreased by 3.5% ($p < .001$) (Table 1, Figure 1).

Conclusion: This is the first study to evaluate trends in Medicare inpatient reimbursement in spine surgery. For included admissions, the average amount paid by Medicare to hospitals decreased, and Medicare reimbursed a decreasing percentage of total submitted costs throughout the study. Consideration of these findings will be important for policy-makers, hospitals, and surgeons as continued progress is made regarding agreeable reimbursement models in spine surgery.

313 Assessing Patient Comorbidities to Reduce Avoidable Readmission

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Introduction: Preventing hospital readmissions are a critical component of managing a patient through the episode of their operative care. Readmissions are major causes of increased costs not only to the health care system, but more importantly to the lives of the individual patient. Accurate assessment of rates of readmissions as well as the causes for them can help physicians develop strategies for preventing them in at risk patients. This study aims to assess whether readmissions could potentially be avoidable by looking at the types and rates of comorbidities the patient had prior to readmission.

Methods: A single institution review of readmissions were analyzed using the Quality Outcomes Database (QOD) and verified with medical records from 2014-2018. Patient comorbidities were reviewed for each individual readmit and taken into account alongside surgical procedure and reason for readmission.

Results: A population of 42 lumbar patients and 28 cervical patients were documented as a readmission in QOD. Only 36 (51%) were found to be true readmissions, where the others were under observation, emergency or outpatient status. The reasons for readmissions were urinary related problems, hemorrhage, deep vein thrombosis (DVT), infection, acute pain and weakness, embolism, cervicgia and sepsis. Of the 36 readmissions, 58% of the patients had at least one comorbidity that made the patient more susceptible to a readmission related to the respective diagnosis. Therefore, the presence of a comorbidity influenced the reason for readmission. The most prevalent comorbidities associated with readmissions in order of rank was: diabetes, coronary artery disease, chronic renal disease, osteoarthritis and depressive mood disorder.

Conclusion: Taking account for the patient holistically post-operatively can help aim to reduce hospital readmission rates. It is clinically valuable to pay attention and providing potential additional treatment to high risk patients when providing post-operative care to therefore reduce an avoidable readmission.

314 The Association Between Patient Satisfaction with Physician Communication on the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) Survey and Clinical Outcomes in Spine Surgery

Nicholas M. Rabah BS; Jay M. Levin BA; Thomas E. Mroz MD; Michael P. Steinmetz MD

Introduction: Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) surveys measure the patient experience of care and influence reimbursement for hospital systems and spine surgeons in the United States. It is well-accepted that better physician communication is associated with greater patient satisfaction and improved clinical outcomes in the inpatient setting. However, it is not known whether patient satisfaction with physician communication is associated with better outcomes following spine surgery. Therefore, we evaluated the association between patient satisfaction with physician communication on the HCAHPS survey and improvements in validated patient-reported clinical outcomes measures in a spine surgery population.

Methods: HCAHPS responses were obtained for patients undergoing elective cervical or lumbar spine surgery from 2013 to 2015. Patient reported health status measures were the primary outcomes, including EuroQol Five Dimensions (EQ-5D), Pain Disability Questionnaire (PDQ), and Visual Analog Scores for Back and Neck Pain (VAS-BP/NP). The association between satisfaction with communication and pre- to one-year postoperative changes in each health status measure were evaluated utilizing multivariable linear regression models, while adjusting for potential confounders.

Results: Our study included 648 patients, of which, 479 (74.4%) created our satisfied cohort. Demographically, our two cohorts were similar with regards to pre-operative clinical measures, however the satisfied cohort had a higher self-rating of their mental health ($p < 0.01$), and overall health ($p < 0.01$). After adjusting for clinically relevant confounders, our results demonstrated no significant association between satisfaction with physician communication and improvement in EQ-5D ($p = 0.312$), PDQ ($p = 0.498$), or VAS pain scores ($p = 0.592$).

Conclusion: Patient satisfaction with physician communication was not associated with one-year postoperative improvement in EQ-5D, PDQ, and VAS-Pain following spine surgery. While effective communication remains a critically important component of the patient-physician relationship, our results suggest that patient satisfaction with physician communication may not be a reliable indicator of the quality of spine surgical care.

315 Predictive Model for Prolonged Length of Stay after Anterior Cervical Discectomy and Fusion (ACDF): Insights from the Quality Outcomes Database (QOD)

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Introduction: Recent changes in healthcare policies implemented as per the Affordable Care Act (ACA) have resulted in providers and hospitals seeking ways to optimize resource utilization and improve patient outcomes. Length of stay (LOS) after surgery has increasingly been used as a surrogate for resource utilization. In the current study, we analyzed patients undergoing a 1-2 level Anterior Cervical Discectomy and Fusion (ACDF) and identified factors associated with increased length of stay.

Methods: The Quality Outcomes Database (QOD) was queried for patients undergoing 1-2 level ACDF between April 2013 and July 2017. LOS comprised the primary outcome and was studied as greater or less than 90th percentile (3 days or greater). Covariates included an array of patient characteristics including demographic, comorbidities, clinical-symptoms and operative-factors. Multiple imputations were used for missing values and multivariable (MV) logistic regression analysis was used to assess factors associated with LOS > 90th percentile

Results: A total of 4955 patients were identified of which 3% ($n = 149$) had an LOS of 3 days or greater. On MV analysis, patients with increased LOS were more likely to have diabetes (OR 1.8, 95%CI 1.2-2.6), Medicare insurance (OR 1.8, 95%CI 1.0-3.3) and those without insurance (OR 3.29, 95%CI 1.09-9.8) compared to private insurance, more likely to be currently employed and not working (OR 2.65, 95%CI 1.02-6.91) and unemployed (OR 2.74, 95%CI 1.42-5.3) compared to those employed and working, more likely to be not ambulating at presentation (OR 3.02, 95%CI 1.9-

4.6), more likely to have myelopathy (OR 1.54, 95%CI 1.01-2.3) and more likely to have longer operative time (OR 1.37, 95%CI 1.25-1.5).

Conclusion: Factors associated with prolonged LOS following 1-2 level ACDF included Medicare insurance, uninsured patients, presence of diabetes and myelopathy at presentation and longer operative time. Our results could help providers identify patients at-risk of prolonged LOS after cervical spine surgery.

316 Surgical Management of Cervical Epidural Abscess: A Treatment Algorithm in Response to the Opioid Epidemic

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Introduction: As the opioid epidemic continues to plague the United States, the incidence of spinal epidural abscesses continues to rise. While a majority of these patients can be managed non-surgically, we identified and tracked the outcomes of patients with cervical epidural abscesses requiring surgical intervention to establish a treatment algorithm. The goal of this study is to put forth a treatment algorithm to maximize clinical outcomes via proper preoperative patient selection and operative planning in patients with cervical epidural abscesses (CEA).

Methods: We conducted a single institution retrospective chart review to identify predisposing factors leading to additional surgery in patients diagnosed with cervical epidural abscess initially requiring surgical intervention. Patients that underwent surgical management for CEA between 9/30/2012 and 9/30/2018 were included in the study with procedures done by 3 primary surgeons. . Inpatient and Outpatient records were reviewed to identify patients that required re-operation .Demographic, surgical data, complications, neurologic, as well as patient reported outcome measures, were analyzed. We designed an algorithm based on the results to maximize clinical outcomes.

Results: 21 (2.5%) patients were identified as undergoing surgery for CEA out of 836 cervical spine procedures with a mean follow-up time of 1229 days (3.4 years). Patients are placed in 4 categories (Anterior Debridement + fusion; Posterior Decompression alone; Posterior Decompression + fusion; 360 (Anterior/Posterior) decompression + fusion). Patient outcomes were tracked including need for additional surgery, and time to return to OR. Six of 21 (28.6%) patients required re-operation for CEA. Five of the 6 patients (83.3%), were extensions of previous constructs. One patient (16.7%) underwent a cervical laminectomy as their index procedure and required an instrumented fusion after developing a cervical deformity. Mean time to re-operation was 108.7 day No patients required a third operation for CEA s.

Conclusion: We propose an algorithm for the surgical management of patients with cervical epidural abscesses. Factors predictive of patients requiring re-operation included clinically symptomatic loss of cervical lordosis, proximity of disease to the craniocervical and cervicothoracic junction

317 Predictors of 90-day Readmission after Spinal Tumor Resection in Children

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Introduction: Hospital readmissions are burdensome to healthcare providers as well as to the hospital system. 30-day readmissions are an important healthcare metric to assess outcomes. The 90-day readmission rate may better define factors contributing to readmissions among pediatric patients undergoing spinal tumor resection.

Methods: The Nationwide Readmissions Database (NRD) was utilized to study demographics, comorbidities, admissions, hospital course, tumor behavior (malignant vs. benign), complications, and surgical revisions. Other variables included, All Patients Refined Diagnosis Related Group (APR-DRG) risk of mortality and severity of illness scores during admission. The primary outcome variables of interest were 30-day and 90-day readmission rates.

Results: Of 397 patients in 30-day readmission cohort, 43 (10.8%) were readmitted. Patients aged 16-20 comprised largest subgroup, however, highest readmission rate was observed among patients younger than age 5 (21.7%). Medicaid patients were three times more likely to be readmitted than private insurance (OR = 3.3, $p < 0.001$). Patients with benign tumors were less readmitted than with malignant tumors (OR = 0.36, $p < 0.02$). Of 377, 52 patients (16.0%) were readmitted within 90-day cohort. On average, patients were readmitted 26.4 days following the initial discharge (versus 10.6 in the 30-day cohort). Patients were readmitted for spinal procedures (13.3%), including fusions, revisions, and stimulator placement, while 16.8% of patients for chemotherapy, and 12.4% of patients were readmitted due to infections/septicemia. The median charges for each readmission approximated \$50,000 and \$40,000 for the 30- and 90-day readmission cohorts, respectively.

Conclusion: Unplanned hospital readmissions and associated charges after resection of spinal tumors remained high. Younger age, insurance through Medicaid, malignant behavior, and complications during the initial admission were studied significant predictors during 30 and 90 days for the readmission. On average, patients were readmitted 15.8 days late following initial discharge, and readmitted 2.2 times during the 90-day vs. 30 day window.

318 Dual Surgeon Operations for Long Segment Posterior Fusion Leads to Reduced Morbidity

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Introduction: Surgical correction of large deformities is associated with high degree of morbidity. Previous reports show benefit of dual attending surgeon presence in reducing operative duration and blood loss in scoliosis surgery. We performed dual surgeon operations for neuromuscular scoliosis (NMS), congenital scoliosis (CS), adolescent idiopathic

scoliosis (AIS) and adult degenerative scoliosis (ADS) and present a series of over 100 cases to show the benefit for dual surgeon operation for large deformity correction.

Methods: Patient list was generated for dual surgeon operations performed by attending neurosurgeon and orthopedic surgeon between 2012 and 2017. There were 149 cases, of which cases for long segment fusion (greater than 6 levels of instrumentation) were included for analysis leaving 111 patients for review. Patients were evaluated for pre- and post-operative deformity measurements, operative duration, estimated blood loss (EBL), readmission rate and complications.

Results: Of 111 patients included in the study, 60/111 (54%) had NMS, 31/111 (27.9%) AIS, 12/111 (10.8%) CS, and 8/111 (7.2%) ADS. Most significant improvement in coronal curvature was noted in NMS (47.5 degrees) followed by AIS (39.6 degrees), followed by ADS (24.9 degrees) and CS (24.3 degrees). Most significant improvement in sagittal imbalance was noted in ADS (30.6mm). Mean length of operation was longest in ADS (306min), followed by NMS (245min), followed by CS (243min), followed by AIS (212min). EBL was largest in ADS (1450cc), followed by NMS (742cc), followed by CS (721cc), followed by AIS (516cc). Complications were reported in 24/111 (24%) patients with infection being most common followed by pseudoarthrosis.

Conclusion: We present first report of a single institution experience with dual surgeon operation for long segment fusion in the treatment of both adult and pediatric scoliosis. We demonstrate comparable outcomes in EBL and length of operation with previously reported publications in dual surgeon operations for scoliosis.

319 Matched-Cohort Analysis of the Short-Term Outcomes Between Surgical Treatments for the Management of Cervical Radiculopathy

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Introduction: The surgical management of cervical radiculopathy has rapidly evolved to include anterior cervical discectomy and fusion (ACDF), posterior foraminotomy (PF) and cervical disc arthroplasty (CDA). However, the clear superiority of any one procedure has not yet been fully determined. Therefore, the purpose of this study was to compare the thirty-day postoperative outcomes of ACDF, PF, and CDA in patients undergoing treatment for cervical radiculopathy.

Methods: Patients who were diagnosed with cervical radiculopathy and subsequently underwent elective non-emergency ACDF, PF, or CDA between 2011 and 2016 were identified from the prospectively-collected, nationally-validated ACS-NSQIP database. Demographics and comorbidities were compared between cohorts and propensity-score matching was utilized to account for baseline characteristics with confounding potential. The rates of postoperative complication were then analyzed via univariate tests with significance assessed at $p < 0.05$.

Results: This study included 18,312 patients of whom 84.1% underwent ACDF, 12.0% underwent PF, and 3.9% underwent CDA. CDA patients were younger ($p < 0.001$), had lower BMIs ($p < 0.001$), and had lower rates of comorbidity ($p < 0.003$ overall). They also demonstrated improved functional status ($p < 0.001$) and better ASA classification ratings ($p < 0.001$). These characteristics were controlled via propensity-score matching, and outcomes were compared between cohorts. ACDF patients had longer operative times (124 vs 110 vs 110 min, $p < 0.001$) and higher rates of mechanical ventilation (0.4% vs 0% vs 0%, $p = 0.037$) while PF patients had higher rates of superficial infection (2.0% vs 0.1% vs 0.1%, $p < 0.001$) and blood transfusion (1.1% vs 0% vs 0%, $p < 0.001$). Both ACDF and PF patients had higher rates of readmission (2.7% vs 3.6% vs 1.1%, $p = 0.005$) than CDA patients.

Conclusion: Through matched-cohort analysis, we found that CDA may offer similar or lower rates of postoperative complications compared to ACDF and PF when utilized in the treatment of cervical radiculopathy. Consideration of these short-term risk profiles may help inform physicians during the surgical decision-making process.

320 Timing of Prophylactic Anticoagulation and Its Effect on Thromboembolic Events after Surgery for Metastatic Tumors of The Spine

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Introduction: Venous thromboembolism (VTE) is a known complication in cancer patients and in patients undergoing spine surgery. The purpose of this study is to investigate the effect of timing of initiation of prophylactic anticoagulation on the incidence of VTE after surgery for metastatic tumors of the spine.

Methods: A retrospective review of our institutional neurosurgical spine database for the years 2012 through 2018 was performed. Patients who underwent surgery for metastatic tumors were identified. The development of VTE within 30 days was examined, as well as the occurrence of epidural hematoma. The incidence of VTE was compared between patients receiving "early" (within postoperative days 1-3) and "delayed" prophylactic AC (on or after postoperative day 4).

Results: Sixty-five consecutive patients were identified (mean age 57, 62% male). The overall rate of VTE was 16.9% all of whom had DVTs with a 3.1% rate of non-fatal PE (two patients also developed PE). From the overall cohort, 36/65 (56%) received prophylactic AC in addition to mechanical prophylaxis 22 in the early group (61.1%) and 14 in the delayed group (38.9%). The risk of VTE was 9.1% in the early group and 35.7% in the delayed group (26.6% absolute risk reduction; $p = 0.049$); there was one case of epidural hematoma (1.5%). On multivariate analysis, delayed

prophylactic AC was found to significantly increase the odds of VTE development (OR 6.43; 95% CI, 1.01–41.2; $p=0.049$).

Conclusion: The findings of this study suggest that administration of prophylactic AC between day 1-3 after surgery for metastatic tumors of the spine may significantly reduce the risk of postoperative thromboembolic events.

321 Low Back Pain after Lumbar Discectomy for Disc Herniation: What can you tell your patient?

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Introduction: Lumbar discectomy is frequently performed to alleviate radicular pain resulting from disc herniation. While this goal is achieved in most patients, improvement in low back pain (LBP) has been reported inconsistently. The goal of this study was to characterize how LBP evolves following discectomy.

Methods: We performed a retrospective analysis of the Canadian Spine Outcomes Research Network (CSORN) registry. Patients who underwent surgery for lumbar disc herniation were eligible for inclusion. The primary outcome was a clinically significant reduction in the back pain numerical rating scale (BPNRS) assessed at 12 months. A binary logistic regression was used to model the relationship between the primary outcome and potential predictors.

Results: There were 751 patients included in the analysis. The chief complaint was radiculopathy in 79%; 47% underwent a minimally invasive procedure and 26% underwent fusion. BPNRS improved at 3 months by 43% and this improvement was sustained at all follow-ups. LBP and leg pain improvement were correlated. Clinically significant improvement in BPNRS at 12 months was reported by 57% of patients. Six factors predicted a lack of LBP improvement: the number of operated level, low education, marriage, not working, low expectations with regards to LBP improvement and a low BPNRS preoperatively.

Conclusion: Clinically significant improvement in LBP is observed in 57% of patients after lumbar discectomy. These data should be used to better counsel patients.

322 Malignant Primary Spinal Column Tumors: Prognostic Significance of hTERT (Human Telomerase Reverse Transcriptase) Promoter Region Mutations C228T and C250T for Overall Survival

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Introduction: Primary spinal column malignancies are rare tumors with poor prognosis, few systemic treatment options, and limited understanding of the molecular drivers of neoplasia.

Methods: Study design was a retrospective review of prospectively collected data. An initial cohort of 1495 patients with primary spinal column tumors were treated at 13 centers within Europe, North America, and Australia between December 1985 and January 2013. Information regarding patient mortality was acquired cross-sectionally. Archived paraffin embedded pathologic specimens were available for 133 patients from 6 of the 13 centers. Tumor DNA was extracted from the paraffin specimens and the hTERT promoter was sequenced using Sanger Sequencing. The hTERT mutational status was correlated to overall survival (OS).

Results: Ninety-two chordomas, twenty-six chondrosarcomas, seven osteosarcomas, three Ewing's sarcomas, and five other malignant spinal tumors were analyzed. Eight chordomas, two chondrosarcomas, one Ewing's sarcoma, and one other malignant spinal tumor harbored either a C228T mutation or a C250T mutation in the hTERT promoter. Median OS following surgery was 5.8 years (95% CI: 4.6 to 6.9) and median time to first local recurrence was 3.9 years (95% CI: 2.5-6.7). OS was worse in the Enneking grade II tumor group ($p=0.047$). After controlling for standard demographic and clinical criteria, including adequacy of surgical resection and adjuvant therapy, hTERT mutational status was associated with improved survival. 100% of patients with hTERT mutation were alive at ten years postoperative as compared to approximately 24% of patients who lacked the mutation ($p=0.031$).

Conclusion: We report for the first time that hTERT promoter mutations C228T and C250T are present in approximately 10% of spinal chordomas. In addition, all individuals with the hTERT mutations were alive at ten years postoperative compared to 24% of those lacking the mutations. Future prospective studies are required to further elucidate the role of hTERT promoter mutations in primary spinal column malignancies.

323 Two-Year Outcomes of Patients Treated with BVN Ablation for the Relief of Chronic Low Back Pain:

Results of the SMART Trial

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Introduction: Thirty percent of Americans have low back pain (LBP) at any given time, leading to approximately 50 million physician visits in the U.S. annually. Chronic low back pain (CLBP) can be difficult to diagnose and treat using either non-surgical therapies or surgical interventions. Antonacci et al. proposed that some pain previously ascribed to the disc actually emanates from the vertebral endplate nociceptors which communicate to the CNS through the basivertebral nerve (BVN).¹ The purpose of the present study is to report the 2-year clinical outcomes for CLBP patients treated with radiofrequency (RF) ablation of the BVN in a randomized controlled trial (RCT) that previously reported 1-year follow-up.

Methods: A total of 147 patients were treated with RF Ablation of the BVN in an RCT designed to demonstrate safety and efficacy as part of a Food and Drug Administration-Investigational Device Exemption (FDA-IDE) trial. Evaluations, including patient self-assessments, physical and neurological examinations, and safety assessments, were performed at two and six weeks, and three, six, twelve, eighteen, and twenty-four months postoperatively.

Results: Clinical improvements in ODI, VAS, and SF-36 PCS were statistically significant compared to baseline at all follow-up time points through 2 years. The mean percent improvements in ODI and VAS compared to baseline at 2 years were 53.7% and 52.9%, respectively. Responder rates for ODI and VAS were also maintained through 2 years with patients showing clinically meaningful improvements in both: ODI = 10-point improvement in 76.4% of patients and ODI = 20-point improvement in 57.5%; VAS = 1.5 cm improvement in 70.2% of patients.

Conclusion: Patients treated with RF ablation of the BVN for CLBP exhibited sustained clinical benefits in ODI and VAS and maintained high responder rates at 2 years following treatment. BVN ablation appears to be a durable, minimally invasive treatment for the relief of CLBP.

324 Consideration for Surgical Management of Osteomyelitis-Discitis at the Thoracolumbar Junction

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Introduction: Spinal deformity and cord/canal compromise with resultant neurologic deficits have historically been used as matrices for surgical management of vertebral osteomyelitis-discitis. However, when such pathology presents at the thoracolumbar (TL) junction, it remains unclear what the appropriate intervention is. Should laminectomy only be performed? Is short segmental instrumentation sufficient? Or should patients undergo a long construct instrumentation to prevent progression of kyphosis and the need for revision surgery? Our study evaluates this therapeutic dilemma.

Methods: A retrospective review of patients with osteomyelitis-discitis at the TL junction between 2014 and 2018 was performed. Patients were 18 years or older with pathologies from T10-L2. Demographics, pre-operative, clinical and radiographic outcome variables were analyzed from the medical records

Results: Sixteen patients were included. Average age was 51.7 years, 19% females. Table 1 shows clinical variables. Surgical indication included progression of kyphosis following prior laminectomy/medical management. One patient had posterior only approach (corpectomy / kyphectomy + fusion) while seven patients had combined anterior-posterior approach (corpectomy + fusion). Figure 1 shows representative cases. Six out of eight surgical patients had Bilsky grade 3 epidural compression versus 7/8 in the medical only group with grade 1 compression. Seven patients requiring surgery had >50% vertebral body collapse at the time of surgery. Overall, the average segmental kyphotic deformity improved by 36° with long construct instrumentation and fusion, Figure 2. Average times to progression of kyphosis after laminectomy and medical management prior to surgery were 2.6 and 6 months respectively, Figure 3.

Conclusion: Given the high risk of progression of kyphotic deformity at the TL junction, patients may benefit from long segment instrumentation for greater stability. Laminectomy alone may speed up kyphosis progression. However, a larger sample size with in depth analysis on predictive variables for kyphotic progression is needed, and this is currently being investigated.

325 Postoperative C5 Palsy Is Best Predicted by Use of Intraoperative C5 Laminectomy Among Patients Operated for Degenerative Cervical Myeloradiculopathy

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Introduction: Annually, it is estimated that 18,000 persons will undergo posterior cervical spine procedure, for which degenerative myeloradiculopathy is one of the most common operations. Post-operative C5 palsy is one complication of this procedure, occurring in ~8% of cases and increasing care cost by more than \$2000 per patient. Here we present a model for predicting post-operative palsy using clinical presentation, preoperative imaging, and procedural details.

Methods: A cohort of 385 patients undergoing posterior cervical decompression with or without concomitant instrumented fusion between January 1, 2014 and December 31, 2016 was queried. Data collected included operative details, clinical presentation, and cervical anatomy on preoperative imaging. A multivariate logistic regression was used to identify significant predictors of post-operative palsy.

Results: Of those patients with full data, 11.3% suffered a postoperative C5 palsy. Patients experiencing a postoperative palsy were more likely to report preoperative hand clumsiness, radicular pain the C5 distribution, and undergo a C5 laminectomy intraoperatively. On multivariate analysis, significant predictors of postoperative palsy were revision v. index case and the performance of a C5 palsy. A receiver-operating curve of our model demonstrated a C-statistic of 0.8075.

Conclusion: Post-operative C5 palsy is best predicted by an aggregate model incorporating both operative details, clinical presentation, and radiographic parameters. Preoperative C5 radicular pain, prior history of posterior cervical decompression, and performance of a C5 laminectomy were the strongest predictors of postoperative palsy, consistent with the notion that preoperative C5 root irritation and intraoperative C5 root manipulation contribute to the etiology of C5 palsy.

326 Impact of Hypothyroidism on In-Hospital Mortality and Cardiac Complications for Lumbar Spinal Fusions

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Introduction: The prevalence of hypothyroidism in the United States is 1-4% and is associated with an increased risk of developing many comorbidities including hypertension, cardiovascular disease, osteoporosis, peripheral neuropathy, and muscular weakness.¹⁻⁴ However, the impact of hypothyroidism on perioperative morbidity in patients undergoing lumbar spinal fusion is limited.

Methods: We performed a retrospective analysis of the Nationwide Inpatient Sample between 2004-2014. Patients who had an ICD-9-CM procedure code indicating a lumbar spinal fusion (81.04-81.08, 81.34-81.38) were included. Patients in this cohort with an ICD-9-CM diagnosis code indicating hypothyroidism (244.x) were compared to euthyroid patients. Primary outcome measures were defined as specific short-term post-surgical complications. Patient, hospital, and Elixhauser comorbidity variables were assessed in univariate analysis to test covariates predictive of specific complications and mortality. Factors predictive in univariate analysis ($p < 0.2$) were utilized to construct a multivariate logistic regression model to analyze the effect of hypothyroidism on complications and mortality.

Results: A total of 2,467,320 patients underwent lumbar spinal fusion from 2004-2014 for which 251,475 (10.19%) carried a diagnosis of hypothyroidism. Although hypothyroid patients had increased risk of developing acute postoperative anemia (OR 1.176, 95% CI 1.160 to 1.192, $p < 0.0001$), they exhibited decreased in-hospital mortality (OR .643, 95% CI .551 to .746, $p < 0.0001$) and decreased risk of developing MI (OR .851, 95% CI .810 to .893, $p < 0.0001$).

Conclusion: Hypothyroid patients undergoing lumbar spinal fusion demonstrated lower rates of in-hospital mortality and MI when compared to their euthyroid counterparts. This suggests that hypothyroidism offers protection against all-cause mortality and acute cardiac complications in the post-operative lumbar spinal fusion patient. The mechanism is poorly understood but may be secondary to either decreased oxygen demand and thus reduced cardiac workload in the hypothyroid-induced hypometabolic state or by the known antithrombotic effects of thyroid hormone supplementation.³

327 Hypervascular Metastatic Spine Tumors Are Rarely Angiographically Associated With The Artery of Adamkiewicz Or Other Radiculomedullary Arteries

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Introduction: Preoperative endovascular embolization of hypervascular metastatic spine tumors can reduce intraoperative blood loss. One frequent objection to embolizing these tumors is the concern for associated large arteries feeding the spinal cord, such as the artery of Adamkiewicz. This study aimed to elucidate a relationship between spinal levels affected by hypervascular spine metastases and associated radiculomedullary arteries.

Methods: Retrospective review of 46 patients undergoing preoperative endovascular embolization of hypervascular metastatic spine tumors. 484 spinal levels were evaluated by diagnostic spinal angiography during embolization procedures. Each spinal level was categorized based on presence or absence of tumor and radiculomedullary artery.

Results: No statistically significant associations were found. Relative risk of affected spinal levels having an associated radiculomedullary artery was 1.10 (95% CI 0.66-1.85). Attributable risk was 0.01 (-0.01-0.02). Chi-squared statistic was 0.13, with p -value of 0.71. Subgroup analysis in renal cell patients was also statistically insignificant, with a relative risk of 0.97 (95% CI 0.43-2.16), Chi-square statistic 0.01, p -value 0.94.

Conclusion: In this study, no association was found between spinal levels affected by hypervascular metastatic spine tumors and radiculomedullary arteries feeding the spinal cord by diagnostic spinal angiography. Thus, while iatrogenic spinal cord stroke is a feared complication of any spinal embolization procedure, additional risk is attributable to hypervascular metastases may be minimal.

328 Combined Magnetic Field Results in Higher Fusion Rates than Pulsed Electromagnetic Field Bone Stimulation after Thoracolumbar Fusion Surgery

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Introduction: Bone growth stimulators have been used as an adjunct to spinal fusion surgery in efforts to increase fusion rates. These electrical stimulators are designed to deliver electrical fields that modulate bone cell activity to enhance bone formation. In this study, fusion rates were compared in patients using pulsed electromagnetic field stimulation (PEMF; Orthofix, Lewisville, TX) versus combined magnetic field stimulation (CMF; DJO Global, Vista, CA) after thoracolumbar fusion surgery.

Methods: The authors retrospectively reviewed the medical records for patients who underwent thoracolumbar fusion surgeries (posterolateral only, interbody only, or posterolateral and interbody) by a single surgeon and were prescribed bone growth stimulators. The patients were separated into two groups, either PEMF or CMF, and computed tomography radiographic results at one year of follow-up were compared (solid fusion, stable nonunion, and pseudarthrosis). Data was analyzed with a Pearson's chi square test.

Results: A total of 46 patients were included; 19 were prescribed PEMF and 27 were prescribed CMF. There were no significant differences between age, sex, BMI, or tobacco use in the two groups. The average number of spine levels treated was 4.63 for PEMF and 3.81 for CMF, with an average follow-up of 15.89 months and 14.70 months,

respectively. There were 14/19 (74%) patients with PEMF demonstrating solid fusion compared to 26/27 (96%) patients with CMF. There were 5/19 (26%) patients with PEMF demonstrating radiographic evidence of pseudarthrosis, compared to 1/27 (4%) patients with CMF ($p = 0.024$). Two patients with PEMF required re-operation for pseudarthrosis, compared to zero patients with CMF.

Conclusion: This is the first study to compare PEMF and CMF bone growth stimulators in patients who underwent thoracolumbar spinal fusions. Patients using CMF postoperatively appear to have higher rates of solid fusion, lower rates of pseudarthrosis, and lower rates of re-operation when compared to PEMF.

330 Sarcopenia Independently and Accurately Predicts Survival in Patients Undergoing Spine Surgery for Metastatic Tumors: A Multi-Center Retrospective Cohort Study

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Introduction: Predicting survival and surgical morbidity in patients with spinal metastases would help guide clinical decision making and stratify treatments between surgical intervention and palliative care. This multi-center retrospective cohort study evaluates whether the frailty/sarcopenia paradigm, as measured by psoas size, is predictive of survival in patients undergoing surgery for spinal metastasis.

Methods: 271 patients from four institutes who had undergone surgery for spinal metastasis were identified. Morphometric measurements were taken of the psoas muscle at the L4 vertebral level <200 days from surgery. Survival hazard ratios were calculated using multivariate analysis, with variables included past medical history, type and extent of tumor, type and intensity of surgery, and postoperative chemotherapy or radiation.

Results: Psoas size was predictive of overall mortality; patients in the smallest psoas tertile had shorter overall survival compared to the middle (OR 0.52, $p < 0.001$) and largest tertile (OR 0.45, $p < 0.001$). Psoas size predicted overall mortality more strongly than Tokumashi score (OR 0.91, $p = 0.010$), Tomita score (OR 1.07, $p = 0.04$), and KPS (OR 0.99, $p = 0.58$). Psoas size was also predictive of 90-day survival; patients in the smallest psoas tertile had shorter 90-day survival compared to the middle (OR 0.24, $p = 0.003$) and largest tertile (OR 0.16, $p = 0.001$). Psoas size predicted 90-day mortality more strongly than Tokumashi score (OR 0.73, $p = 0.002$), Tomita score (OR 1.00, $p = 0.92$), and KPS (OR 0.98, $p = 0.39$).

Conclusion: In patients undergoing surgery for spine metastases, psoas size as a surrogate for frailty/sarcopenia predicts 90-day and overall mortality, independent of demographical, functional, oncological, and surgical characteristics. The sarcopenia/frailty paradigm is a stronger predictor of survival at these time points than the Tokumashi score, Tomita score, and KPS. Psoas size can be used in clinical decision-making to select which patients with metastatic spine tumors are appropriate surgical candidates.

331 Long Term Outcomes after Minimally Invasive Transforaminal Lumbar Interbody Fusion for Lumbar Spondylolisthesis

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Introduction: Degenerative spondylolisthesis results in significant debilitating back pain and spinal stenosis. Transforaminal Lumbar Interbody Fusion (TLIF) for Lumbar Spondylolisthesis leads to excellent clinical outcomes.

Methods: A retrospective chart review study of cases with symptomatic lumbar spondylolisthesis operated using TLIF surgery. Data was collected on patient demographics, pre-operative imaging, complications, and reoperation rates. Outcome scales; Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS) were answered prospectively and over a 5-years follow-up period.

Results: In 262 patients, 173 (66%) were females. The mean age was 66.3 ± 12.4 years and mean BMI was 29.5 ± 6.1 kg/m². The average follow-up time was 2.6 ± 1.7 years. Operated levels were L3-4 13.4% and L4-5 59.6% and L5-S1 23.3%. Two levels spondylolisthesis percentage was 9.8%. Ninety percent of cases had almost total reduction. Mean OR time was 202.86 ± 26.6 minutes, mean EBL was 97.5 ± 51.8 cc³, and mean LOS was 2.93 ± 3 days. Mean VAS scores improved from 7.2 ± 2.2 pre-operative to 2.32 ± 1.9 , 2.86 ± 1.6 at 1 year and 5 years follow up consequently ($p > 0.001$). Mean ODI improved from 43.89 ± 16.3 pre-operative to 21.98 ± 17.7 , and 22.01 ± 17.6 at 1 and 5 years follow up consequently ($p > 0.001$). Fusion rate was >95% measured at 3months and one-year follow-up.

Conclusion: TLIF for lumbar spondylolisthesis is an effective technique with excellent clinical outcomes.

332 Outcome Analysis of Long Term Cancer Survivors Surgically Treated for Symptomatic Spinal Metastases

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Introduction: Targeted therapies have recently improved overall survival in multiple cancer types. and associated complications must be considered. The objective of this study is to evaluate outcomes of long-term cancer survivors surgically treated for symptomatic spinal metastases.

Methods: A retrospective chart and imaging review of patients who were surgically treated from January 2010 to December 2015 and survived at least 24 months after treatment. Collected data included patient demographics, tumor

histology, type and extent of spinal intervention, radiation data including treatment dose and field, long term sequelae including local tumor control, re-irradiation, re-operation or post-operative kyphoplasty at previously treated level.

Results: Seventy-three patients were included in the final analysis (36 males, mean age 60.9). The most common histologies were renal cell (19.1%), breast (17.8%), multiple myeloma (16.4%), thyroid (12.3%) and non-small cell lung carcinoma (8.2%). Open surgery was performed in 56 patients (76.7%) and minimal access surgery (MAS) in 17 (23.2%). Mean clinical and radiographic follow-up were 3.7 years at long-term follow-up 80% of patients had a Karnofsky performance status (KPS) of 80 or higher (i.e. functionally independent). Re-operations were performed in 16 patients (22%) including 8 for hardware revision, 4 tumor progressions, 3 wound complications and 1 post-operative blood clot. Post-operatively, kyphoplasty for progressive fractures at the treated level was performed in 3 cases (4%). Re-irradiation was performed in 13 cases (17.8%) with a median time to re-irradiation of 1.8 years.

Conclusion: Durable tumor control can be achieved in long term cancer survivors surgically treated for symptomatic spinal metastases with a limited complication profile. Long-term sequelae include local tumor recurrence/progression, marginal radiation failures, early or late hardware failures and progressive spinal instability or deformity.

333 C2-7 SVA and T1 Slope are Predictable Factors of the Dropped-Head Cervical Deformity after Laminoplasty

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Introduction: Laminoplasty is an effective surgical procedure for cervical degenerative disease, but it has a potential risk of postoperative kyphotic alignment change. Some patients develop the dropped-head cervical deformity after laminoplasty, though in rare instances. The purpose of this study is to investigate preoperative radiological factors associated with the dropped-head cervical deformity after laminoplasty.

Methods: Patients with ossification of posterior longitudinal ligament or patients underwent anterior cervical fusion were excluded. Among 532 patients we performed laminoplasty on from 2015 to 2016, 115 patients with kyphosis or sigmoid alignment were enrolled. C2-7 cervical lordosis (CL), C2-7 sagittal vertical axis (SVA) and T1 slope were analyzed on preoperative radiographs in neutral, flexed and extended positions. Four patients developed postoperative dropped-head deformity requiring surgery within one year after laminoplasty. They were compared with other patients.

Results: C2-7 SVA of patients with postoperative dropped-head deformity (54.8 ± 13.0) was significantly higher ($p < 0.001$) compared with others (20.4 ± 14.4) in neutral position. T1 slope of patients with postoperative dropped-head deformity (30.0 ± 6.4) was also significantly larger ($p < 0.01$) compared with others (19.3 ± 7.5) in neutral position. They were also significant differences in flexed and extended positions. There were no statistically differences of CL in any position. Cutoff values for predicting the postoperative dropped-head deformity were C2-7 SVA=38mm (AUC 0.96) and T1 slope=31 degrees (AUC 0.87) in neutral position.

Conclusion: Patients with high C2-7 SVA and large T1 slope have a high risk of dropped-head cervical deformity after laminoplasty. In other words, patients even with kyphosis or sigmoid alignment have low risk of deformity progression unless they show cervical sagittal imbalance.

334 Predictive Modeling of Adverse Event Occurrence after Spine Surgery

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Introduction: Complication occurrence impacts episodes of care and physician quality metrics. Understanding expected rates of complications is vital to appropriate risk modeling. We previously presented a risk modeling algorithm based upon privately insured patients; Medicare aged patients are more relevant to elective spine care.

Methods: We extracted 345,510 patients from the Truven MarketScan (MKS) and MarketScan Medicaid Databases and 760,724 patients from the Centers for Medicare and Medicaid Services (CMS) Medicare database who underwent spine surgeries between 2009 and 2013. We applied a least absolute shrinkage and selection operator (LASSO) regularization method and a logistic regression approach for predicting the risks of the top six most commonly observed adverse events. Predictors included patient demographics, location of the spine procedure, comorbidities, type of surgery performed, and pre-operative diagnosis.

Results: The median ages of MKS and CMS patients were 49 years and 69, respectively. The most frequent individual adverse event was a pulmonary complication (4.7%) in MKS and a cardiac dysfunction in CMS (10.6%) patients. Medicaid status was one of the most important factors in predicting the occurrences of adverse events; Medicaid recipients had increased risks of adverse events by 20-60% compared to non-Medicaid patients (odds ratios: 1.28-1.6; $P < 10^{-10}$). Among the six individual prediction models, the model for predicting the risk of a pulmonary complication showed the greatest accuracy (AUC 0.76), with the range of AUC for these six models between 0.7 and 0.76. Logistic regression showed higher AUCs than LASSO across these different models.

Conclusion: We present a tool for developing accurate expected rates of complication occurrence after spine surgery procedures. Integrating multiple administrative claims databases, encompassing privately and publicly insured patients, provides greater accuracy in predicting the risks of AEs following spine surgery. Socioeconomic status was the single greatest predictor of complication occurrence.

335 The Influence of Surgical Intervention and Sagittal Alignment on Frailty in Adult Cervical Deformity

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Introduction: Frailty, a decrease in physiologic reserve and increased vulnerability to adverse outcomes, falls, disability, and hospitalization, is a relatively new area of study for patients with cervical deformity. Recently, Miller et al have described a CD-FI for utilization in preoperative risk stratification. As of yet, little is known of how operative intervention influences frailty status for patients with adult cervical deformity.

Methods: Descriptive analysis of the cohort were performed, in addition paired t-tests determined significant baseline to 1Y postoperative improvements of factors comprising the CDFI. Pearson Bivariate Correlations identified significant associations between postoperative changes in overall CD-FI score and CD-FI score components. Linear regression models determined the effect of successful surgical intervention on change in frailty total.

Results: 138 patients were included with baseline frailty scores of 0.44. Following surgery, mean 1Y frailty score was 0.27. Of the CD-FI variables, 13/40 (32.5%) were able to improve with surgery. Frailty improvement was found to significantly correlate with baseline to 1Y change in CBV, PI-LL, PT, and SVA C7-S1. HRQL CD-FI components Reading, Feeling Tired, Feeling Exhausted, and Driving were the greatest drivers of change in frailty. Linear regression analysis determined successful surgical intervention and Feeling Exhausted to be the greatest significant predictors of postoperative change in overall frailty score.

Conclusion: Complications, correction of sagittal alignment, and improving a patient's ability to read, drive, and chronic exhaustion can significantly influence postoperative frailty. This analysis is a step towards a greater understanding of the relationship between disability, frailty, and surgery in ACD.

336 A Comparison of 30-Day Hospital Readmission Rates following Outpatient versus Inpatient 1 and 2 level Anterior Cervical Discectomy and Fusion Surgeries: An Analysis of a Medicare Patient Sample

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Introduction: Same day surgery has been demonstrated to be a safe and cost-effective alternative to traditional inpatient surgeries. Several studies have demonstrated no difference in post-operative complications profile or 30-day hospital readmission rates with outpatient versus inpatient anterior cervical discectomies and fusions (ACDFs). However, none of these studies have compared outcomes in elderly patients (>65 years old) undergoing ACDFs. Whether the results of previous studies applies to this subgroup of patients remains unknown. The aim of this study is to compare 30-day hospital readmission rates in Medicare patients (>65 years old) undergoing an outpatient versus inpatient ACDF.

Methods: A total of 17,421 patients were analyzed, with 16,386 undergoing inpatient ACDF surgery and 1,035 undergoing outpatient ACDF surgery. Age, sex, comorbidities, postoperative complications, readmission rates and overall financial cost were compared between both cohorts.

Results: In a Medicare sample (>65 years of age), ACDFs performed in an inpatient setting was associated with a higher incidence of post-operative complications when compared to those performed in an outpatient setting. outpatient surgery was associated with significantly lower rates of postoperative complications (UTI, SSI, DVT, PE, and MI), and a significantly lower cost of treatment ($p < 0.001$). All cause 30-day hospital readmission rates were also higher for inpatients (10.1% vs 4%, $p = 0.17$).

Conclusion: This study suggests that in a Medicare patient sample, outpatient ACDFs appear to be safe and effectiveness with low complication and readmission rates.

337 Perioperative Transfusion Threshold of Hemoglobin ≤ 9.0 mg/dL Results in Better Early Ambulation and Shorter Length of Stay for Patients Undergoing Complex Spine Surgery

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Introduction: Complex spine surgery for the correction of adult spinal deformity is associated with high complication rates and involves significant intraoperative blood loss with continued blood loss in the postoperative period through surgical drains. However, no transfusion threshold has been set for patients undergoing complex spine surgery.

Methods: We retrospectively reviewed the records of 150 consecutive patients who underwent surgery for the correction of adult spinal deformity with two staged approach including multilevel minimally invasive lateral lumbar interbody fusion with either T10-pelvis or T4-pelvis posterior fusion. Patient demographics, postoperative day one and day two hemoglobin levels, day of first ambulation, length of stay, and 30-day and 90-day complications were collected. Multivariable logistic regression analyses were used to account for age, sex, duration of surgery, comorbidity status, and preoperative hemoglobin.

Results: Mean length of stay was 12.1 days. Mean postoperative day one hemoglobin was 9.9mg/dL (range 8.3 to 11.9). Patients who had a postoperative day one hemoglobin ≥ 9.0 mg/dL demonstrated earlier first ambulation (1.6 days vs. 2.7 days; $p < .05$) and had a shorter duration of stay after final surgical stage (10.5 days vs. 14.1 days; $p < .05$) vs. those who had a hemoglobin < 9.0 mg/dL. There were no significant demographic differences between these two

groups. A hemoglobin threshold of 10.0mg/dL did not confer any advantage with respect to length of stay or ambulation. There was no difference in complication rates or 90-day readmission rates.

Conclusion: A perioperative transfusion threshold hemoglobin = 9.0mg/dL appears to allow patients to ambulate earlier and have shorter hospital stays after complex spine surgery without additional complications.

338 Can We Do Better? An Early Assessment of the First Real-Time, Image-Guided Robot in Spinal Surgery

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Introduction: The ExcelsiusGPS robot (Globus Medical, Inc., Audubon, PA) was FDA-approved in August 2017 and represents the first device to integrate image-guided navigation with robotics for the placement of pedicle screws in spinal surgery. We report the operative technique, clinical presentation, outcomes, and pedicle screw accuracy in the first twenty-two patients undergoing spinal surgery with the ExcelsiusGPS at our institution.

Methods: The first twenty-two consecutive patients who underwent spine surgery at a single institution with the ExcelsiusGPS surgical robot were included in this study. We collected the following variables: age, BMI, pre-operative pain, neurologic deficits, Karnofsky Performance Status [KPS], Frankel Grade, ambulatory status, surgical indication and approach, estimated blood loss [EBL], instrumented levels, and post-operative pain, neurologic deficits, KPS, Frankel grade, and ambulatory status. Screw accuracy was determined by a blinded neuroradiologist using the Gertzbein-Robbins method. We also developed and applied a novel screw accuracy grading system that incorporates neurologic symptoms, pedicle breach, and deviation from planned screw trajectory.

Results: 132 pedicle screws were placed in 22 thoracolumbar fusion cases. Average levels fused=3.45±0.63; mean EBL=450.7±113.5 mL; average fluoroscopy exposure=86.6±33.7 seconds. KPS score improved in 91% (20/22 patients; p<0.05). Among the 111 screws for which we had post-operative CTs, 95.5% (106/111) were accurately placed: 88.3% (98/111) Gertzbein-Robbins A, 7.2% (8/111) grade B. Two screws (1.5%) were revised in the same patient due to persistent radiculopathic pain and numbness.

Conclusion: Here we describe our operative technique with the ExcelsiusGPS, the first spinal device to integrate navigation with robotics. Spinal fusion with the ExcelsiusGPS can be performed safely, with good screw accuracy and clinical outcomes, using either pre-operative or intra-operative CT. We propose a novel grading system for pedicle screw accuracy that incorporates neurologic symptoms, pedicle breach, and deviation from planned screw trajectory that should be further validated in future studies.

339 Undesired Bony Overgrowth After Use of rhBMP-2 in Spinal Surgery: A Case Series

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Introduction: Bone healing is a necessity after bony fracture or surgery to stabilize and fuse the human spinal column. Bone morphogenetic proteins (BMPs) are growth factors pivotal in regulation of bone induction during growth, maintenance and repair. Two recombinant human BMPs (rhBMPs), rhBMP-2 and rhBMP-7, have been developed and approved by the Food and Drug Administration for specific applications; however, the vast majority of rhBMP use is off-label. They are touted to be short-term stimulants for bone healing and fusion, their osteoinduction and osteogenesis effects are reported to last only 7-14 days. Despite multiple late safety concerns, rhBMP-2 remains available for commercial use.

Methods: The surgical experience at the University of Alabama at Birmingham was retrospectively reviewed. Patients were identified who underwent reoperation after a lumbar fusion procedure that utilized rhBMP-2. Details of their clinical course and radiographic findings were reviewed.

Results: Twelve patients treated with rhBMP-2 in conjunction with posterolateral (PLIF) or transforaminal lumbar interbody fusion (TLIF) procedures and lumbar spinal internal fixation have been re-operated upon in the last nine years for delayed recurrent radiculopathy. In each patient exuberant bony overgrowth, bony masses typically at the site of the interbody fusion have been identified and surgically resected.

Conclusion: The use of genetically engineered bone morphogenetic proteins in spinal surgery can form bone masses in undesired locations, can cause marked scarring, nerve tethering and compression leading to significant late neurological symptoms and signs and should only be utilized for FDA approved indications, only with the understanding their effects may have late, potentially long-term deleterious consequences.

340 Can PROMIS be Used to Evaluate Patients with Primary or Metastatic Spine Tumors?

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Introduction: There is a paucity of work determining the concurrent validity and comparing the performance of PROMIS to a legacy PRO tool in primary and metastatic spine tumor patients. This study aims: 1) To assess the correlation of PROMIS Physical Function (PF), Pain Interference (PI) and Depression scores with Oswestry Disability Index (ODI) and Neck Disability Index (NDI) ODI/NDI scores; 2) To assess ceiling and floor effects of PROMIS PF, PI and Depression domains and the ODI/NDI.

Methods: Patients confirmed to have a primary or metastatic spine tumor by a single orthopaedic spine surgeon at a large, urban academic medical center were asked to complete PROMIS PF, PI and Depression domains and either an

ODI or NDI questionnaire based on lesion location. Patients completing all questionnaires and presenting between May 2015 and December 2017 were included. Pearson correlation coefficients (r) were calculated. Ceiling and floor effects were determined and compared. Significance was set at $p < 0.05$.

Results: Eighty unique visits from 51 patients with spine tumors (44 metastatic/67 visits; 7 primary/13 visits) met our inclusion criteria. A strong correlation existed between PROMIS PI and the ODI/NDI in both primary and metastatic tumor patient subgroups (range, $r = 0.75 - 0.86$, $p < 0.05$). PROMIS PF and the ODI/NDI demonstrated a strong correlation among all patients ($r = -0.75$, $p < 0.05$) and in the metastatic disease subgroup ($r = -0.78$, $p < 0.05$). A strong correlation existed between PROMIS Depression and the ODI/NDI in the primary tumor subgroup ($r = 0.79$, $p < 0.05$). PROMIS Depression demonstrated the largest floor effect (13.6%); there were similar ceiling effects.

Conclusion: PROMIS PF and PI domains correlate well with the ODI/NDI in patients with spine tumors with a similar ceiling effect but better floor effect. PROMIS Depression does not appear to be captured as well in the ODI/NDI except in the primary tumor subgroup.

341 The Comparative Safety of Lumbar Spinal Fusion for Degenerative Spondylolisthesis Among Older Adults

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Introduction: Degenerative spondylolisthesis (DS) is often treated with lumbar spinal fusion (LSF). However, there is concern that the morbidity of LSF may be unacceptably high in older adults, owing to poorer physiological reserves. Using a large administrative healthcare dataset, we sought to evaluate the impact of advanced age on the safety of LSF for DS.

Methods: Patients who underwent LSF for DS were identified from the NSQIP datasets for years 2011 through 2015 using standard CPT codes. Data relating to demographic characteristics, comorbidities, surgical factors, and 30-day morbidity and mortality were collected. Propensity score matching (nearest neighbor) was performed in a 1-to-1 ratio with age (< 70 yrs vs. $= 70$ yrs) as the treatment indicator and sex, type of fusion procedure, number of levels fused, diabetes, smoking, hypertension, and chronic steroid use as covariates (Fig 1). Outcomes were compared between age < 70 yrs and age $= 70$ yrs groups.

Results: The study cohort consisted of 2,238 patients, with 1,119 patients aged less than 70 years and 1,119 patients 70 years or older. The mean age was 67.0 ± 11.0 years. The two age groups were balanced for key covariates including sex, race, diabetes, hypertension, CHF, smoking, chronic steroid use, type of fusion, and number of levels. Rates of all complications were similar between younger and older age groups, except UTI, which was more frequent among the $= 70$ yrs group (OR 2.32, $P < 0.01$). Further, patients in the older age group were more likely to be discharged to a rehabilitation (OR 2.94, $P < 0.01$) or skilled care (OR 3.66, $P < 0.01$) facility, rather than directly home (OR 0.25, $P < 0.25$).

Conclusion: LSF may be performed safely in older adults with DS. Older age alone should not exclude a patient from undergoing a lumbar fusion operation.

342 Risk Factors for Surgical Site Infection After Posterior Spinal Fusion: A Single-Center Experience with 4046 Patients

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Introduction: Posterior spinal fusion (PSF) is used to treat numerous spinal pathologies, but can be complicated by surgical site infection (SSI) necessitating operative wound washouts, hardware revision removal and/or replacement, and long-term antibiotics. Identifying factors associated with such complications could help risk stratify patients and tailor clinical management.

Methods: We retrospectively analyzed all posterior spinal fusions performed at our institution from 2000 to 2015. Posterior spinal fusions were identified using Current Procedural Terminology codes. Data was collected on patients' clinical characteristics, procedural factors, and antimicrobial management, and multivariable analysis identified factors independently associated with postoperative infection, readmission, and reoperation.

Results: 4046 patients were identified. SSI was independently, positively associated with staged procedures (OR=3.00, $p < 0.001$), higher number of levels fused (OR=1.08, $p = 0.011$), and steroid use (OR=2.98, $p = 0.010$). SSIs were negatively associated with the use of antibiotic irrigation (OR=0.49, $p = 0.013$), but were more common among patients whose irrigation was cefazolin (OR=2.22, $p = 0.034$), particularly gram-negative infections (OR=5.75, $p = 0.003$). Reoperation was associated with staged procedures (OR=6.47, $p < 0.001$), having more levels fused (1.06, $p = 0.044$), having more participants in the room during surgery (OR=1.02, $p = 0.046$), or using cefazolin as the antibiotic irrigant (OR=2.52, $p = 0.002$). Readmission within 30 days was associated with undergoing a staged procedure (OR=3.02, $p < 0.001$), cervical surgery (OR=1.50, $p = 0.043$), or higher Charlson Comorbidity Index (CCI) (1.03, $p = 0.030$). Higher CCI was also independently associated with gram-positive infections (OR=1.11, $p = 0.047$) and infection requiring hardware removal (OR=1.23, $p = 0.011$), and showed a trend toward significance in predicting SSI (OR=1.05, $p = 0.070$).

Conclusion: PSF procedures that are staged or that involve more levels carry a higher risk of infection. Comorbid disease burden and the choice of antibiotic irrigant, and the number of participants/surgeons may also affect infection risk, and the corresponding need for readmission or operative intervention.

343 Closing the Treatment Gap for Lumbar Disc Herniation Patients with Large Annular Defects: Techniques and Outcomes for this High-risk Population

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Introduction: Discectomy is the primary surgical intervention for lumbar disc herniation (LDH) and is generally successful. Some patients still experience recurrent LDH (rLDH) after discectomy, which is associated with worse clinical outcomes and greater socioeconomic burden. Large defects in the annulus fibrosis are a significant risk factor for rLDH and present a critical treatment challenge. This study aimed to perform a critical evaluation of treatment strategies for this at-risk population.

Methods: A systematic review of the PubMed and Embase databases was performed according to PRISMA guidelines to identify studies describing the treatment of LDH patients with large annular defects. The incidence of large annular defects, measurement technique, rLDH rate, and reoperation rate were compiled and stratified by surgical technique. The risk of bias was scored for each study and for the identification of rLDH and reoperation. Study heterogeneity and pooled estimates were calculated from the included articles.

Results: Fifteen unique studies describing 2,768 subjects were included. The pooled incidence of patients with a large annular defect was 44%. The pooled estimates of rLDH and reoperation rates following limited discectomy in this population was 10.6% and 6.0%, respectively. More aggressive subtotal discectomy tended to have lower rates of rLDH (5.8%) and reoperation (3.8%). A recent randomized controlled trial (RCT) with 550 subjects described an annular closure device (ACD) that resulted in >50% reduction in rLDH and reoperation rates compared to limited discectomy alone.

Conclusion: Limited discectomy in patients with large annular defects has a greater risk of rLDH and reoperation. Subtotal discectomy may reduce this risk, but those patients were reported to experience greater pain associated with disc degeneration. The quality of evidence was low for subtotal discectomy as an alternative to limited discectomy. The strongest evidence suggested that an ACD can significantly reduce rLDH and revision rates in patients with large annular defects.

344 Worldwide Knowledge and Attitude of Spine Surgeons Regarding Radiation Exposure

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Introduction: Spine surgery often requires the use of radiation by means of fluoroscopy during surgery, and fluoroscopy-assisted spinal procedures are on the rise world-wide due to the growth in the popularity of minimally invasive techniques and endoscopy (1). These techniques often require real-time fluoroscopic visualization to perform precise intraoperative localization and minimize instrument and implant malposition, leading to an increase in the exposure of spine surgeons to radiation (2, 3). Since studies of spine surgeons' knowledge and attitude regarding radiation exposure are scarce in the literature, this study aims to assess worldwide, the spine surgeon's perceptions and attitudes regarding radiation exposure during spine procedures.

Methods: Questionnaire about general information and the surgeon's perception and attitude regarding radiation exposure during spine surgery. We sent it to worldwide AOSpine members from December 15th 2016 to April 15th 2017. The main variables studied were: specialty, years of experience, surgeon's position during fluoroscopy, and practices to reduce the patient's and surgeon's radiation exposure during surgery.

Results: The questionnaire was answered by 979 spine surgeons, who were members of AOSpine LA (n=371), EU (n=248) AP (n=204), NA (n=112), and ME (n=44). Most were orthopaedic surgeons (64.5%) with = 10 years of experience (54.9%). A thyroid shield was used by 66.4% and lead glasses by 17.3%. A dosimeter badge was rarely or never used by 67.8% of the participants. Only 36.7% of the surgeons worldwide knew the correct answer for optimum surgeon position during lateral lumbar fluoroscopy, with the highest percentage being amongst NA spine surgeons (61.6%; $p < 0.001$). Pulse-mode fluoroscopy is used with a similar frequency among regions.

Conclusion: Independent of the region analyzed, we observed a lack of adequate awareness regarding intraoperative radiation exposure as well as available safety measures. We strongly recommend further education for all spine surgeons using fluoroscopy during surgical procedures.

345 Accuracy of Pedicle Screw Placement Using Next-Generation Spinal Robotics: Evaluation of Deviation from Pre-Planned Trajectory

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Introduction: The ExcelsiusGPS® (Globus Medical, Inc., Audubon, PA) is a next-generation real-time image-guided surgical robotic system approved for use in the United States. The objective of the current study is to assess pedicle screw accuracy and clinical outcomes among the first ten operative cases utilizing the ExcelsiusGPS® robotic system and describe a novel metric to quantify screw deviation.

Methods: Ten patients who underwent thoracic and/or lumbar fusion at a single institution with the ExcelsiusGPS® surgical robot were included. Pre-operative trajectory planning was performed from an intra-operative CT scan using

the O-arm (Medtronic, Inc., Minneapolis, MN). After robotic-assisted screw implantation, a post-operative CT scan was obtained to confirm ideal screw placement and accuracy with the planned trajectory. A novel pedicle screw accuracy algorithm was devised to measure screw tip/tail deviation distance and angular offset on axial and sagittal planes. Clinical variables such as symptomatology, operative data, and post-operative follow-up were also collected.

Results: A total of 50 pedicle screws were instrumented in ten cases. Mean screw tip deviation was 2.7mm (range 0.5-5.2mm), mean tail deviation was 3.6mm (range 0.5-8.4mm), and mean angular offset was 4.8 degrees (range 0-16.2 degrees). There were no cases of screw revision or new post-operative deficit. 98% (49/50) of the screws were considered appropriately placed based on the Gertzbein-Robbins scale (88% Grade A and 10% Grade B). All patients experienced improvement in Frankel grade and Karnofsky Performance Status (KPS) score by 6 weeks post-op.

Conclusion: The ExcelsiusGPS robot allows for accurate pedicle screw placement and acceptable execution of an intended pre-planned trajectory in the first patients to undergo robotic-assisted instrumentation with this technology.

346 Risk Factors for Perioperative Non-Neurological Morbidity and Mortality in Patients Undergoing a Surgical Intervention for Spinal Epidural Abscess: National Database Study.

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Introduction: Although Spinal Epidural Abscess (SEA) is a somewhat uncommon disease, the incidence has increased significantly over the past several decades. Recent estimates of perioperative morbidity are 40% and mortality is approximately 5%. In this retrospective review we identify predictors of non-neurological morbidity and mortality in patients undergoing surgery for SEA.

Methods: Patients undergoing surgery for SEA were identified in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2006 to 2016. Pre-operative lab values, demographics, and comorbidities were reviewed. Multivariate analysis was used to identify predictors of non-neurologic surgical complications and mortality within 30 days of surgical intervention.

Results: We identified 702 patients who underwent surgery for SEA. Overall morbidity and mortality rate were 42.5% and 7.1%, respectively. On multivariate analysis, predictors of thirty-day mortality were age over 60, insulin dependent diabetes mellitus (IDDM), history of Chronic Obstructive Pulmonary Disease (COPD), pre-operative BUN>20, and dependent functional status. Of these, COPD (OR 2.7 95% CI: 1.17-6.25 p=0.020), IDDM (OR 2.69, 95% CI 1.28-4.85, p=0.007), and dependent functional status (OR 2.4 95% CI: 1.39-5.13, p=0.003) were the strongest predictors of thirty-day mortality. Predictors of non-neurological morbidity were WBC > 12 (OR 2.1, 95% CI: 1.5-2.9, p<0.001) and BMI over 30kg/m² (OR 1.5, 95% CI: 1.06-2.02, p=0.02).

Conclusion: SEA is an uncommon condition with estimated morbidities > 40% and mortality > 5%. This study shows that WBC > 12 and obesity were strong independent predictors of post-operative complications, while COPD, IDDM and dependent functional status were the most significant predictors of mortality in patients undergoing operative treatment for SEA. This study is the first, to our knowledge, to identify dependent functional status as a significant determinant of mortality in patients undergoing operative treatment of SEA.

347 Assessing the Performance of NSQIP Surgical Risk Calculator in Elective Spine Surgery: Insights from Patients Undergoing Single-Level Posterior Lumbar Fusion

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Introduction: The American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) Surgical Risk Calculator (SRC) is a tool developed to use 21 individual patient characteristics to make predictions for occurrence of 13 general and 2 procedure specific outcomes. Literature on the role of NSQIP-SRC in spine surgery is sparse. The goal of this study was to evaluate the performance of the SRC in predicting outcomes in patients receiving posterior lumbar fusion.

Methods: The ACS-NSQIP user file for 2015 was queried for patients with age=18 undergoing single level posterior lumbar fusion (PLF) surgery. Individual patient characteristics were entered into the online risk calculator interface to retrieve the predicted estimated risk for perioperative outcomes and complications including surgical site infection, readmissions, reoperations, major complication, any complication and mortality. Following this, predictive performance was analyzed by computing brier score, c-statistic and sensitivity values for all observed outcomes.

Results: A total of 2808 undergoing single-level PLF patients were included in the analysis with 53.7% (1510) females. Overall, a very low incidence of 30-day postoperative complications was observed with the procedure (0.9%-6.3%). Poor predictive performance was found for all outcomes including readmissions (c-statistic=0.63, sensitivity=15.28%, brier score=0.048) and returns to OR (c-statistic=0.63, sensitivity=15.28%, brier score=0.048). The best performance was observed for venous thromboembolism (c-statistic=0.66, brier score=0.008) although sensitivity was poor (3.85%) on account of low incidence. Predictive performance for length of stay revealed good agreement between observed and predicted values with the exception of prolonged predicted hospital stays (>3.5 days).

Conclusion: This study assessed the performance of the risk calculator for a homogenous population of patients undergoing a single level posterior lumbar fusion. Although the calculator did not fare well in predicting most outcomes, results need to be interpreted in the context of the low incidence rate of such outcomes.

348 Can Machine Learning Algorithms Accurately Predict Discharge to Rehabilitation and Early Unplanned Readmissions Following Spinal Fusion? Analysis of a National Surgical Registry

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Introduction: Predictive models for discharge to rehabilitation and unplanned readmissions following spine surgery are sparse in the literature. We sought to utilize different machine learning algorithms to predict these outcomes in patients receiving spinal fusion.

Methods: We queried 2012-2013 ACS-NSQIP data for patients undergoing cervical or lumbar spinal fusion. Outcomes assessed included discharge to rehabilitation and unplanned readmission within 30 days after surgery. A total of 7 classification algorithms were assessed: Generalized Linear Model (logistic regression), elastic net, penalized discriminant analysis, naive Bayes, Artificial Neural Networks, Random Forest and Gradient Boosting Machines. Model performance was evaluated using overall accuracy, area-under-receiver operating characteristic curve (AUC), as well as sensitivity, specificity and positive and negative predictive values.

Results: Among 59, 145 cases of spinal fusion, incidence of discharge to rehabilitation/skilled nursing facility and 30-day unplanned readmission was 12.6% and 4.5% respectively. All classification algorithms showed excellent discrimination ($AUC > 0.85$) for discharge to rehabilitation/skilled nursing facility with marginally higher sensitivity noted for Neural networks (80%). Logistic regression showed comparable performance to other machine learning algorithms. By comparison, all models showed poorer predictive performance for unplanned readmission with $AUC: 0.63-0.66$. Neural networks showed highest accuracy (71%) and specificity (72%) for predicting unplanned readmission compared to other algorithms. In general, better predictive performance was noted with models using imputed data.

Conclusion: In analysis of data from a multi-institutional surgical registry, multiple machine learning algorithms were found to reliably predict discharge to rehabilitation/skilled nursing facility. Unplanned readmissions remained more challenging to predict. Logistic regression achieved equivalent predictive performance to more complex machine learning approaches. Future research should further validate these findings by utilizing larger datasets with a wider array of baseline variables, such as patient reported outcomes in order to generate possibly superior predictive models for each of the above outcomes.

349 Utility of Thoracolumbar Bracing following Spinal Fusion

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Introduction: There exists a lack of consensus regarding the role of orthoses following thoracolumbar spinal fusion surgery. The potential benefit and stability conferred by postoperative immobilization must be balanced by the potential morbidity and patient discomfort associated with bracing. Limited clinical evidence is available for the utility of thoracolumbar bracing following spinal fusion. This study aims to assess the utility of external fixation of the thoracolumbar spine following fusion for pathologies including trauma, tumor, degenerative disk disease, and scoliosis.

Methods: A systematic review was performed using Medline. The search queried studies published between the years of 1990-2018 that evaluated whether post-operative bracing conferred any benefit to recovery or quality-of-life following spinal fusion.

Results: Our search identified 1706 publications. These were narrowed to 29 publications that evaluated bracing in the post-operative setting. Of these, only five studies specifically evaluated postoperative bracing in thoracolumbar patients following spinal fusion. Demographic information, surgical details, complication rates, and a variety of quality of life measures, were extracted and analyzed. Mean complication rates, instrumentation failure rates, pseudarthrosis rates, Oswestry Disability indices, visual analog scale Spine Scores, SF-12v2 scores, American Spinal Injury Association impairment scores, and Roland Morris Disability scores, were calculated across bracing and control cohorts and compared using independent samples t-test. Ultimately, thoracolumbar bracing was not found to significantly affect complication rates, or impact postoperative quality of life.

Conclusion: This systematic review does not find any significant effect of postoperative bracing on complication rates or quality-of-life for patients recovering from thoracolumbar fusion. This review was limited by a paucity of available studies, and further investigation is warranted into this topic to determine optimal postoperative management of such patients.

350 Assessing the Differences in Outcomes Between General and Regional Anesthesia in Spine Surgery: Results from a National Registry

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Introduction: Endotracheal or general anesthesia is one of the most commonly used anesthetic techniques when performing thoracic and lumbar surgeries. However, spinal and epidural anesthesia have been increasingly employed for lumbar decompressions and lumbar fusion recently. The objective of this study was to investigate the outcomes of general and non-general (spinal and epidural) anesthesia in patients undergoing posterior lumbar fusion and lumbar decompression using a national registry.

Methods: The American College of Surgeons National Surgical Quality and Improvement Program(NSQIP) database was queried to identify patients who underwent LD or PLF with general or non-general anesthesia between 2011 and 2015. Patient characteristics and postoperative variables were compared. Multivariable regression was used to identify predictors of thirty-day readmission, any complication and length of hospital stay(LOS). Three-to-one propensity-score matching and conditional logistic regression were used to adjust for potential bias.

Results: A total of 60,222 patients who underwent LD were identified; 59,876(99.4%) received general anesthesia and 342(0.6%) were given non-general anesthesia. On multivariable conditional regression, type of anesthesia was found to have no significant effect on any of the outcomes analyzed(Readmission: OR: 0.90, p=0.79; Any Complication: OR: 0.75, p=0.75; LOS: Coef.: 0.18, p=0.35, respectively). A total of 31,419 patients who underwent PLF were identified; 31,377(99.9%) were given general anesthesia and 42(0.1%) were given non-general anesthesia. The type of anesthesia had no significant effect on any of the outcomes analyzed(Readmission: OR: 0.78, p=0.83; Any Complication: OR: 0.50, p=0.40; LOS: Coef.: 0.17, p=0.68, respectively).

Conclusion: Our analysis showed that non-general anesthesia had equivalent outcomes with respect to readmission, LOS and complication, when compared to general anesthesia in patients undergoing lumbar decompression or posterior lumbar fusion. While the choice of anesthesia type remains a matter of preference, our results show that non-general anesthesia may be practiced safely and is associated with equivalent outcomes.

351 Dysphagia After Occipitocervical Fusion: Are We Measuring the Correct Parameters?

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Introduction: Recently, several publications have focused on dysphagia after occipitocervical fusion (OCF) and relevant radiographic parameters. Unfortunately, there is not a reliable way to prevent the occurrence at this time. This study introduces a new parameter that is easy to measure in the operating room and is unaffected by soft tissue changes introduced by endotracheal tube placement or positioning.

Methods: We performed a retrospective chart review from a single institution from 2014-2018. We measured the O-C2 angle (O-C2a, Figure 1), narrowest oropharyngeal airway space (nPAS), and the distance between the posterior edge of the hard palate and the anterior inferior corner of C2 (HPC2, Figure 2).

Results: We identified 28 patients that underwent OCF. Seven were excluded due to confounding injuries or lack of complete imaging. Post-operative parameters are summarized in Table 1. Only five patients from the non-dysphagia group and three patients from the dysphagia group had a full complement of pre- and post-operative imaging to enable calculation of changes in these parameters. Results are summarized in Table 2. In the group without dysphagia, there was a good correlation between both the changes in the O-C2a and HPC2 and the corresponding change in the nPAS (Graphs 1 and 2). Parameters involving the EAM were hard to identify in many cases.

Conclusion: Despite the low number of patients with complete imaging in this study, we believe the magnitude of change of cervical spine parameters is more important than the absolute value in preventing post-OCF dysphagia. Measured parameters should consider both rotation and translation of the occiput relative to the spine. The HPC2 line is easily measured on intraoperative images and may add important information about translation when combined with the OC2a. The combination may serve as a good surrogate marker for the change in nPAS, which is difficult to measure intraoperatively.

353 Opioid Use Associated with Worse Post-operative Lumbar Fusion Outcome at 1-year

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Introduction: Opioid utilization and abuse has reached epidemic proportions in the U.S. Lower back pain is a dominant factor in opioid usage in America. It is imperative to fully understand the impact of opioids usage on outcome from surgery for lower back pain disorders.

Methods: A retrospective review of prospectively collected registry data on lumbar spinal fusion at a single center from 2015-2018 was performed. Opioid utilization was captured using a novel algorithm to extract these data from the electronic health record. Other variables: number of levels fused, type of fusion, minimally invasive surgery (MIS) status were collected from the registry. Patient-reported outcome: EuroQoL-5D (EQ-5D) and Oswestry Disability Index (ODI) were obtained from registry data 1-year post-operatively.

Results: 300 patients (mean age 62 years, 47% male) were included. Pre-operative opioid use predisposes a patient to post-operative opioid use (P-value= 0.0049, OR 2.24 (1.2, 4.0)). Of the 19.3% of patients taking opioids pre-operatively, 60.3% continued taking opioids post-operatively. Type of lumbar fusion (TLIF, PLIF, ALIF, XLIF, MIS) is not associated with post-operative opioid usage (P-value(type)=0.5 30-day, 0.246 90-day; P-value(MIS)=0.48 30-day, 0.27 90-day). Greater than 4 levels of fusion trends towards an association with 90-day opioid use (P-value=0.08). Worse 1-year ODI outcome is associated with opioid utilization before (P-value= 0.02; 28.2±22.9 vs. 16.3±16.8) and after (P-value= 0.013; 22.1±20.9 vs. 14.1±14.1) lumbar fusion, but not with 1-year EQ-5D scores (P-value= 0.17 pre-op, 0.19 post-op).

Conclusion: This registry finds that opioid use 3-months before and after lumbar fusion surgery is associated with worse outcome at 1 year. Preoperative narcotic use, and greater number of levels fused increases the likelihood of opioid use after surgery.

354 Analysis of the Correlation of Intraoperative Neuromonitoring Changes with Postoperative Neurological Outcome

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Introduction: Intraoperative neuromonitoring (IONM) is a standard technique for spine surgery, allowing early detection of irritation or damage of neural elements. Most research on its utility focuses on sensitivity and specificity of monitoring changes. In addition to gaining more data on specific patient groups who benefit from the use of monitoring, we believe that positive predictive value and negative predictive value better characterize the value of information provided by IONM. Based on a high number of false positives in IONM, we hypothesize a low PPV, while NPV will be relatively high.

Methods: We retrospectively reviewed charts of 1043 consecutive patients undergoing spine surgery with and without IONM at Loyola University Medical Center over the past two years. Demographic data were collected, as was clinical outcome data at several time points. A motor evoked potential (MEP) amplitude decrease of 50% or greater was correlated with sustained motor deficit at multiple points postoperatively to assess PPV and NPV of IONM.

Results: On multivariable analysis, IONM is associated with better patient outcomes when undergoing lumbar spine surgery ($p = .053$) and patients with a neurogenic claudication ($p = .01$). However, IONM showed no difference in outcomes otherwise. The probability that patients' postoperative motor score worsened when their intraoperative MEP changed (PPV) was 26.32% (day 1), 28.57% (day 30), and 0% (day 90). Conversely, the probability patients' postoperative motor score remained stable or improved when the MEP did not change (NPV) was 74.25% (day 1), 79.85% (day 30), and 88.41% (day 90).

Conclusion: The use of IONM was correlated with better clinical outcomes within certain patient populations. Low PPV of intraoperative motor changes indicate a high false positive rate, and require careful interpretation of IONM data. The relatively high NPV is a strong predictor for good clinical outcomes.

355 Which Patients Undergoing Lumbar Decompression are Most Appropriate for an Ambulatory Surgery Center? A Pilot Study

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Introduction: Ambulatory surgery centers (ASCs) are becoming increasingly utilized for spinal procedures and represent an opportunity for cost savings. However, ASCs are under increasing scrutiny for profit-driven motives and inability to handle complications. Using a national inpatient cohort undergoing lumbar decompression (LD) with short hospitalization as a surrogate for a potential ASC population, the current objectives were to: 1) outline factors that may delineate which patients are best suited for an ambulatory versus inpatient setting, and 2) describe potentially catastrophic complications.

Methods: Adults who underwent LD from 2008-2014 were identified in the National Surgical Quality Improvement Program (NSQIP) database. Inclusion criteria were: principal procedure LD (CPT 63030), elective procedure, neurologic/orthopaedic surgeons, length of stay (LOS) 0/1 days, and discharged home. The primary outcome was presence of any complication. The secondary outcome was occurrence of potentially catastrophic complication. Univariate/multivariable logistic regression was conducted.

Results: A total of 19,908 patients underwent elective LD with a LOS of 0/1 days and were discharged home. Of this potential ASC population, 564 (2.8%) experienced a complication. After univariate logistic regression, the following factors were significantly associated with a complication: age, Charlson comorbidity index, ASA, HTN, diabetes, COPD, cardiac intervention, cancer history, chronic steroids, smoking, abnormal labs (BUN, WBC), and operative time over 2 hours. The only factor to remain significant after multivariable testing was cardiac intervention (OR 2.02, 95%CI 1.00-4.07, $p=0.049$). A total of 96 (0.5%) patients experienced potentially catastrophic complications.

Conclusion: Using a national inpatient database, the current results represent a preliminary, pilot analysis in selecting which patients may be safely treated in the ambulatory setting. The incidence of potentially catastrophic complication was 0.5%. Though not a true ambulatory population, by using patients who were discharged home with a short hospitalization, these results can be validated in spine-specific databases to further optimize selection of patients most appropriate for ASCs.

356 Incidence and Risk Factors for Venous Thromboembolism After Surgery for Metastatic Tumors of The Spine

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Introduction: The purpose of this study is to investigate the incidence and risk factors for venous thromboembolism (VTE) after surgery for metastatic tumors of the spine.

Methods: A retrospective review of our institutional neurosurgical spine database for the years 2012 through 2018 was conducted to identify adult patients who underwent surgery for metastatic tumors. The incidence of VTE deep vein thrombosis (DVT) and/or pulmonary embolism (PE) occurring within 30 days was examined. Patient characteristics were compared between patients with and without VTE to identify any significant predictors via logistic regression analysis.

Results: There were 65 patients identified from our database with a mean age of 57 years. The overall incidence of VTE was 16.9% - all of whom had DVTs with a 3.1% rate of non-fatal PE (two patients developed both DVT and PE). A poor preoperative functional status (Karnofsky less than 70) was a significant predictor of VTE occurrence (OR 7.61; 95% CI 1.76–32.8; $p=0.006$), as well as non-ambulatory status at presentation (OR 4.79; 95% CI, 1.17–19.51; $p=0.029$). Age, sex, BMI, smoking status, history of remote VTE, or medical comorbidities were not found to be associated with postoperative VTE development.

Conclusion: Poor preoperative functional status and inability to ambulate on presentation were found to be significant predictors of VTE after surgery for metastatic tumors of the spine in this study.

357 Ahead of the Curve: Automated Multi-modal Non-rigid Fusion of Preoperative MRI and Intraoperative CT for Neuro-navigation during Surgical Resection of Spinal Tumors

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Introduction: Recent advances in spinal imaging and post-processing techniques have allowed for the adoption of functional and anatomical imaging modalities that have been traditionally used for cranial neurosurgery, such as diffusion tensor imaging (DTI), to guide resection of complex spinal tumors. Differences in patient positioning between preoperative (supine) and intraoperative (prone) scans poses a challenge to accurate multi-modal image co-registration for intraoperative use in spine surgery.

Methods: We describe our experience with multi-modal image co-registration for neuro-navigation during surgical resection of spinal tumors. Algorithm-based elastic fusion and automated multi-modal image co-registration was used to correct for differences in patient positioning between preoperative and intraoperative scans. Osseous anatomical landmarks were fused with deformed preoperative image sets.

Results: Co-registered imaging correlated accurately with intraoperative observation of spinal anatomy and lesions. During resection of a spinal cord glioma, the preoperative MRI was integrated with the operative microscope to allow for continuous navigation during resection. During resection of a sacral liposarcoma, navigation facilitated identification and preservation of sacral nerve roots.

Conclusion: We present a proof of concept that pre-operative MRI can be co-registered with intraoperative CT using curve correction software for navigation assisted resection of spinal tumors. This tool may serve as an important adjunct to intraoperative ultrasound.

358 A Comparison of Peri-Operative Outcomes in Patients Undergoing Two-Level Anterior Cervical Decompression and Fusion Versus One-Level Anterior Cervical Corpectomy for Treatment of Cervical Degenerative Conditions: A Propensity Score Matched Analysis

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Introduction: There are clinical situations where the surgical decision must be made between two-level ACDF and one-level ACCF for two level cervical pathology. The aim of this study is to compare the perioperative morbidity of two-level anterior cervical decompressions and fusion (ACDF) with that of one-level anterior cervical corpectomy and fusion (ACCF) for the treatment of cervical degenerative conditions.

Methods: A retrospective study of the 2005-2016 National Surgical Quality Improvement Program (NSQIP) database for patients undergoing two-level ACDF and one-level ACCF was performed. Patient data included: age, gender, BMI, functional status, and ASA class. Hospital data included: operative time and length of hospitalization (LOS). Thirty-day outcome data included: any, major, and minor adverse events; return to the operating room, readmission, and mortality. After controlling for age, gender, ASA, functional status, and BMI, multivariate logistic regression analyses was used to compare outcome between the two cohorts, as well as between propensity-matched sub-cohorts.

Results: A total of 17,497 cases were identified, with 15,783 undergoing two-level ACDF and 1,714 undergoing one-level ACCF. Cases of two-level ACDF were younger, more female, greater functional status and had shorter operative time and LOS ($p<0.001$). After propensity score matching, cases undergoing a one-level ACCF had significantly higher rates of any adverse event ($p=0.032$), serious adverse events ($p=0.006$), and failure to wean from ventilator ($p=0.002$).

Conclusion: Relevant to cases where there is the surgical decision between two-level ACDF and one-level ACCF, the current study finds that one-level ACCF is associated with higher rate of adverse outcomes (including airway compromise) than two-level ACDF for cervical degenerative pathology.

359 Objective Functional Assessment Using the Timed-Up and Go test in Patients with Lumbar Spinal Stenosis and Neurogenic Claudication

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Introduction: Patient-reported outcome measures (PROMs) are increasingly complemented by objective outcome measures, such as the "Timed-Up and Go" (TUG) test. Currently, only few reports exist on pre- and postoperative TUG assessments of patients with lumbar spinal stenosis (LSS).

Methods: We collected prospective data at two centers. In any LSS patient, who underwent microsurgical lumbar decompression with or without fusion, the subjective functional status was estimated using PROMs for pain (VAS),

disability (Roland-Morris disability index; RMDI and Oswestry disability index; ODI) and quality of life (QoL; SF-12 and EQ-5D) preoperatively and on postoperative week 6 (W6). Objective functional impairment (OFI) was measured using age- and sex-standardized TUG test results.

Results: 64 patients (n=32 (50%) male, mean age 66.8±11.7 years (SD)) were included. Preoperatively, they reported VAS back pain of 4.1±2.7, VAS leg pain of 5.4±2.7, RMDI of 10.4±5.3, ODI of 41.9±16.2, SF-12 PCS of 32.7±8.3, and an EQ-5D index of 0.517±0.226. The preoperative rates of severe, moderate and mild OFI were n=3 (4.7%), n=8 (12.5%) and n=5 (7.8%) and the mean OFI T-score was 116.3±23.7. At W6, 60 of 64 patients (93.8%) had a TUG test result within the normal population range (no OFI); three patients (4.7%) had mild and one patient (1.6%) severe OFI. The mean W6 OFI T-score was significantly decreased (103.1±13.6; p<0.001). Correspondingly, the PROMs showed a decrease in subjective VAS back (1.6±1.7) and leg pain (1.0±1.8), disability (RMDI 5.3±4.7; ODI 21.3±16.1) and increase in QoL (SF-12 PCS 40.1±8.3; EQ-5D 0.737±0.192) at W6 (all p<0.001). Depending on the metric, the W6-responder status (=clinically meaningful improvement) ranged between 81.3% (VAS leg pain) and 29.7% (EQ-5D). **Conclusion:** The TUG test is an easily applicable tool that reliably measures OFI in LSS patients. Objective tests incorporating longer walking time should be considered if OFI is suspected but fails to be proven by the TUG test.

360 Cerebrospinal Fluid Leak and Symptomatic Pseudomeningocele Following Intradural Spine Surgery

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Introduction: Cerebrospinal fluid leak and/or symptomatic pseudomeningocele (CSFL/SP) is a non-trivial concern following intradural spine surgery, reported in 2-13% of cases. However, literature to date has largely focused on incidental durotomy during extradural spine surgery. We present the second-largest intradural case series to date, and the largest to focus specifically on CSFL/SP.

Methods: A retrospective analysis of a prospectively collected and consecutive series of patients undergoing intradural spine surgery by a single surgeon was conducted over a period of 20 years. Patients were selected who had undergone elective intradural surgery. Records were collected including demographic, clinical, and operative variables, in an attempt to identify factors associated with CSFL/SP incidence and management.

Results: Data on 460 surgeries performed on 430 consecutive patients was gathered. The incidence of CSFL/SP formation was 2.8% (n=13). Of the 13 cases complicated by CSFL/SP, 4 were successfully managed non-operatively (4/13, 31%); 9 post-operative CSFL/SP required surgical repair (9/13, 69%), making for an overall post-operative surgical repair rate of 1.9% (9/460). Factors significantly related to development of post-operative CSFL/SP on Fisher's exact test (FET) were surgery located at the cranio-cervical junction (RR 2.7, p=0.03) and use of any external CSF drain (RR 2.5, p=0.02, lumbar drain specifically (RR 2.6, p=0.02), the latter finding most likely being attributable to selection bias. No significant difference was observed between primary dural closure and closure incorporating the use of one or more dural repair adjuncts. Additionally, the total number of dural repair adjuncts used did not significantly influence the development of post-operative CSFL/SP.

Conclusion: We present the largest series of intradural spine surgeries focusing specifically on the risk factors for and management of CSFL/SP. While cranio-cervical junction surgery and use of external CSF drain were associated with CSFL/SP, type of closure and type/number of dural substitutes were not.

361 Consultation and Surgical Waits Time in Patients with Cervical Spondylotic Myelopathy: A Prospective Canadian Spine Outcomes and Research Network (CSORN) Study

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Introduction: Cervical spondylotic myelopathy (CSM) is the leading cause of spinal cord impairment. Prompt surgical intervention halts clinical deterioration and results in clinical improvement in most patients. However, in a public healthcare system, wait-times to see a spine specialist and eventually access surgical treatment may be substantial. The goals of this study were to assess the consultation wait time (CWT) and the surgical wait time (SWT), as well as to identify predictors of wait time length in this population.

Methods: Consecutive patients enrolled in the CSORN prospective, observational CSM study from March 2015 to July 2017 were included. Predictors of CWT and SWT were assessed using survival analysis. Results were stratified by disease severity based on the mJOA. A data-splitting technique was used to develop and test the multivariable models looking at potential predictive factors.

Results: CSORN query returned 264 CSM patients for CWT (88 female and 176 male). Mean age was 59.4 y. The median CWT was 46 days. There were 31% mild, 35% moderate and 33% severe CSM. There was a statistically significant difference in median CWT between moderate and severe groups. 207 patients underwent surgical treatment. Median SWT was 42 days. There was a statistically significant difference in SWT between mild/moderate and severe groups. Short symptom duration, less pain, lower BMI and lower PCS scores were predictive of shorter CWT. On the other hand, SWT was mainly affected by pain and symptom duration. Both CWT and SWT were shorter for CSM patients compared to a concurrent cohort of lumbar stenosis patients (P< 0.001).

Conclusion: CSM patients with more severe symptoms had a shorter CWT and SWT. Patients with shorter symptom duration and less pain waited less to see a spine specialist in Canada compared to patients with symptom duration

more than a year and more neck pain. Patients with less pain and symptom duration less than a year had shorter SWT compare to the patients with duration of symptoms more than a year and more neck pain.

362 Abdominal Obesity and Paraspinal Muscularity Predict Proximal Junctional Kyphosis Requiring Surgical Revision Among Patients Undergoing Thoracolumbosacral Fusion

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Introduction: Each year thousands of American adults undergo lumbosacral or thoracolumbosacral fusion operations for degenerative spine conditions. Prior research estimates that PJK occurs in 20-40% of these patients, of which 50% require surgical revision, with an average cost of over \$77,000. Elevated BMI and sagittal malalignment have been described as risk factors for PJK, but no literature exists describing weight distribution as a risk factor for PJK. Here we describe the influence of abdominal girth and paraspinal muscular sarcopenia as independent predictors of PJK.

Methods: Retrospective review of all adult (>18yo) neurosurgical spine patients undergoing lumbosacral or thoracolumbosacral fusion (T10-L4 to S1/pelvis) at the Johns Hopkins Hospital for degenerative conditions of the lumbar spine between January 1, 2013 and December 31, 2017. Variables considered were patient BMI, thoracolumbar muscularity, abdominal girth, operative details, and surgical history. All patients had a minimum of six months of radiographic follow-up and PJK was classified as having to undergo surgery with primary indication of PJK or adjacent segment disease.

Results: Of the 81 patients with full records, 16 (19.7%) underwent surgery for PJK. These patients had significantly larger preoperative sagittal vertical axis, sacral slope, pelvic incidence, pelvic incidence-lumbar lordosis mismatch, postoperative SVA, postoperative change in LL, and postoperative change in PI-LL mismatch. They also had less robust muscularity at the top of their construct, larger girth-to-muscle ratios, and longer constructs. Multivariate logistic regression incorporating these factors successfully predicted surgical PJK with a C-statistic of 0.9028.

Conclusion: Body habitus, body mass distribution, and construct characteristics all determine the risk of postoperative PJK in patients undergoing thoracolumbosacral or lumbosacral fusion for degenerative spine disease. The independent nature of construct and body habitus suggest that optimal surgical outcomes can be achieved by modifying the preoperative surgical plan to match patient body habitus.

363 Perioperative Neurological Complications Following Anterior Cervical Discectomy and Fusion: Clinical Impact on 317,789 Patients from the National Inpatient Sample

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Introduction: Perioperative neurological complication may occur after an anterior cervical discectomy and fusion (ACDF) with devastating consequences. We aim to estimate the incidence of perioperative neurological complications, identify their risk factors, and to evaluate their impact on morbidity and mortality after ACDF.

Methods: ACDF cases (n=317,789 patients) were extracted from the National Inpatient Sample (NIS) between 1999 and 2011. Based on their Elixhauser-van Walraven score (VWR) score, patients were classified as low (VWR<5), moderate (5-14), or high-risk (>14) for surgery. The primary outcome was perioperative neurological complications, which were defined as events with potential central nervous system injury including spinal cord injury, cerebral hypoxia, cerebrospinal fluid leak, postoperative stroke, or any other unspecified nervous system complication. Secondary outcomes included in-house morbidity (hospital length of stay >14 days or discharge disposition to a location other than home) and in-hospital mortality.

Results: The rate of perioperative neurological complications, morbidity, and mortality after ACDF was 0.4%, 8.4%, and 0.1%, respectively. Perioperative neurological complications were highly associated with in-house morbidity (OR, 3.7 [3.1-4.4]) and mortality (OR, 8.0 [4.1-15.5]). The strongest predictors for perioperative neurological complications were moderate (OR, 3.1 [2.6-3.7]) and high-risk VWR (OR, 5.4 [3.3-8.9]), hematoma/seroma formation (OR, 5.4 [3.9-7.4]), and obesity (OR, 1.9 [1.6-2.3]). The rate of perioperative neurological complications increased from 0.2% to 0.7% from 1999 to 2011, which was temporally associated with the rise in moderate (R²=0.57, p=0.002) and high-risk patients (R²=0.61, p=0.001) undergoing ACDF (Figure 1).

Conclusion: Perioperative neurological complications are independent predictors of in-hospital morbidity and mortality after ACDF. Both morbidity and perioperative neurological complications have increased between 1999 and 2011, which may be due, in part, to increasing numbers of moderate and high-risk patients undergoing ACDF.

364 The Increasing Frequency of Intravenous Drug Abuse Associated Spinal Epidural Abscesses: A Case Series.

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Introduction: Intravenous drug abuse (IVDA) associated spinal epidural abscesses (SEA) are an unfortunate sequela of the opioid crises in the United States.

Methods: This study is a retrospective chart review of patients presenting with IVDA associated SEA at our institution from 2013-2018, spanning the state-wide implementation of opioid prescribing restrictions.

Results: 45 patients presented with IVDA associated SEA. 46.5% presented with a neurologic deficit. 31 patients underwent surgery, either for neurologic deficit, failure of medical therapy or both. 19 surgical patients underwent a fusion procedure along with decompression. The complication rate was 41.9% and the mortality rate was 6.7%. The average length of stay was 27.6 days. Patients operated on within 24 hours of onset of neurologic symptoms trended toward more improvement in AIS grade compared to those who did not (0.5 vs. -0.2, $p = 0.068$). 57.8% of patients had MRSA isolated as the causative pathogen. 23 patients (51.5%) kept their scheduled clinic follow up appointments. Of the fusion patients with adequate follow up, 5 showed bony arthrodesis and 3 had pseudoarthroses. The rate of IVDA associated SEA increased after opioid prescribing restrictions were put in place, from 0.54 cases per month to 1.15 cases per month ($p = .017$).

Conclusion: Patients with IVDA associated SEA are challenging to treat, with high complication rates and poor follow-up. This disease is increasing in frequency and opioid prescribing restrictions did not slow that rise. Community outreach to promote prevention, early medical attention and medication compliance would benefit this largely publicly funded patient population.

365 Utilization of a D-dimer Protocol for Detection of Deep Vein Thrombosis in Spine Patients

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Introduction: Venous thromboembolism, comprising deep vein thrombosis (DVT) and pulmonary embolism, is a significant source of mortality for spine patients and remains difficult to diagnose. The use of venous duplex ultrasound (VDU) for confirmation of venous thromboembolism is costly and requires experienced personnel for acquisition and interpretation. We evaluated a novel protocol using levels of D-dimers to screen for DVT.

Methods: A retrospective bioinformatics analysis identified neurosurgical inpatients who underwent a D-dimer screening protocol and had a VDU study evaluating the presence of DVT from March 2008 through July 2017. The D-dimer screening protocol involved assessing serum D-dimer levels at baseline and every other day during hospitalization. Patients with levels $>3.0 \mu\text{g/ml}$ or that increased over 2 consecutive days underwent a VDU. Clinical risk factors and D-dimer levels were evaluated for prediction of DVT.

Results: Among a total of 1918 patient encounters ($n=1854$ patients), 506 spine patients were identified with an overall DVT detection rate of 15.4%. A D-dimer of $>2.5 \mu\text{g/ml}$ on admission conferred sensitivity=0.68, specificity=0.52, positive predictive value (PPV)=0.20, and negative predictive value (NPV)=0.90. A D-dimer value of $>3.5 \mu\text{g/ml}$ during hospitalization predicted DVT risk with a sensitivity=0.77, specificity=0.27, PPV=0.17, and NPV=0.88. Multivariable logistic regression showed that after adjusting for age, gender, length of stay, and completion of a major surgical procedure within the last 30 days, a D-dimer level $>2.5 \mu\text{g/ml}$ on admission conferred an independent risk of DVT (odds ratio=2.23, 95% confidence interval=1.30-3.81).

Conclusion: The use of a D-dimer protocol was effective in screening for DVTs in spine patients. A cutoff of $>2.5 \mu\text{g/ml}$ at day 0 or $>3.5 \mu\text{g/ml}$ during admission could be utilized for screening purposes. Additional refinement of this screening model could further improve identification of DVT in a practical and cost-effective manner.

366 Durotomy Following Extradural Tumor Resection: A Retrospective Analysis of Risk Factors

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Introduction: Patients undergoing surgery for extradural tumor removal can be at increased risk for unintended durotomies and cerebrospinal fluid (CSF) leaks due to tumor erosion of native dural tissue and potentially radiation-induced adhesions. In this series, we sought to identify risk factors for intraoperative durotomy in our patient series.

Methods: We conducted a retrospective single-institution review of patients undergoing resection of extradural spine tumors over a four-year period. Data was collected on baseline demographics, tumor type, presence of pre-operative radiotherapy, presence and nature of intraoperative CSF leak, attempted repair technique, and post-operative course. Patients with intraoperative CSF leaks were analyzed and compared to the larger cohort to identify potential risk factors.

Results: A total of 105 patients undergoing primary extradural tumor resection were identified, including 78 (74%) vertebral metastases, 15 (14%) hematogenous malignancies, and 10 (10%) primary vertebral tumors. Overall, 12 (11.4%) of these surgeries featured an intraoperative CSF leak, with many of these occurring near the exiting nerve root ($n=5$, 42%). Attributable reasons for the unintentional durotomies were varied, with the most common being dural adhesions or dural erosion by the tumor ($n = 5$, 42%) and iatrogenic durotomies during either the corpectomy ($n=3$, 25%) or laminectomy ($n=2$, 17%). Patients with CSF leaks were more likely to have had pre-operative radiation (75% vs. 29%, $p = 0.0187$). However, we did not find a significantly higher leak rate based on tumor pathology ($p = 0.1455$) and patients with a leak did not have a significantly longer length of inpatient stay (7.2 vs. 6.7 mean days, $p=0.1868$).

Conclusion: CSF leaks during extradural spine tumor resection can be encountered as a result of tumor-related dural erosions or iatrogenic durotomy. Patients with preoperative radiation are at increased risk and should warrant special consideration. Durotomy does not seem to impact length of stay in patients with extradural tumors.

367 Iliac Screws May Not Be Necessary in Long Segment Constructs with L5-S1 ALIF: Cadaveric Study of Instrumentation Strain

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Introduction: Lumbosacral pseudoarthrosis and instrumentation failure is common with long segment constructs. Optimizing lumbosacral construct biomechanics may help to reduce failure rates. The influence of iliac screws and interbody type on lumbosacral stability and instrumentation bending strain is not well established.

Methods: Fourteen human cadaveric spine (L1-ilium) specimens were prepared and potted at L1 and ilium. Specimens were equally divided into either an L5-S1 ALIF or TLIF group. All specimens underwent testing in the following conditions: 1) Intact 2) L2-S1 Pedicle Screw Fixation (PSR) 3) L2-ilium (PSR-I) 4) PSR+ALIF (ALIF-S) or TLIF (TLIF-S) 5) PSR-I + ALIF (ALIF-I) or TLIF (TLIF-I). Pure moment bending (7.5Nm) in flexion(F), extension(E), lateral bending (LB), axial rotation (AR) and axial compressive (C) loads(400N) were applied to all conditions and range of motion (ROM), sacral screw bending strain (SS), and L5-S1 rod strain (RS) were measured. Statistical comparisons were performed using one-way ANOVA ($p < .05$).

Results: ALIF-S and TLIF-S provided similar decreases in ROM as TLIF-I ($p > .05$). Compared to PSR-S, PSR-I significantly decreased SS during bending in all directions ($p < .02$) but increased RS in flexion and extension ($p < .02$). ALIF-S provided similar decreases in SS as TLIF-I in all directions ($p > .40$) and had significantly less RS than TLIF-I in F,E,C ($p < .01$). TLIF-S had more SS than TLIF-I in F,E,AR ($p < .02$) while TLIF-S had less RS only in F ($p = .03$). Compared to PSR-I, ALIF-I decreased the RS ($p < .02$) but TLIF-I did not have a significant effect ($p > .67$).

Conclusion: Iliac screws diminish SS during pure moment bending in all directions except LB but increase RS. ALIF-S provides comparable decreases in SS as TLIF-I and has significantly less RS, perhaps obviating the need for iliac fixation in long segment fixation. Iliac screw induced RS is only significantly reduced with ALIF but not TLIF.

368 Predicting Outcomes after Surgical Decompression for Mild Degenerative Cervical Myelopathy: Moving Beyond the mJOA to Identify Surgical Candidates

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Introduction: Patients with mild degenerative cervical myelopathy (DCM) represent a heterogeneous population, and indications for surgical decompression remain controversial. We sought to dissociate patient phenotypes within the broader population of mild DCM associated with degree of impairment in quality of life (QOL) and surgical outcomes.

Methods: This was a post-hoc analysis of patients with mild DCM (mJOA 15-17) enrolled in the AOSpine CSM-NA/CSM-I studies. A k-means clustering algorithm was applied to baseline SF-36 scores to separate patients into two clusters based on pattern and degree of impairment in QOL. Baseline variables and surgical outcomes were compared between clusters. The primary outcome of interest was change in QOL (SF-36) at 1 year post-surgery compared to baseline. Secondary outcomes included change in mJOA, Nurick grade, NDI, and SF-6D scores. A k-nearest neighbors (kNN) algorithm was used to evaluate the ability to classify patients into the two clusters by significant baseline clinical variables.

Results: One-hundred eighty-five patients were eligible. Two groups were generated by k-means clustering over baseline QOL (SF-36) scores (Fig 1). Cluster 1 ('more impaired') had a greater proportion of females (44% vs. 28%, $P = 0.029$) and symptoms of neck pain (32% vs. 11%, $P = 0.001$), gait difficulty (57% vs. 40%, $P = 0.025$), or weakness (75% vs. 59%, $P = 0.041$) (Fig 2). While baseline mJOA correlated with neither baseline QOL nor outcomes, Cluster 1 was associated with significantly greater improvement in disability (NDI) ($P < 0.01$) and QOL (SF-36) ($P < 0.05$) scores following surgery (Fig 3). A kNN algorithm could predict cluster classification with 71% accuracy by neck pain, motor symptoms, and gender alone.

Conclusion: We have dissociated a distinct more impaired phenotype of patients with mild DCM, characterized by neck pain, motor symptoms, and female gender, in whom surgical intervention resulted in greater gains. Identification of patient-related predictive factors may help guide surgical decision-making and inform treatment paradigms for mild DCM.

369 The Utility of Cervical Spine Bracing as a Postoperative Adjunct to Multi-Level Anterior Cervical Spine Surgery

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Introduction: Use of cervical bracing/collar subsequent to anterior cervical spine discectomy and fusion (ACDF) is variable. Outcomes data regarding bracing after ACDF are limited. Here, we study the impact of bracing on short-term outcomes related to safety, quality of care, and direct costs in multilevel ACDF.

Methods: Retrospective cohort analyses of all consecutive patients undergoing multi-level ACDF with or without bracing from 2013-2017 was undertaken ($n = 616$). Patient demographics and comorbidities were analyzed. Tests of independence (Chi-square, Fisher's exact test), Mann-Whitney-Wilcoxon tests, and logistic regressions were used to

assess differences in length of stay (LOS), discharge disposition (home, rehabilitation facility, or nursing facility), quality-adjusted life year (QALY), direct cost, readmission within 30 days, and ER visits within 30 days.

Results: Amongst the study population, 553 were braced and 63 were not braced. There was no difference in readmission ($P=0.181$), QALY gain ($P=0.968$), and direct costs ($P=0.689$). There was no difference in comorbidities ($P>0.05$) such as obesity, smoking, chronic obstructive pulmonary disease, hypertension, coronary artery disease, congestive heart failure, and total comorbidities. A significant difference in ASA score was found, with more ASA 2 patients in the braced cohort and more ASA 3 patients in the unbraced cohort ($P=0.007$). LOS was extended for the unbraced group (median 156.9 ± 211.4 vs. 86.67 ± 130.6 hr., $P=0.003$) and ER visits within 30 days were 0.21 times less likely in the braced group ($P=0.006$).

Conclusion: Bracing following multi-level cervical fixation does not alter short-term post-operative course, including return to surgery and readmission, or reduce the risk for early adverse outcomes in a significant manner. The absence of bracing is associated with increased LOS, but cost analyses show no difference in direct costs, at the hospital level. Further evaluation of long-term outcomes and fusion rates will be necessary prior to definitive recommendations regarding bracing utility following multilevel ACDF.

370 The Utility of Lumbar Spine Bracing as a Postoperative Adjunct to Multi-Level Posterior Lumbar Spine Surgery

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Introduction: Clinical practice in post-operative bracing after posterior lumbar spine fusion (PLF) is inconsistent between providers. Direct evidence for its efficacy is limited. We sought to elucidate the effect of bracing on short-term outcomes related to safety, quality of care, and direct costs.

Methods: Retrospective cohort analyses of consecutive patients undergoing multilevel PLF with or without bracing (2013-2017) was undertaken ($n=980$). Patient demographics and comorbidities were analyzed. Tests of independence (Chi-square, Fisher's exact test) and logistic regressions were used to assess differences in length of stay (LOS), discharge disposition/need for post-acute care, quality-adjusted life year (QALY), surgical-site-infection (SSI), hospital cost, total cost, readmission within 30 days, and ER visits within 30 days.

Results: Amongst the study population, 936 were braced and 44 were not braced. There was no difference between the braced and unbraced groups regarding LOS (126.1 ± 125.9 vs. 183.9 ± 193.3 hr., $P=0.106$), odds of 30-day ER visit ($P=1.000$), 30-day readmission ($P=0.434$), and discharge disposition ($P=0.900$). There was also no difference in total costs ($P=0.230$) or QALY gain ($P=0.740$). There was no difference in comorbidities such as obesity, smoking status, pack years, chronic obstructive pulmonary disease, hypertension, coronary artery disease, congestive heart failure, body mass index, problem list number, and ASA score ($P = 0.259-1.000$). The braced group was older than the unbraced group (63 vs. 56 yr., $P=0.003$).

Conclusion: Bracing following multilevel posterior lumbar fixation does not alter short-term post-operative course or reduce the risk for early adverse events. Cost analyses show no difference in direct costs, at the hospital level, between the two treatment approaches. Short term data suggest that removal of bracing from the post-operative regimen for PLF will not result in increased adverse outcomes. Long-term analysis of risk and fusion rates is necessary prior to elimination of post-operative bracing from care algorithms.

371 Systematic Review and Meta-Analysis of Randomized Controlled Trials in Anchored Spacers versus Plate-Screw Systems in Anterior Cervical Discectomy and Fusion

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Introduction: Anterior Cervical Discectomy and Fusion (ACDF) is one of the most commonly performed spinal procedures. Traditional ACDF constructs consist of autologous cages and a plate-screw system. These constructs have been associated with plate breakage or loosening, and postoperative dysphagia are some complications that can severely affect patients' quality of life. Recently, a stand-alone anchored spacer - proposed as an alternative to the cervical plate-screw construct, has shown promise in minimizing postoperative complications. The purpose of our study was to perform a systematic review of clinical outcomes between stand-alone anchored spacers and traditional cages with plate fixation in treating cervical spine disease using data from clinical trials.

Methods: Our search protocol was added to PROSPERO register. Then, a systematic review using PRISMA method was performed. Using both the Cochrane central register of clinical trials (CENTRAL) and the MEDLINE databases, we systematically searched for studies addressing stand-alone anchored spacers in patients who underwent ACDF. Mean Neck Disability Index (NDI), Dysphagia incidence % (Dinc%) and Swallowing-Quality of Life (SQOL) improvement scores during immediate postoperative (<3 months) and last follow-up (3 months - 3 years) visits were extracted. Fusion rates were also extracted. Student T-tests was used for statistical comparison ($p < 0.05$).

Results: The initial search generated 506 articles in CENTRAL and 40 articles in MEDLINE. Finally, 20 articles were included because they addressed dysphagia. Total number of patients was 1307 (548 cage and 759 plate). Dinc% scores were statistically significantly lower in the stand-alone anchored spacer compared to the plate-screw construct

during immediate postoperative and last follow-up visits ($p < 0.05$). On the other hand, student T-test showed no statistically significant difference in comparisons in the SQOL or NDI scores (figure 1). Importantly, there was also no significance in the fusion rates between the two different constructs.

Conclusion: Our study results showed lesser complications in stand-alone anchored spacers versus plate-screw constructs in ACDF over time. Based on these findings, anchored spacers maybe good alternative to the traditional ACDF plate-screw constructs.

372 Symptomatic Improvement of Dysautonomia and Pain in Patients with Craniovertebral Instability via Occipital Cervical Fusion

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Introduction: Joint hypermobility in patients with inherited conditions of connective tissue has recently been shown to cause excess mobility of the movement of the odontoid process in relationship to the skull base. A subset of these patients will develop distortion of the relationship of the odontoid to the brainstem leading to tonsillar herniation, severe headaches and mechanical neck pain. These patients are also known to have associated abnormalities of the function of the autonomic nervous system. The purpose of this study is to assess the effect of reduction of the distortion of the brainstem and fusion of the occiput to the upper cervical spine could have an effect on the debilitating effect of the dysautonomia.

Methods: A prospective outcome study of patients undergoing intraoperative reduction of abnormal occipito-cervical relationships with distortion of the brainstem who presented with severe unremitting headaches and mechanical neck pain were selected for study. All patients had documented type 3 Ehlers Danlos Syndrome (hypermobility). They all had abnormal movement of the occipito-cervical junction, excess movement on flexion-extension MRI studies and improvement with use of a rigid cervical collar. A subset of 27 of these patients also suffered from severe dysautonomia and chronic fatigue syndrome. Questionnaires using available outcome measures were completed preoperatively at least 12 months postoperatively.

Results: Karnofsky scores improved significantly post operatively ($P < 0.05$). Pain was relieved or substantially improved in 63% of patients, palpitations were improved in 55%, Orthostatic intolerance improved in 52% and disabling chronic fatigue was improved in 48%. In total, 23/27 would definitely have gone through surgery in retrospect. All patients had normalizations of the cranial-axial angle via intraoperative reduction.

Conclusion: In this small series, pain, dysautonomia, and chronic fatigue syndrome responded to occipitocervical reduction and occipito-cervical fusion.

373 Persistent or Newly Developed Buttock and/or Leg Pain after Lumbar Degenerative Spine Surgery

Masahiko Akiyama MD, DMSc

Introduction: Persistent or newly developed buttock and/or leg pain is not rare and known as failed back surgery syndrome. Failed back surgery syndrome, which includes multiple etiologies such as restenosis, foraminal stenosis and peripheral entrapment, is real pain for both patients and spine surgeons. This retrospective study analyzes etiologies of persistent or newly developed buttock and/or leg pain after lumbar degenerative spine surgery.

Methods: One hundred eighty two consecutive lumbar degenerative surgeries were included in this study.

Results: Persistent or newly developed buttock and/or leg pain occurred 39 cases. Etiologies of pain were foraminal or different level spinal stenosis in 13 cases, further peripheral dysfunction in 25 cases, and vascular claudication in 1 case. Further peripheral dysfunction included cluneal nerve entrapment in 2 cases, piriformis or gluteal muscle dysfunction in 16 cases, iliosacral joint dysfunction in 3 cases, tarsal tunnel syndrome in 3 cases, and common peroneal nerve entrapment in 1 case.

Conclusion: Persistent or newly developed pain occurred about 20% after lumbar degenerative spine surgery and 2/3 of etiologies were further peripheral dysfunction. Spine surgeons should be aware of these peripheral dysfunctions such as piriformis, gluteal dysfunctions and peripheral nerve entrapment to reduce "unknown" cause of failed back surgery syndrome.

374 Post-operative Dysphagia in Patients Undergoing a Four Level ACDF.

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a commonly performed procedure for cervical spine pathologies, with excellent arthrodesis and symptom resolution. Post operative dysphagia is a significant concern for patients undergoing this procedure because it can significantly affect their quality of life. Studies have shown that the incidence of post operative dysphagia increases with an increase in the number of levels performed, some quoting up to a 50% incidence. Our goal is to investigate the incidence of post operative dysphagia at our institution, and factors pertaining to its occurrence.

Methods: A retrospective chart review was performed by interrogating our procedure log system and the key words "anterior cervical discectomy and fusion" was inserted in to the search bar. All patients with an ACDF for the past ten years were reviewed and patients with a four level ACDF were selected. Chart review was performed for their speech evaluation immediate after surgery and three months post operatively.

Results: A total of 28 patients were identified for the study. Speech evaluation records were available for 21 of the 28 patients. There were 13 females and 8 males, average age was 62 (range 47–73), and all the patients had a C3–C7 ACDF. 3 out of the 21 (14%) patients had dysphagia diagnosed via barium swallow evaluation immediately after surgery, which persisted for 3 months. Of the 3 patients diagnosed with dysphagia, 2 were females and 1 was male. Two of the three patients were 72 years old and one was 73 years old.

Conclusion: The incidence of post-operative dysphagia in patients undergoing 4 levels ACDF at our institution was found to be lower than the current literature quotes. Age and gender were more predictive of developing dysphagia in this study.

375 A Two-Year Cost Analysis of Maximum Non-Operative Treatments in Patients with Cervical Stenosis that Ultimately Required Surgery

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Introduction: Maximal non-operative therapies (MNTs) are typically implemented in patients diagnosed with cervical stenosis prior to surgery. The extent of the costs and utilization of MNT associated with cervical stenosis remains unknown. The study aims to characterize the utilization and associated costs of MNTs received within 2-years prior to anterior cervical discectomy and fusion (ACDF) surgery in patients with symptomatic cervical stenosis.

Methods: Clinical records from patients with symptomatic cervical stenosis undergoing 1, 2, or 3-level index ACDF procedures from 2007-2016 were gathered from an insurance database. Patient records were searched by ICD, CPT, and generic Humana-specific drug codes. Utilization of MNTs, characterized by cost billed to patients, prescriptions written, and number of units billed, within 2 years prior to index ACDF surgery was assessed.

Results: 15,825 eligible patients were included in the study. Patient breakdown of MNT modalities was as follows: 5,731 (36.2%) used NSAIDs, 9,827 (62.1%) used opioids, 7,383 (46.7%) used muscle relaxants, 3,609 (22.8%) received CESI, 5,504 (34.8%) attended PT/OT, 1,663 (10.5%) received chiropractor treatments and 200 (1.3%) presented to the ED. During the 2-year preoperative period, there were 71,602 prescriptions for narcotics, 22,028 prescriptions for NSAIDs, 38,846 prescriptions for muscle relaxants, 11,692 prescriptions for CESI, 9,647 prescriptions for PT/OT, 17,051 prescriptions for chiropractor treatments, and 51,675 prescriptions for diagnostic cervical imaging. The total direct cost associated with all MNTs prior to index spinal fusion was \$16,056,556. Cervical spine imaging comprised the largest portion of the total MNT cost (\$8,677,110; 54.0%), followed by CESI (\$3,315,913; 20.7%) and opioids (\$2,228,221; 13.9%). Opiates were the most frequently prescribed therapy (71,602 prescriptions).

Conclusion: Opioids are the most frequently prescribed and used therapy in the preoperative period for cervical stenosis. Assuming minimal improvement in pain and functional disability after maximum non-operative therapies, the incremental cost effectiveness ratio for MNT could be highly unfavorable.

376 Chlorhexidine Showers are Associated With a Reduction in Surgical Site Infection Following Spine Surgery: An Analysis of 4,266 Consecutive Surgeries

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Introduction: Surgical site infection (SSI) is a common complication following spinal surgery. Prevention is critical to maintaining safe patient care and reducing additional costs associated with treatment. The objective of this study was to determine the efficacy of preoperative chlorhexidine (CHG) showers on SSI rates following spine surgery.

Methods: A mandatory preoperative CHG shower protocol was implemented at our institution in November 2013. A cohort comparison of 4,266 consecutive patients assessed for differences in SSI rates for the pre- and post-implementation periods. Subgroup analysis was performed on the type of spinal surgery (e.g., fusion versus nonfusion). Multivariate analyses were conducted to determine the effect of CHG showers on SSI while adjusting for patient characteristics, comorbidities, pathology, and surgical characteristics (fusion, revision, approach, location, number of levels, minimally invasive, non-elective, resident involvement, case classification, steroid use, antibiotic use, operative time, estimated blood loss, and surgeon). Data represents all spine surgeries performed between April 2012 and April 2016.

Results: The overall mean SSI rate was 0.4%. There was no significant difference between the pre- (0.7%) and post-implementation periods (0.2%) ($p=.08$). Subgroup analysis stratified by procedure type showed that the SSI rate for the nonfusion patients was significantly lower in the post- (0.1%) than the pre-implementation group (0.7%) ($p=.02$). There was no significant difference between SSI rates for the pre- (0.8%) and post-implementation groups (0.3%) for the fusion cohort ($p=.21$). In multivariate analysis, the implementation of preoperative CHG showers were associated with a significantly decreased odds of SSI (OR=0.15, 95% CI [0.03-0.55], $p<.01$).

Conclusion: This is the largest study investigating the efficacy of preoperative CHG showers on SSI following spinal surgery. In adjusted multivariate analysis, CHG showering was associated with a significant decrease in SSI following spinal surgery. Further randomized, prospective study is required to clearly elucidate the impact of preoperative CHG showers on SSI following spinal surgery.

377 Development and Validation of Clinical Prediction Models of Survival and Clinical Outcomes for Patients with Metastatic Epidural Spinal Disease: A Systematic Literature Review

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Introduction: In multivariable prognostic research, the development and external validation are the first phases typically involved towards the establishment of clinical prognostic models (CPMs) in practice. This systematic review aims to identify and assess CPMs created to predict clinical outcomes in patients with metastatic epidural spinal disease (MESD) and their subsequent validation studies.

Methods: Three electronic databases were searched (January 1, 1990 to December 31, 2017), without language restriction, to identify studies that addressed review question: What are the existing CPMs that have been developed and/or externally validated to predict survival or other clinical outcomes in patients with MESD? Data extraction, reporting and appraisal of the selected studies were conducted following recommended guidance: CHARMS, TRIPOD, and PROBAST (CRD42017072908).

Results: Among 8,077 unique full-text articles, 117 were included. Among the 52 articles describing a CPM (CPM creation, n=44; update of an existing CPM, n=8), 44 did not include any assessment of model performance (calibration and/or discrimination) while 20 reported the number of outcome events and 7 discussed missing data. Among the 5 articles with the term "external validation" or "external validity" in the title or abstract, missing data, number of outcome events, and both calibration along with discrimination were discussed in 4, 3 and 2 studies, respectively.

Conclusion: Since 1990, while over 50 CPMs predicting clinical outcomes in patients with MESD were developed, only 5 studies claimed performing an external validation of any of these tools. The majority of the studies included in this review did not report on key methodological and data analysis elements. The lack of rigor in the development and validation of CPMs may explain why most CPMs are not generally used in clinical practice in this patient population.

378 The Prophylactic Use of Closed Incisional Negative Pressure Therapy (ciNPT) to Reduce Surgical Site Infections in Posterior Spine Procedures: Initial Experience of 30 High-risk Patients

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Introduction: Surgical site infections in spine surgery result in significant patient morbidity as well as increased healthcare cost. Obesity, diabetes, and multiple levels are known to increase a patient's risk for developing a surgical site infection. We aimed to investigate whether the prophylactic application of closed incisional negative pressure therapy at the time of surgery led to a reduction in the development of infections in high-risk patients.

Methods: We prophylactically placed an incisional wound vac on the closed incision at the time of surgery for patients undergoing spine surgery who had at least one of the following indications: suprafascial distance >3cm, obesity, risk factors for wound healing, limited mobility, >3 operative levels or increased tension needed to close the fascial layer ("pull test"). Incisional wound vacs were set at 125 mmHg continuous for 7 days. Wound complications up to 60 days following surgery were recorded.

Results: A total of 30 patients underwent ciNPT. No patient developed a deep surgical site infection requiring a return to the operating room. 1 patient required one week of antibiotics during the outpatient setting for a small non-union at the inferior aspect of a posterior cervical incision secondary to continuous collar wearing.

Conclusion: Prophylactic ciNPT resulted in no surgical site infections requiring a return to the operating room for debridement in high-risk patients. This measure can be used to reduce SSI rates and improve the quality of spine care.

379 Enhanced Recovery After Surgery (ERAS): Implementation in Anterior Lumbar Interbody Fusion Surgery

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Introduction: Enhanced Recovery After Surgery (ERAS) is a multi-modal, evidence based approach to perioperative care that aims to prepare patients for and reduce the impact of surgery to facilitate quicker recovery. We instituted a comprehensive ERAS program that spanned our entire spine care continuum and report on outcomes in our anterior lumbar interbody fusion (ALIF) patients.

Methods: We report on our institutional outcomes of all ALIF patients from 2013-2018 surrounding the implementation of our comprehensive spine ERAS. Our program encompassed specific interventions geared towards standardizing care pathways including: pre-operative work-up and patient education, pre-operative and intra-operative anesthesia protocols, pre- and post-operative surgical order sets, patient flow and nursing care process metrics, acute and chronic pain management, pre-hab and disposition planning, and outcomes evaluation tools. Statistical analysis was performed on process measures, outcomes (LOS, readmission, return to ED, mortality), and complications in our patient cohort before and after ERAS implementation.

Results: 302 patients underwent ALIF during the study period with 152 patients receiving surgery prior to ERAS implementation and 150 patients post-ERAS. In terms of general outcomes, there were no significant differences noted. Analysis of complications revealed a significant decrease in blood transfusion (6.6% pre-ERAS to 0.7% ERAS, p = 0.01), but no other differences. In terms of process metrics, there was a significant reduction in time to PO pain control with ERAS (8.49 hours pre-ERAS to 3.4 hours ERAS, p = 0.0001).

Conclusion: An institution-wide implementation of spine surgery oriented ERAS program led to decreased blood transfusions, and improved pain control. These changes may be due to improved intraoperative anesthesia and post-operative pain management protocols, and improved surgery-specific nursing care guidelines.

380 Regional Differences in Prolonged Non-Operative Therapy Utilization Prior to Primary ACDF Surgery

Mark A. Davison BS; Daniel Lilly BS; Shyam Desai; Victoria D. Vuong; Jessica R. Moreno RN, BSN; Carlos A. Bagley MD; Owoicho Adogwa MD, MPH

Introduction: There is a paucity of data adequately characterizing geographic variations in utilization and costs of non-operative therapies in patients with symptomatic cervical stenosis who fail conservative management and opt for surgery. As outcomes-based reimbursement strategies prioritize prudent resource utilization, an understating of these regional trends becomes critical. The objective of this investigation was to evaluate for regional differences in utilization and associated costs of maximal non-operative therapy (MNT) prior to anterior cervical discectomy and fusion (ACDF) surgery in patients with symptomatic cervical stenosis.

Methods: Medical records from patients with symptomatic cervical stenosis undergoing 1, 2, or 3-level index ACDF procedures between 2007 and 2016 were gathered from an insurance database consisting of 20.9 million private/commercially covered and Medicare Advantage beneficiaries. Geographic regions (Midwest, Northeast, South, and West) reflected the U.S. Census Bureau definitions. The utilization of MNTs within 5 years prior to index ACDF surgery was assessed. "Utilization" was characterized by cost billed to patients, prescriptions written, and number of units billed.

Results: A total of 15,825 patients underwent 1, 2, or 3-level ACDF surgery. Patient regional breakdown was: South 67.6%, Midwest 21.8%, West 8.9%, Northeast 1.6%. Regional variations were identified in the number of patients utilizing NSAIDs ($p<0.0001$), opioids ($p<0.0001$), muscle relaxants ($p<0.0001$), CESI ($p=0.0014$), physical therapy/occupational therapy treatments ($p<0.0001$), and chiropractor visits ($p<0.0001$). Total direct costs associated with all MNT was \$17,255,828. The Midwest(\$1,277.72 per patient) and South(\$1,047.86 per patient) had the greatest average dollars billed. Normalized by the number of opioid using-patients, the Northeast (691.4 pills/patient) and South (674.4 pills/patient) billed for the most opioid pills. The Midwest (21.8% of patients) was responsible for a disproportionate percentage of the CESI(28.9%), PT/OT(27.1%), chiropractor(35.6%), cervical imaging(26.6%), and emergency department(29.0%) costs.

Conclusion: Regional variations in the costs and utilization of MNT may exist in patients with symptomatic cervical stenosis who fail conservative management.

381 The Incidence of Sacroiliac Fusion After Lower Lumbar Fusion: A Multi-Center Retrospective Cohort Study

Justin G. Thomas DO; Doris Tong MD; Matthew Bahoura BA; Clifford Houseman DO; Teck M. Soo MD

Introduction: Sacroiliac (SI) joint dysfunction following lower lumbar fusion surgery has been suggested as a form of adjacent level disease. We sought to determine the incidence of SI dysfunction requiring surgery in patients with a previous lower lumbar fusion which remains unreported.

Methods: From 12/20/2012 to 03/31/2014 at three institutions, retrospective chart review was performed for consecutive patients who underwent L4-L5, L5-S1 or L4-S1 lumbar fusion surgery. Patients were followed up for at least two years post-operatively. Our primary outcome was SI fusion within the follow-up period. Patients were interviewed during a clinic visit or by phone. Patients were considered for SI fusion after a positive diagnostic and/or therapeutic SI joint injections. Patient and perioperative characteristics were collected. Descriptive statistics were used. We accounted for patients lost to follow up by including them in a sensitivity analysis.

Results: One hundred thirty-three patients underwent lower lumbar fusion surgery. Eighty-six patients (64.7%) had at least two years follow-up. Patient demographics were presented in table one. Nine out of 86 patients (10.5%) required SI fusion after lower lumbar fusion surgery. The mean follow-up interval was 50.4 ± 13.8 months, giving 2.5% SI fusion/follow-up year. The mean interval between the lower lumbar surgery and the SI fusion was 32.4 ± 6.6 months (table two). Sensitivity analysis estimated our SI fusion rate to be as low as 6.7%.

Conclusion: Our SI fusion rate of 10.5%, 2.5% SI fusion per follow-up year, in patients with at least two years follow up after lower-level lumbar fusion is similar to the current reported rate of adjacent segment disease requiring surgery. Our conclusion is limited by the retrospective nature of the study. Further prospective studies are warranted.

382 Complications Related to Immobilization of Cervical Spine Fractures with a Halo Vest

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Introduction: The halo immobilization commonly used for a variety of cervical spine injuries. Here we review a case series of patients with cervical spine trauma to determine halo related complications.

Methods: All patients with cervical spine injuries managed with halo immobilization over a 10-year period. Patients' medical records were accessed to determine the type of injury, length of halo immobilization, complication profile, outcome.

Results: Total of 39 patients (23 males) was identified with a mean age of 41 years (12-81 years). 30 sustained their injury after traffic accidents, 5 after fall. There were 11 (28%) C2 hangman's type fractures, 11 (28%) type II-III odontoid fractures, 7 (18%) complex C1-2 fractures, 4 (10%) C1 Jefferson fractures. Halo was applied in average within 1 day

after injury and stayed on for an average of 106 days (range of 27-300). 18 (46%) patients had pin site infection and 7 (18%) required the short antibiotic course. Only 5 (13%) required halo removal due to infection and transition to another type of brace. 18 (46%) patients had pin loosening in average after 1.5 months of halo application, which required repositioning of the pin. 2 (5%) developed pressure sores from the halo vest. Average follow up was 8 months (range 3-19). 32 (82%) patients had fractured healed with halo, 5 (13%) developed stable pseudoarthrosis and 2 (5%) did not heal and required surgical stabilization.

Conclusion: Halo provides a certain degree of discomfort for patients, however, it allows for motion preservation after the injury is healed. Despite multiple pin site complications, most of them were self-limited and did not affect fracture healing.

383 SINS Score and Stability - Evaluating the Need for Stabilization Within the Uncertain Category

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Introduction: Among neurologically-intact patients, mechanical instability is the prime motivator for intervention. Previous multi-institutional collaboration has led to the Spinal Instability Neoplastic Score (SINS) which classifies lesions as stable, unstable, or potentially unstable. Currently uncertainty exists regarding whether lesions in this latter category should be stabilized.

Methods: We retrospectively reviewed all patients consulted for metastatic spine disease between January 1, 2013 and December 31, 2013. Patients were included if they were neurologically intact, had complete medical records, and had preoperative imaging for assessment of SINS score at every tumorally-involved level. Examined variables included epidural spinal cord compression scale, SINS score, revised Tokuhashi grade, age at consultation, and Karnofsky Performance Scale. Endpoints were whether the lesions were stabilized (instrumentation or vertebroplasty) or not.

Results: In the time examined, 51 patients (average age 61.6) were consulted with 436 lesions, of which 50.5% were lytic and 31.4% were blastic. The most common primaries were lung (n = 12), breast (n = 10) and prostate (n = 8). The average SINS score across all lesions was 4.9 ± 0.1 . Logistic regression demonstrated that a SINS score of 10.84 was associated with a 50% probability of undergoing some stabilization procedure; less than 25% of all lesions with a SINS score of less than or equal to 9 were offered stabilization. Multivariable logistic regression demonstrated that SINS score (OR = 2.29; $p < 0.001$) and Karnofsky Performance Status (OR = 1.12; $p < 0.001$) were independent predictors of being offered stabilization.

Conclusion: The decision to stabilize a metastatically involved vertebral body remains one dependent upon a combination of the patient's clinical picture and the radiographic picture of the involved body. However, our logistic regression suggests that lesions with a SINS score of 9 or less do not require stabilization.

384 The "July Effect" Revisited: July Surgeries at Residency Training Programs are Associated with Equivalent Outcomes Following Lumbar Spendylolisthesis Surgery

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Introduction: There is a paucity of investigation on the long-term outcomes following surgeries involving new trainees utilizing high-quality, prospectively collected data. To this end, we utilized the Quality Outcomes Database (QOD) registry to investigate the "July Effect" at QOD spondylolisthesis module sites with residency trainees.

Methods: This was a retrospective analysis of a prospective registry of 797 patients who underwent surgery for grade 1 degenerative lumbar spondylolisthesis at twelve high-enrolling sites. Surgeries were classified by month (July vs. Non-July). Baseline variables were collected. Short-term and long-term outcomes were collected including estimated blood loss, length of stay, operative time, discharge disposition, cumulative reoperation and readmission rates, and patient reported outcomes [Oswestry Disability Index (ODI), Numeric Rating Scale (NRS) Back Pain, NRS Leg Pain, EuroQol-5D (EQ-5D)] and the North American Spine Society (NASS) Satisfaction Questionnaire. Multivariate analyses were conducted and included covariates that reached $p < 0.20$ on univariate analyses.

Results: 485 (60.9%) surgeries occurred at centers with a residency training program. Of these, 35 (7.2%) took place in July. Aside from a higher proportion of minimally invasive surgeries in the non-July cohort (43.1 vs. 25.7%, $p = 0.04$), there were no significant differences in demographic and socioeconomic characteristics, comorbidities, clinical presentation, or surgical characteristics between July and non-July surgeries. In adjusted multivariate analyses, July surgeries were not associated with significantly different outcomes for perioperative parameters (operative time, estimated blood loss, length of stay, discharge disposition), overall reoperation rates, overall readmission rates, and 24-month ODI, NRS back pain, NRS leg pain, EQ-5D, and NASS satisfaction score ($p > 0.05$, all comparisons).

Conclusion: In adjusted analyses, July lumbar spondylolisthesis surgeries were not associated with significantly different outcomes from non-July surgeries. The influx of new trainees in July did not significantly affect surgical outcomes.

385 Targeting the Renin-Angiotensin System Might Enhance Spinal Fusion: Retrospective Analysis of Antihypertensives in ACDF Patients.

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Introduction: Recent evidence suggests an association between Renin-angiotensin system (RAS) blockers and bone metabolism, particularly in the context of bone healing. We aimed to determine whether there is a correlation between the use of antihypertensive medication and outcomes in anterior cervical discectomy and fusion (ACDF) surgery.

Methods: We performed a chart review of 128 degenerative disc disease patients who underwent ADCF, with 1-year minimum follow-up. Information on demographic data, comorbidities, antihypertensive medication, neurological examination, and fusion status were collected. Spinal fusion was evaluated via plain cervical x-ray, resorting to dynamic radiographs in cases of doubt.

Results: Of the 128 patients (52% females, 48% males, with a median age of 53.7 years), 46 hypertensive patients were identified: 44 (95.7%) were taking antihypertensive drugs as follows: 17 angiotensin II receptor blockers [ARBs], 14 angiotensin-converting enzyme inhibitors [ACEIs], and the remaining 13 other medication). In the analysis of fusion rates, patients treated with ARBs exhibited a higher fusion rate compared to those untreated or treated with ACEIs ($p=.03$ and $.005$, respectively). Patients treated with ARBs displayed a relative benefit of fusion over untreated patients of 1.289 (95%CI 1.12, 1.48, $p=.03$). Smoking presented a negative correlation with spinal fusion compared to non-smokers ($p=.03$). In the neurological examination analysis, ACEIs were correlated with lower preoperative modified Japanese Orthopedic Association (mJOA) and Nurick scores compared to non-treatment ($p=.01$ and $<.001$). Patient age, diabetic status, hypertension, and other drugs, did not significantly influence fusion rates or neurologic examination scores.

Conclusion: In ACDF patients, we found that ARBs were associated with higher fusion rates. Conversely, smoking was related to pseudoarthrosis. Also, ACDF patients treated with ACEIs exhibited lower preoperative mJOA and Nurick scores compared to untreated patients. Further studies with a larger population and different spinal levels are required to confirm that ARB treatment has beneficial effects on spinal fusion.

386 Ninety-Day and One-Year Mortality in Spinal Metastatic Disease: Machine Learning Prediction and Explanation

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Introduction: Increasing prevalence of metastatic disease has been accompanied by increasing rates of surgical intervention. Current tools have poor to fair predictive performance for intermediate (ninety-day) and long-term (one-year) mortality. The primary purpose of this study was to improve prediction at these time points.

Methods: Retrospective review was conducted at two large academic medical centers to identify patients undergoing initial operative management for spinal metastatic disease between January 2000 and December 2016. Five models (penalized logistic regression, random forest, stochastic gradient boosting, neural network, and support vector machine) were developed to predict ninety-day and one-year mortality.

Results: Overall, 732 patients were identified with ninety-day and one-year mortality rates of 181 (25.1%) and 385 (54.3%), respectively. The stochastic gradient boosting algorithm had the best performance with good calibration, Brier score, and c-statistic of 0.83 for ninety-day mortality and 0.89 for one-year mortality. On global variable importance assessment, albumin, primary tumor histology, and performance/functional status were the three most important predictors of ninety-day mortality. The final models were incorporated into an open access web application able to provide predictions as well as patient-specific explanations of the results generated by the algorithms. The application can be found here: <https://sorg-apps.shinyapps.io/spinemetssurvival/>

Conclusion: Preoperative estimation of ninety-day and one-year mortality was improved with the assessment of more flexible modeling techniques such as machine learning. Integration of these models into applications and patient-centered explanations of predictions represent opportunities for incorporation into healthcare systems as decision tools in the future.

387 Incidence and Risk Factors for Hardware Failure After Instrumentation for Spine Metastasis: A Single-institutional Series

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Introduction: Instrumentation failure is a rare but significant complication in patients that require spinal fusion. The incidence may be higher in patients undergoing surgery for spine metastasis, yet there is limited data on predisposing factors. We report a retrospective analysis of hardware failure in patients requiring instrumentation for spinal metastasis.

Methods: We identified 58 patients that underwent spinal instrumentation for metastasis from 2012 to 2018. Hardware failure was defined as screw pullout/loosening, cage migration, progressive kyphosis, implant angulation, or an otherwise noticeable instrumentation deficit detectable on imaging. Fischer's exact tests and Student's t-tests were applied to categorical and continuous variables, respectively. Risk factors for hardware failure with a p -value <0.10

were included in controlled multivariate logistic regression models controlled for age, gender, and previously identified risk factors for hardware failure.

Results: 58 patients required instrumentation for metastatic spine disease. Mean age was 57.6 (± 12.8), 38 patients (65.5%) were male, and median follow-up was 8.1 months (IQR 3.1-20.7). 8 patients (13.8%) developed signs of hardware failure during follow-up. 2 patients (3.4%) underwent operative revision, while 6 patients (10.3%) did not. In univariate analysis, Eastern Cooperative Oncology Group (ECOG) performance status >2 ($p=0.049$) and multiple myeloma lesions ($p=0.010$) were significant predictors of failure. ECOG performance status over 2 ($p=0.047$; OR 12.7 [95% CI 1.03-156.4]) and multiple myeloma lesions ($p=0.012$; OR 31.5 [95% CI 2.2-460.0]) maintained significance in a multivariate logistic regression model controlled for age, gender, history of spine radiation, and number of fused levels.

Conclusion: The rate of hardware failure in this cohort was 13.8%, although operative revision rate was 3.4%. Spinal instrumentation in patients with poor preoperative functional status or multiple myeloma may be more likely to develop instrumentation failure. Further study on modifying instrumentation strategies including possible cement augmentation in multiple myeloma patients requiring instrumentation may be warranted.

388 Surgical Approach and Cervical Spine Alignment: Analyzing changes in Radiographic Sagittal Alignment after Anterior vs. Posterior Procedures

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Introduction: Spinal malalignment leads to pain, disability and a decreased quality of life. Recent work has focused on translating these findings to the cervical spine, elucidating the relationship between sagittal alignment parameters and patient outcomes. Little is known regarding the effect of surgery in the cervical spine on sagittal alignment. A retrospective cohort analysis was performed to explore the differences between pre- and post-operative sagittal alignment as a function of surgical approach.

Methods: Pre- and post-operative sagittal cervical x-rays of 216 patients who underwent cervical spine surgery at UCLA between 2013 and 2017 were evaluated. C2-7 cervical lordosis (CL), cervical sagittal vertical axis (cSVA), T1 slope (T1S), C2-Occiput angle (C2O) were measured. Patients were subdivided into groups based on anterior vs. posterior approach.

Results: On average, CL increased by 2.39° in the anterior group (-6.03° vs -8.32° ; $p = 0.002$) and decreased by 6.09° in the posterior group (-6.84° vs -0.75° , $p < 0.0001$). cSVA increased by 3.99 mm in the posterior group (26.76 vs 30.75mm; $p = 0.006$). The anterior group showed no significant change. Pre-operative T1S decreased 1.9° in the posterior group (24.33° vs 26.66° ; $P = 0.02$). The anterior group showed no significant change. Similarly, there was an increase in C2O by 3.13° in the posterior group (22.94° vs 23.84° ; $P = 0.001$). The anterior group showed no significant change.

Conclusion: Our results suggest that anterior approaches lead to increased lordosis, posterior approaches lead to increased kyphosis and cSVA. Patients with increased kyphosis post-operatively exhibit compensatory changes, namely: increased C2O and decreased T1S. These relationships should be considered during preoperative planning for cervical procedures, especially in patients with already compromised cervical spinal balance or prior fusions spanning the occipital-cervical and cervical-thoracic junctional region.

389 Feasibility of Quantitative Magnetic Resonance Imaging in the Spinal Cord

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Introduction: Conventional MRI imaging only provides limited information about the structure and integrity of the spinal cord. We describe a multiparametric quantitative MRI protocol for microstructural analysis of the spinal cord to determine the precise degree of injury to the spine in the setting of degenerative cervical myelopathy (DCM) as well as traumatic spinal cord injury.

Methods: 35 healthy controls and 56 DCM patients have so far been studied. Each patient underwent a battery of clinical assessments including mJOA, ISNCSCI, QuickDASH, GRASSP-M and GaitRITE. Each patient had MRI acquisitions using our protocol in a 3T GE clinical scanner. The multi-parametric protocol combines MRI techniques including conventional MRI, diffusion tensor imaging (DTI), magnetization transfer (MT) and T2* weighted imaging (T2*WI). Image analysis was performed using the Spinal Cord Toolbox (SCT) v.3.0 to calculate spinal cord cross-sectional area (CSA), fractional anisotropy (FA), magnetization transfer ratio (MTR) and T2* weighted white matter to gray matter ratio (T2*WI WM/GM).

Results: Study of healthy subjects identifies an alarming rate of asymptomatic spinal cord compression. Significant differences in 10 metrics were identified between 56 DCM and 32 healthy subjects. These 10 measures of tissue injury correlate with disability (mJOA) in a linear regression model ($R^2=0.55$) and T2*WI WM/GM showed strongest correlation with upper extremity motor and sensory scores ($P=1 \times 10^{-11}$). Longitudinal study (ongoing) of DCM patients correlates qMRI findings with clinical assessment and suggest mJOA underestimates progression.

Conclusion: We have established a reliable, clinically feasible quantitative MRI protocol where the combined methodologies in the protocol can help overcome several individual limitations. This protocol can be used for diagnosis,

detection of subclinical tissue injury and can potentially help with prediction of outcomes in DCM as well as spinal cord injury.

390 Outcomes Following Surgical vs Endovascular Treatment of Spinal Dural Arteriovenous Fistula: Systematic Review and Meta-analysis

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Introduction: Although surgical resection is associated with a complete cure in most cases of Spinal Dural Arterio-Venous Fistulas (SDAVF), there has been an increasing trend towards embolization given the morbidity associated with surgery. We sought to perform a systematic review and meta-analysis comparing surgical resection with endovascular treatment in terms of success of treatment, rate of recurrence and complications.

Methods: A literature search was conducted using PRISMA ((Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Strength of evidence was assessed using the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) Working Group system. Surgical outcomes such as initial treatment failure, late recurrence and complications were compared between the 2 approaches

Results: A total of 60 studies with 2029 patients were included: of which 33 studies with 1359 patients directly compared surgery (596 patients) and endovascular treatment (763 patients). From 33 direct comparisons, it was found that endovascular treatment was associated with higher odds of initial treatment failure (OR: 0.23, CI: 0.14-0.40, I²: 6.4%, p<0.001) and late recurrence (OR: 0.31, CI: 0.16-0.58, I²: 0.0%, p<0.001). Complication rates were found to be equivalent between the two approaches (OR: 1.51, CI: 0.87-2.62, I²: 0.0%, p>0.05) Indirect comparison between the 2 approaches also yielded similar trends of higher odds of initial failure (OR: 0.01, CI: 0.00-0.04, I²: 57.24%, p<0.001) and late recurrence (OR: 0.00, CI: 0.00-0.02, I²: 38.37%, p=0.03) in endovascular treatment, and complications were again found to be equivalent between the two approaches (OR: 0.02, CI: 0.00-0.04, I²: 0.00%, p>0.05).

Conclusion: Surgery may be associated with superior outcomes for spinal dural arteriovenous fistulas in comparison to endovascular ablation. Further studies will validate the findings of this study and elucidate the role of endovascular treatment as a possible adjunct to surgical resection.

391 Evaluating Pain in Patients with and without Stabilization Surgery using Multifraction Stereotactic Body Radiation Therapy for Spine Metastases

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Introduction: Pain is significant cause of morbidity in the treatment of pathological fractures with multifraction stereotactic body radiation therapy. Single-fraction radiation surgery for spine metastases is highly effective; however, the outcomes including the patient's improvement or worsening of pain has not been evaluated. We report our experience using multifraction SBRT.

Methods: All patients who were treated with multifraction SBRT for spine metastases at our institution between 2009 and 2017 were retrospectively analyzed. SBRT was delivered in 2 to 5 fractions using Cyberknife. Patients were followed clinically and with magnetic resonance imaging every 3 to 6 months. Pain, local control, complications, and overall survival were evaluated. Patient, disease, and treatment variables were analyzed for a statistical association with outcomes.

Results: A total of 89 patients were treated to 98 spine lesions with a median follow-up of 7.6 months. Histologies included non-small cell lung cancer (24%), renal cell carcinoma (18%), and breast cancer (12%). Surgery or vertebroplasty were performed before SBRT in 21% of cases. Patients received a median SBRT dose of 24 Gy in a median of 3 fractions. Local control was 93% at 6 months and 84% at 1 year. Higher prescribed dose, higher biologic effective dose, higher minimum dose to 90% of the planning target volume, tumor histology, and smaller tumor volume predicted improved local control. Pain scores were available for 65 patients, with 69 lesions treated. We analyzed two groups comparing the surgical stabilization group to SBRT alone using Fisher's exact test. In the stabilization group of 4 patients, all patients at follow-up had improvement of their pain; there were no patients whose pain score remained unchanged or worsened. In the non-stabilization group, 29 out of 65 patients had an improvement (44%), but 36 (55.4%) had pain unchanged or worsened (Fisher's exact p = 0.047).

Conclusion: Multifraction SBRT results in a high local control rate for metastatic spinal disease. Patients in the stabilization group had significantly better improvement in their pain score compared to patients who underwent SBRT alone.

392 Quantitative Assessment of Hand Function in Cervical Spondylotic Myelopathy and Response to Surgical Treatment

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Introduction: Cervical spondylotic myelopathy (CSM) is the most common cause of spinal cord dysfunction in adults. Diminished hand strength and dexterity in CSM is a major contribution to disability. The goal of this study was to

establish the functional impact of CSM severity on hand function using quantitative testing and evaluate the response to intervention.

Methods: Consecutive adult patients from a single institution with plans for surgical treatment of CSM were prospectively enrolled. Demographics, clinical history, physical exam, modified JOA score were collected. Patients underwent preoperative and postoperative functional hand testing at 6 weeks: 1) grip strength (Jamar dynamometer), 2) pinch strength (palmar pinch gauge), 3) dexterity (9-hole peg test). Preoperative and postoperative test results were compared to evaluate the impact of surgery; changes were expressed as continuous variables and as proportion achieving minimum clinically important differences (MCID). For analysis, patients were stratified into mild, moderate, and severe myelopathy based on mJOA score (=15, 12-14, =11). Significance was defined as $p < .05$.

Results: 33 patients were enrolled (Age: 58.1 ± 13.1 , Gender: 51.5% Male). Primary presenting symptoms were neck pain (11/33), numbness (7/33), and upper extremity weakness (4/33). 10/33 patients had severe myelopathy, 12/33 had moderate myelopathy, and 11/33 had mild myelopathy. Preoperative pinch and grip strength were lower in severe CSM ($p = .014$). 20/30 patients underwent anterior approach decompression, with mean of 3 levels treated. Significant improvement was observed in dominant grip strength ($p = .004$), non-dominant grip strength ($p = .008$), and dominant hand dexterity ($p = .001$); no significant improvement was observed in pinch strength ($p = .054$). 11/33 patients achieved MCID in dominant grip strength at 6 weeks; greatest proportion of patients improved in the moderate (58.3%) compared to low (30%) and high (9%) mJOA groups.

Conclusion: Patients with myelopathy demonstrate improvement in hand function following surgery, particularly in the moderate group.

393 Epidural Dose Constraints in Stereotactic Body Radiation Therapy

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Introduction: The epidural space is a common site of local recurrence following spinal stereotactic body radiation therapy (SBRT). However, it remains unclear whether a reduction in recurrence could be safely achieved by requiring a minimum dose in this space. We investigated the feasibility of a minimum dose constraint of 1000 cGy to 95% of the epidural space near the planning tumor volume (PTV) for single fraction cases without compromising the dose objectives placed on the spinal cord.

Methods: 19 spinal SBRT plans were retrospectively reviewed. The region of the epidural space of interest (RESI) was defined as the overlap between a 3mm shell around the spinal cord and a 4mm expansion of the PTV. Cases were re-planned using three coplanar volumetric modulated arc therapy (VMAT) arcs centered on the PTV. Plan prescriptions were normalized to 1800 cGy to the PTV in one fraction, with D95 and D5 PTV constraints being 1750 cGy and 1950 cGy, respectively. D10 and Dmax spinal cord constraints were 1000 cGy and 1400 cGy, respectively. Under these constraints, dose to the RESI was optimized in a treatment planning system. Dose delivered to the RESI was computed, along with the D95 and D5 of the PTV and the D10 and Dmax of the spinal cord. Data were analyzed using descriptive statistics.

Results: Among the 13 cases capable of meeting dose-volume constraints, the mean RESI D95 was 1074 cGy (SD = 79 cGy), with 11 reproduced plans achieving an RESI D95 above 1000 cGy. For the 6 cases that failed the constraints, mean RESI D95 was 1137 cGy (SD = 104 cGy), with the lowest value being 1056 cGy.

Conclusion: 1000 cGy to 95% of the RESI volume is a feasible dose constraint during single-fraction spinal SBRT treatment planning. A prospective study is warranted to determine the clinical impact of this constraint.

394 Health Economics of BMP: Cost Awareness Effect Analysis

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Introduction: BMP is used, both on and off label, in spinal arthrodesis procedures to enhance bony fusion. Though previous studies have suggested it is the most cost effective fusion enhancer, it has significant upfront costs for the healthcare system. Control of healthcare costs is a primary concern, and as such implementation of techniques that reduce costs while still effectively treating patients is of high importance.

Objectives: The primary objective is to complete a before and after BMP cost awareness analysis to assess if intraoperative dosing management is altered by cost awareness and secondarily how this affects a hospital's reimbursement.

Study Design: Retrospective medical record review.

Patient Sample: 48 patients who underwent spinal arthrodesis supplemented by BMP from June 2016-June 2018.

Outcome measures: medicare reimbursement, BMP dose size, BMP list price

Methods: Data was extracted by UW Financial department. Medical record review and analysis was performed on spinal fusion cases supplemented with BMP from June 2016 to June 2018. Cases were filtered to show one surgeon under analysis. Basic data analysis was then performed using Microsoft Excel.

Results: Overall from June 2016 to June 2018, the physician being analyzed performed 48 operations supplemented with BMP at this facility, with 16 of these cases being performed prior to cost awareness and 32 being performed after cost awareness. Cost awareness resulted in a preference for smaller dosages of BMP. After cost awareness, there was an increase in XXS usage by 100% and a decrease in large dose usage by 51.37%. Prior to cost awareness, the

surgeon was spending an average of \$4,116.56 per case on BMP. After cost awareness, the surgeon was spending an average of \$2,268.38 per case on BMP. Thus, after cost awareness there was a 44.90% reduction in amount spent on BMP per case. Prior to cost awareness, BMP costs took up 7.61% of the medicare reimbursement for hospital charges for the overall admission. After cost awareness, BMP costs took up 3.33% of the medicare reimbursement for hospital charges for the overall admission. Thus, after cost awareness there was a 56.24% reduction in medicare reimbursement allocated to BMP.

Conclusions: Surgeon awareness of BMP cost resulted in a preference for smaller, less expensive doses of BMP, resulting in decreased BMP cost per case. Thus, making surgeons aware of the cost of BMP does result in decreased spending on BMP, reducing overall hospital admission charges. This study suggests that surgeon awareness of cost is a potential way to help control healthcare costs. The authors recognize that while controlling healthcare costs is an important consideration, the most important consideration is patient care. As such future studies could analyze the effect on fusion rates with reduced BMP dosages after cost awareness.

395 Preoperative Embolization of Vascular Spinal Metastasis Does Not Confer Improved Perioperative and Postoperative Outcomes

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Introduction: Preoperative embolization is commonly performed for treating vascular spine metastases to minimize perioperative blood loss to improve clinical outcomes. We compare the perioperative and postoperative outcomes of surgical treatment of vascular spinal metastases with and without preoperative embolization.

Methods: Retrospective review of patients with spinal metastases who underwent surgical treatment at our institution (2005-2015) and review of corresponding costs.

Results: There were 68 patients (median age=61 years; females=26.5%) with highly vascular spine metastases; 26 (38.2%) underwent preoperative embolization prior to surgery. Operating time for preoperative embolization (PE) plus surgery was longer versus just surgery (NPE) (423 vs 351 mins; $p=0.037$). There were no differences in perioperative blood loss (1.9L vs 2L; $p=0.81$) and blood transfusion (50% vs 54%; $p=0.7$) between NPE and PE. However, the PE group had almost twice as high rates of perioperative complications (46.2% vs 23.8%; $p=0.04$) when compared to NPE. Postoperatively, mean KPS (NPE=67.3 vs PE=64.4; $p=0.7$) and neurological improvement (NPE=23.8% vs PE=26.9%; $p=0.8$) was similar between the two cohorts. PE cohort had higher 30 day postoperative complications (46.15% vs 26.2%; $p=0.04$) as well as higher 90 day unplanned readmission to the hospital (23.08% vs 2.38%; $p=0.006$) versus NPE patients. Moreover, Kaplan-Meier survival analysis revealed no postoperative survival benefit to the PE group versus NPE patients (16.6 vs 15.9 months, $p=0.16$). PE patients had approximately a 40% higher cost of surgery compared to NPE (\$65,145 vs \$46,832; $p=0.016$). QALY scores were similar between NPE and PE (1.38 vs 0.89; $p=0.1$) and the incremental cost per QALY was \$37,373.47 lower for NPE.

Conclusion: Preoperative embolization is an expensive procedure that does not improve perioperative and postoperative outcomes in spine metastases patients as compared to surgery alone. Thus, preoperative embolization should be reconsidered if it will create a delay of urgently needed spinal cord decompression.

396 Balloon Kyphoplasty for Vertebral Fractures with Posterior Wall Disruption

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Introduction: Percutaneous Balloon Kyphoplasty (BK) is widely accepted as both a safe and effective method for the treatment of symptomatic benign vertebral compression fractures of the thoracic and lumbar spines. In addition to pain control, BK also allows for a correction of kyphotic deformity in certain cases. A disruption in the posterior wall of the affected vertebrae as seen on pre-procedure CT imaging is considered by many clinicians to be either a relative or an absolute contraindication to BK. This study was performed in order to determine the safety and the efficacy of BK for vertebral body compression fractures with posterior wall disruption.

Methods: One hundred fourteen consecutive patients (treated between 2010 and 2015) were retrospectively identified with posterior wall disruption as determined on pre-procedure imaging. All cases were performed using a bi-pedicular technique. Each case was examined for cement leakage, anterior vertebral body height, improvement in pain determined by VAS from baseline and 1-month post procedure, and clinical sequelae from cement leakage.

Results: 157 levels of BK were performed. No patient had radiographic evidence of cement leakage into the spinal canal; 14 (9%) cases had asymptomatic cement leakage outside of the vertebral body. The mean anterior vertebral body height was 14.35 +/- 5.4 mm pre-procedure and 19.32 +/- 5.3 mm post-procedure ($p=0.001$). Mean VAS was 8.7 pre- and 2.5 post-procedure ($p=0.001$). There were no cases of new neurological symptoms in any patient after BK.

Conclusion: Balloon Kyphoplasty in the setting of posterior wall disruption as seen on pre-procedure imaging was found to be a safe and highly effective treatment for patients with benign compression fractures. Posterior wall disruption should not be considered a contraindication to BK. Patients can still achieve a high level of clinical success and safety in this setting.

397 The Occipitocervical Angle and Post-Operative Dysphagia following Occipitocervical Fusion: An Analysis of 55 Patients

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Introduction: The craniovertebral junction(CVJ) is an intricate interface between the cranium and the cervical spine through which many vital structures pass. Instability at this joint can cause pain, neurologic deficits, and in some cases death due to brainstem and upper cervical spinal cord compression. CVJ instability is commonly corrected by performing an occipitocervical fusion (OCF). One well known complication of this procedure is postoperative dysphagia. The aim of this study was to study was to analyze the association of changes in the occipitocervical angle O-C2 and C2-C7 angle and the presence of post-operative dysphagia.

Methods: Fifty-five patients who underwent OCF surgery were included in this study. For each plain radiographs were taken pre-and post-operatively. From these imaging studies occipitocervical angle O-C2 (measured between McGregor's line and C2 end plate) and C2-C7 Cobb angles were measured. Pre-to post-operative change in the O-C2 angle was defined as dO-C2 (postoperative O-C2 angle - preoperative O-C2 angle). Pre-to post-operative change in the C2-C7 angle was defined as dC2-C7 (postoperative C2-C7 angle - preoperative C2-C7 angle).

Results: We found no significant difference in dO-C2 or dC2-C7 in either improving pre-op dysphagia, or causing post-operative onset dysphagia (Figures 1 and 2).

Conclusion: Currently, there a major emphasis is placed on the dO-C2 >10 degrees as a predictor of post-operative dysphagia. However, from this cohort we conclude that the O-C2 and C2-C7 angle are not solely predictive of postoperative dysphagia due to its uncommon occurrence. Rather, we believe there may be other intraoperative factors that contribute to post-op dysphagia which may be difficult to assess due to retrospective nature of these studies.

398 Pain Sensitivity and Modulation in Patients with Spinal Stenosis Selected for Lumbar Fusion

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Introduction: Pain is a complex phenomenon influenced by facilitatory and inhibitory processes. Central sensitization and inefficient endogenous pain inhibition have been associated with several chronic painful conditions. Growing evidence has suggested that the measurement of pain processing and modulation may help clinicians to predict treatment success. The goal of this study was to evaluate pain sensitivity and modulation in patients with focal lumbar spinal pathology.

Methods: 18 patients with single/two levels stenosis presenting with chronic back pain and neurogenic claudication were included in the surgical group(SG). Sex and age matched control group of healthy volunteers (CG, N=18) was used for comparisons. Participants were evaluated with a standard quantitative sensory testing(QST) and validated questionnaires. 7 QST parameters were evaluated, including pain pressure threshold at a non-painful control site(PPTforearm) and at the most painful site at the back(PPTback), heat pain threshold(HPT), heat tolerance threshold(HTT), cold pressor test(CPT), temporal summation of pain(TSP), conditioned pain modulation(CPM).

Results: The mean pain during the first heat task was 55.5(25.1) in the SG versus 41.5(16.2) in the CG(P=0.055). After the conditioning stimulus, mean pain was 45.9(24.5) in the SG and 27.7(16.4) in the CG(P=0.013). The mean pain reduction after the conditioning stimulus was 9.6 (21.0, P=0.069) in the SG and 13.7 (13.7, P=0.001) in the CG. An increase in pain ratings during the first heat task (TSP) was observed in 77% of SG. In addition, 38.9% of SG did not present any inhibition after the conditioning stimulus (16.7%CG, P=0.137). There was a positive correlation between pain catastrophizing and pain during the cold pressor task ($r=0.483$, $P=0.042$). Mental component of SF12 correlated negatively with pain pressure threshold ratio ($r=-0.512$, $P=0.039$): the more sensitive was the back, the lower was the mental health.

Conclusion: Patients with chronic low back pain and neurogenic claudication present higher pain sensitivity and less efficient conditioned pain modulation in comparison with healthy individuals.

399 Impact of Distal And Proximal Extensions on Short-Term and Long-Term Outcomes in Long-Segment Posterior Fusion Involving the Cervicothoracic Junction

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Introduction: Long-segment posterior spinal fusion involving the cervicothoracic junction carries higher complication rates due to its biomechanical stress when compared with non-junctional regions. To overcome this problem, the extension of fusions from C7 to the thoracic spine and/or C3 to C2 is sometimes considered. However, the impact of the caudal/rostral extension alone or the combination of both on clinical outcomes has not been thoroughly explored in the literature yet.

Methods: Retrospective clinical record review from 2010 to 2016 identified 162 patients who underwent long-segment posterior fusion (C3-C7, C3-T2, C2-C7, or C2-T2) for degenerative diseases, trauma, or infection with a minimum one-year follow-up period. They were sub-classified into the two groups: fusions ending in the cervical spine (Group 1, n=60) and those ending in the thoracic spine (Group 2, n=102). Rates of pseudarthrosis, adjacent segment disease (ASD), and overall surgical revision were collected and statistically analyzed.

Results: There were no statistically significant differences in baseline characteristics such as age, BMI, and gender. Group 2 had significantly higher estimated blood loss and longer operative time and hospital stay than those in Group 1. Rates of all three primary outcomes were comparable between the two groups. In multivariate analysis, C7 to T2

extension (Group 1 versus Group 2) independently reduced rates of pseudoarthrosis at the most distal level ($P=0.02$) and distal ASDs ($P=0.04$), whereas C3 to C2 extension was independently protective against pseudoarthrosis at the most proximal level ($P=0.01$) and proximal ASDs ($P=0.03$).

Conclusion: The rates of pseudoarthrosis and ASDs at distal and proximal segments were independently reduced by C7 to T2 and C3 to C2 extension, respectively. The judicious selection of the upper-most fusion level and the lower-most fusion level should be weighed against the detrimental short-term outcomes in treating this patient population with unique biomechanical considerations.

400 Current Treatment Strategy for Newly Diagnosed Chordoma of the Mobile Spine and Sacrum: Results of an International Survey

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Introduction: To understand the spectrum of current treatment protocols for managing newly diagnosed chordoma of the mobile spine and sacrum.

Methods: A survey on the treatment of spinal chordoma was distributed electronically to members of the AOSpine Knowledge Forum Tumor, including neurosurgeons, orthopaedic surgeons, and radiation oncologists from North America, South America, Europe, Asia, and Australia. Survey participants were pre-identified clinicians from centers with expertise in the treatment of spinal tumors. The data were collected and analyzed using descriptive statistics.

Results: A total of 39 of 43 (91%) participants completed the survey. Most (80%) favored en bloc resection without preoperative neoadjuvant radiation therapy (RT) when en bloc resection is feasible with acceptable morbidity. The main area of disagreement was with the role of postoperative RT, where 41% preferred giving RT only if positive margins were achieved and 38% preferred giving RT irrespective of margin status. When en bloc resection would result in significant morbidity, 33% preferred planned intralesional resection followed by RT, and 33% preferred giving neoadjuvant RT prior to surgery. In total, 8 treatment protocols were identified: 3 in which en bloc resection is feasible with acceptable morbidity and 5 in which en bloc resection would result in significant morbidity.

Conclusion: The results confirm that there is treatment variability across centers worldwide for managing newly diagnosed chordoma of the mobile spine and sacrum. This information will be used to design an international prospective cohort study to determine the most appropriate treatment strategy for patients with spinal chordoma.

401 A Quantitative Assessment of the Accuracy and Reliability of Robotically Guided Percutaneous Pedicle Screw Placement: Technique and Application Accuracy

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Introduction: Minimally-invasive (MIS) approaches to the anterior column such as transforaminal (TLIF) or lateral lumbar interbody fusion (LLIF) often require percutaneous screw fixation to achieve circumferential fusion. Robotic guidance represents a new technology for augmenting the surgical workflow to improve screw placement accuracy and decrease operative time.

Methods: Data from single or multiple level fusions with robotically assisted percutaneous pedicle screw fixation (PSF) were prospectively collected. In combination with intraoperative navigation, a novel CT-guided robotic guidance arm was used for screw placement (ExcelsiusGPS). Demographic data, surgical timing, and perioperative complications were collected. Postoperative thin cut CT imaging was used for screw localization. 3D and 2D coordinates of the screw tip and tail were calculated and compared with the intended target trajectory to calculate targeting error. A breach was defined as violation of the lateral or medial pedicle wall.

Results: Robotic-guided screw placement was successfully used in 28 of 31 patients. In 28 patients, 116 of 116 screws were successfully implanted. The breach rate was 3.4% (4/116). Across 17 patients (70 screws), the mean 3D accuracy was 5.0 ± 2.4 mm, mean 2D accuracy was 2.6 ± 1.1 mm, and mean angular offset was $5.6 \pm 4.3^\circ$ with a corresponding intraclass correlation coefficient (ICC) of 0.775 and 0.693. 3D accuracy was correlated with age ($R=0.306$, $p=0.011$) and BMI ($R=0.252$, $p=0.038$). Accuracy did not significantly differ between vertebral body levels ($p>0.22$). Mean operative time for MIS-TLIF and percutaneous screws was 277 ± 52 minutes and 183 ± 54 minutes, respectively.; Operative time did not significantly decrease across the study period in either group ($p>.187$).

Conclusion: ExcelsiusGPS robotic guidance system allows for accurate percutaneous pedicle screw placement in the majority of cases with 2mm 2D accuracy. Nonetheless, this technology represents an early phase of development, with a steep learning curve. Future studies are needed to demonstrate the utility of this novel guidance system and continued improvement in workflow.

402 PROMIS Pain Interference is Superior to the Numeric Pain Rating Scale for Pain Assessment in Spine Patients

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Introduction: An accurate understanding of a patient's pain is beneficial in setting expectations and pain management goals. PROMIS is a universal, validated PRO tool that may capture clinical information more completely than traditional methods. We aimed to determine whether PROMIS Pain Interference (PI) or the Numeric Pain Rating Scale (NPRS) demonstrates a stronger association with physical function, as determined by PROMIS Physical Function (PF).

Methods: Spine center patients from 2/2015-11/2017 were asked to complete PROMIS PF and PI domains, as well as to report their pain level on a 0 (no pain)-10 (worst pain) NPRS at each visit. Pearson correlation coefficients were calculated between PROMIS PF and PROMIS PI; PROMIS PI and NPRS; and PROMIS PF and NPRS. Fisher r-z transformation method was utilized for confidence intervals and to determine significant correlation differences.

Results: A total of 21,774 first visit, 11,130 second visit, 6,575 third visit, 4,202 fourth visit and 2,819 fifth visit patients' data were recorded. PROMIS PF demonstrated a low significant correlation with the NPRS over all visits ($r=0.46-0.49$, $p<0.05$). PROMIS PI demonstrated a moderate significant correlation with the NPRS over all visits ($r=0.59-0.63$, $p<0.05$). PROMIS PF demonstrated a high significant correlation with PROMIS PI over all visits ($r=0.73-0.77$, $p<0.05$). Overall, PROMIS PI demonstrated significantly better correlation to self-reported physical function, as determined by PROMIS PF, than the NPRS ($p<0.05$).

Conclusion: While PROMIS PI and NPRS both demonstrated significant correlation with self-reported physical function, PROMIS PI had a significantly stronger correlation. This suggests PROMIS PI may better capture the impact of pain on patient health. This finding can assist surgeons in setting pain level expectations, which may help decrease opioid use and patient dissatisfaction. Further, such information is important as healthcare shifts to a value-based medicine model with a focus on efficiency and high quality care at an affordable cost.

403 Clinical Outcomes Following Surgical Obliteration of Cerebrospinal Fluid Venous Fistula in Patients with Intracranial Hypotension: A Prospective Study

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Introduction: Cerebrospinal venous fistula (CVF) is a newly described etiology for spontaneous intracranial hypotension (SIH) (Figure 1). Recently, surgical ligation of CVF has been recognized as a therapeutic option for patients failing more conservative therapy; however, there is a paucity of clinical data regarding its efficacy and safety profile.

Methods: Patients undergoing surgical ligation for CVF causing SIH between 2012 and 2018 were prospectively enrolled in this study. Inclusion criteria included 1) diagnosis of SIH, and 2) demonstration of CVF on CT-myelogram. Demographic factors, CVF location, and description and duration of symptoms were recorded for each patient. Preoperatively, the Headache Impact Test (HIT-6) was administered to all patients, who were then re-administered the test at least 6 weeks after surgical intervention. Additionally, the Patient Global Impression of Change (PGIC) was also administered at follow-up. Perioperative complications and 30-day readmission rates were recorded.

Results: 20 total patients were included in statistical analysis. Average age was 51.3 ± 13.6 years, BMI 26.0 ± 4.2 kg/m². There was an average of 2.5 epidural or fibrin blood patches attempted prior to surgery, with T8-9 (N=5, 25.0%) and T11-12 (N=5, 25.0%) being the most commonly involved level. The average HIT-6 score was almost universally high (64.7 ± 6.4 , range [44-76]). Postoperatively, the mean follow-up was 16.0 ± 9.7 months with an average postoperative HIT-6 score of 44.1 ± 8.4 with average change of -20.6 ± 9.3 points. With respect to the PGIC survey, 18 (90.0%) patients responded most favorably that surgery resulted in headaches that were "a great deal better, and a considerable improvement that has made all the difference". No patient suffered any short or long-term perioperative complications or 30-day readmission.

Conclusion: Surgical ligation of CVF for SIH is a safe and efficacious therapeutic option for patients failing more conservative therapy. Larger trials with longer follow-up period are indicated to better assess its long-term efficacy and safety profile.

404 Complications of Robotic Spine Surgery

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Introduction: Robotic-assisted spinal instrumentation is becoming increasingly widespread. We report our early experience utilizing robotic assisted spinal instrumentation. The aim of the study is to review complications experienced during robotic-assisted spinal instrumentation including pedicle screw accuracy, medical, and surgical complications.

Methods: This study was performed as a descriptive, retrospective study. We reviewed cases over the course of 12 months and examined all operative and postoperative data including pedicle screw accuracy and medical and surgical complications related to the surgery and hospital stay. Pedicle screw accuracy was assessed utilizing the Gertzbein-Robbins scale.

Results: The study included 67 consecutive patients undergoing 68 robotic-assisted procedures. Patient ages ranged from 20-90. There were 37 males and 30 females. Indications for surgery included degenerative disease (48%), trauma (35%), tumor (7.4%) and infection (1.4%). There were a total of 592 pedicle screws placed. 26 (4.3%) screws were revised intraoperatively using the robot. An additional 32 (5.4%) screws were aborted from robotic assistance. Pedicle

screw accuracy was noted to be excellent with 97% of screws rated as clinically acceptable. There were 4 deaths (5.8%) 18 patients (26%) experienced a medical complication, 26 patients (38%) experienced a surgical complication, 6 patients (9%) experienced both a medical and surgical complication. 38 patients (55%) experienced any morbidity or mortality related to surgery. Mean operative time was 277 minutes.

Conclusion: We report our initial experience with robotic-assisted spine surgery. Pedicle screw accuracy was noted to be high. We experienced a broad array of medical and surgical complications. The high complication rate may be due to long operative times and presence of a learning curve utilizing the robot. Further study is warranted to note if more experience decreases complication rates. It is unclear if the overall complication rate is significantly different pared with more traditional methods of spinal instrumentation.

405 MRI-Guided Cryoablation for Metastatic Spine Disease

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Introduction: Minimal access ablative techniques have emerged as a less invasive option for spinal metastatic disease reduction. Percutaneous image-guided cryoablation allows for more distinct visualization of treatment margins compared to heat-based ablation modalities. We report on a series of patients undergoing MRI-guided cryoablation as a feasible method for treating spinal metastatic disease.

Methods: A retrospective review of 14 patients with metastatic spine disease undergoing MR-guided cryoablation was performed. Procedures were performed in an advanced imaging operating suite with the use of both CT and MR imaging to gain access to the spinal canal and monitor real-time cryoablation. An example of the standard workflow in the operating suite is depicted (Figure 1).

Results: Baseline data are presented in Table 1. The average age was 54.5 (range 35-81). Pre-operative mean Karnofsky Performance Scale (KPS) score was 79.3 (range 35-90). Average radiographic follow-up was 7.1 months (range 25-772 days) and average clinical follow-up was 9.8 months (range 7-943 days). In 10 patients with epidural disease, 7 patients had post-procedure imaging, and of these 71% (5/7) had stable or reduced radiographic disease burden. Bone regrowth was observed in 63% (5/8) of patients with bone ablation during the treatment who had post-operative imaging. Please see Figure 2 for an example of a patient with pre- and post-procedure epidural disease reduction. Pre- and post-operative Visual Analogue Scale (VAS) scores were obtained and a significant reduction in these scores was found following ablation (Figure 3). There were no complications.

Conclusion: MR-guided cryoablation is a promising minimally invasive tool for treating metastatic spine disease. In patients with epidural disease, the majority experienced tumor reduction or arrest at follow-up. In addition, pain was significantly improved following ablation. Average hospital stay was short and the procedure was safe in a range of patients who are otherwise not ideal candidates for standard treatment.

406 Assessing the Differences in Measurement of Degree of Spondylolisthesis between Supine MRI and Erect X-Ray: An Institutional Analysis of 255 Cases

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Introduction: Degenerative Spondylolisthesis (DS) is the displacement of one vertebral body over the adjacent one secondary to degenerative changes in the vertebral column. While standing and flexion extension X-Rays are preferred for determining listhesis and instability, MRI is often utilized to assess the compression of nerve root or spinal cord. In the present study, we sought to investigate the difference in radiographic measurements of spondylolisthesis between lateral standing X-rays and supine MRI.

Methods: We retrospectively reviewed the records and radiographic images of all cases with a confirmed diagnosis of spondylolisthesis undergoing an operation in 2016. Primary variable of interest was the degree of slippage as per the Meyerding method, measured independently by 2 reviewers on lateral X-ray and sagittal MRI cuts. Agreement between the two reviewers was assessed using the two-way intraclass correlation coefficient (ICC) for slippage percentage and Cohen's Kappa for grade. Agreement of Meyerding grade between the two imaging techniques was assessed using Cohen's Kappa while the slip percentage measured for each technique was compared using a Bland-Altman (BA) plot, mean difference (MD) and one-way ICC.

Results: A total of 255 cases were considered eligible for analysis. ICC between the two reviewers was found to be 0.75 (95%CI=0.64-0.83, $p<0.001$) for X-ray and 0.76 (95%CI=0.66-0.83, $p<0.001$) for MRI showing good agreement. Agreement between X-ray and MRI for grading of spondylolisthesis was found to be poor (Kappa= 0.32, $p<0.001$). BA plot between X-ray and MRI measurements revealed a MD of 4.4% (95% limits of agreement: -10.3% to 19.3%) with 5.16% observations outside the limits of agreement and one-way ICC of 0.35 showing poor agreement.

Conclusion: Our results demonstrate the discrepancy of spondylolisthesis grade measurements between weight-bearing X-ray and non-weight-bearing MRI. Careful evaluation of both imaging technique is warranted to determine the final severity of pathology and tailoring of management plan.

407 Regional Variation in Opioid Use After Lumbar Decompression and Fusion Surgery

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Introduction: The increasing concerns about opioid use and its associated negative consequences highlight the importance of understanding the drivers of regional variation in opioid prescription and use after lumbar surgery. The aim of this study was to investigate regional variations in use of opioids after lumbar decompression and fusion surgery for patients with symptomatic lumbar stenosis or spondylolisthesis.

Methods: An insurance database, including private/commercially insured and Medicare Advantage beneficiaries, was queried for patients undergoing 1 to 3-level index lumbar decompression and fusion procedures between 2007-2016. Research records were searchable by International Classification of Diseases diagnosis and procedure codes, and generic drug codes. Opioid use 6-months prior to index surgery through 2-years after surgery was assessed.

Results: Of the 13,257 patients included in the study, 63.1% were from the South, 24.3% from the Midwest, 10.5% from the West, and 2.1% from the Northeast. 57.8% of patients had history of opioid use prior to index surgery, of which 64.4% were from the South and 23.0% from the Midwest. Over the 6-month preoperative period, 51.6 opioid pills were billed by opioid users monthly (Midwest:52.7 pills/patient/month, Northeast:64.9 pills/patient/month, South:50.6 pills/patient/month, West:52.2 pills/patient/month). During the 2-year period after surgery, an average of 33.6 opioid pills were billed by opioid users monthly (Midwest:32.9 pills/patient/month, Northeast:35.4 pills/patient/month, South: 33.9 pills/patient/month, West: 32.9 pills/patient/month). Receiving treatment in the South (OR 1.18, 95% CI:1.07-1.29) or West (OR 1.26, 95% CI:1.10-1.45) was independently associated with prolonged (>1year) opioid use after index surgery.

Conclusion: Our study suggests regional variations may exist in the use of opioids after lumbar decompression and fusion surgery for patients with symptomatic lumbar stenosis or spondylolisthesis. Future prospective studies are needed to corroborate these findings.

409 Outpatient and Inpatient Readmission Rates of 1 and 2 Level Anterior Cervical Discectomy and Fusion Surgeries

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Introduction: With increasing costs within the United States medical system, one emerging cost-saving strategy is to evolve traditional inpatient procedures into outpatient same-day surgeries. However, patient safety remains a crucial priority. This study investigates the various comorbidities and postoperative complications and their impact on readmission rates of patients undergoing outpatient versus inpatient 1 and 2 level ACDF.

Methods: A total of 28,427 patients were analyzed, with 26,368 undergoing inpatient ACDF surgery and 2,059 undergoing outpatient ACDF surgery. Age, sex, comorbidities, postoperative complications, readmission rates and overall financial cost were compared between both cohorts.

Results: Data from 28,427, 1 and 2 level ACDF procedures that was split between inpatient and outpatient was collected. 30-day readmission rates were significantly lower in patients undergoing outpatient ACDFs (outpatient: 4% vs Inpatient 10.1%). Outpatients had increased readmission risk with comorbidities of diabetes (OR = 48.93, $p < 0.001$), smoking (OR = 4.6, $p < 0.001$), BMI = 30 (OR = 2392, $p < 0.001$). There were no significant differences between both cohorts in postoperative complications. Average cost of outpatient surgery was less than inpatient surgery (\$7,774.8 vs \$7,956.75, $p = 0.0444$).

Conclusion: This study suggest that in the appropriately selected patients, ACDF can safely be performed in an outpatient setting.

410 Axial Radiculopathy as a Manifestation of Cervical Stenosis: A Retrospective Review of 800 Patients

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Introduction: Axial neck pain (ANP) is ubiquitous. Precise diagnosis and subsequent treatment can be daunting, typically resulting in less favorable clinical outcomes. Consequently, the treatment of ANP, per se, is commonly relegated to non-surgical approaches. This is in contrast to clearly diagnosed conditions of nerve compression resulting in classic radiculopathy. ANP is regularly associated with symptomatic cervical stenosis (CS), which often improves with surgery. We hypothesize that ANP associated with CS is often an axial manifestation of nerve compression or axial radiculopathy (AR). As such, it would be expected to respond favorably to surgical decompression. This study examines the response of AR to surgical decompression in patients with symptomatic CS.

Methods: From June 2013 to October 2016, 800 patients undergoing cervical decompression were retrospectively evaluated. Indication for surgery was symptomatic CS based on clinical presentation, diagnostic radiologic studies, and diagnostic nerve blocks confirming concordance of observed pathology with symptoms. Patients were grouped I - V, based on their preoperative axial pain percentage: I $\leq 59\%$ (n=366), II 60-69% (n=72), III 70-79% (n=109), IV 80-89% (n=130) and V 90-100% (n=123). Preoperative and postoperative patient-reported outcomes data, including a visual analog scale (VAS) and a neck disability index (NDI), were collected. Estimated blood loss (EBL), length of surgery (LOS) and intraoperative complications were extracted from electronic health records.

Results: Mean follow-up was four months. Significant reductions ($p < .05$) in VAS and NDI from preoperative to postoperative were observed for the entire sample. Patients in group II reported the greatest improvement in VAS while patients in group IV reported the greatest improvement in NDI. Mean EBL and LOS values for the entire sample were 86.09 mL and 62.63 minutes, respectively. Three complications were identified (0.38%).

Conclusion: Our study suggests that, in some instances, ANP associated with CS arises from nerve compression. This AR is successfully treated with surgical decompression.

411 Surgical Outcomes In Patients With Congenital Cervical Spinal Stenosis

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Introduction: Congenital Cervical Spinal Stenosis (CCSS) is a condition which predisposes patients with cervical spondylosis to cervical spondylotic myelopathy (CSM). Surgical outcomes data is lacking regarding CCSS patients treated for myelopathy. Here, we compare surgical outcomes of CSM patients with and without CCSS.

Methods: Retrospective chart review was performed of CSM patients who underwent decompression/fusion surgeries from 2010-2016. CCSS patients were identified using the Torg-Pavlov ratio (TPR) or lateral mass/canal diameter (LM/CD) ratio on lateral cervical radiographs. Pre- and post-operative outcome measures were assessed using the modified Japanese Orthopedic Association (mJOA) and EuroQol five-dimensions questionnaire (EQ5D).

Results: Of 208 patients, LM/CD identified 72 CCSS patients, TPR identified 85, with an overlap of 28. Multivariable logistic regressions were performed adjusting for age, race, gender, BMI, and age-adjusted Charlson Score. On preoperative EQ5D, TPR-diagnosed CCSS patients were 50% less likely to report extreme pain/discomfort, and 1.86 times more likely to report a health-index score greater than the median compared to patients without TPR-diagnosed CCSS. They were 55% less likely to report some problems performing/inability to perform usual activities, 48% less likely to report moderate/extreme anxiety/depression, and 1.95 times more likely to report a health-index greater than the median on earliest post-operative EQ5D. At one year, they were 48% less likely to report moderate/extreme anxiety/depression, and 1.88 times more likely to report a health-index greater than the median. On earliest post-operative EQ5D, LM/CD-diagnosed CCSS patients were 58% less likely to report some problems performing/inability to perform usual activities, and twice as likely to report extreme pain.

Conclusion: Postoperatively, compared to non-CCSS patients, CCSS patients were more likely to report better/equal quality of life for all aspects with the exception of pain in the LM/CD CCSS group. Further study is warranted to determine the cause for increased post-operative reported pain in LM/CD CCSS patients.

412 Complication Rates of Spine Surgeries in Patients Aged 80 or Over: A Single-Center Retrospective Series and Review of Literature

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Introduction: Spinal disorders such as metastatic spinal tumors, degenerative spine disease, and deformity are becoming increasingly more prevalent due to population aging. Hence, the demand for spinal surgery in the elderly, especially aged over 80, is dramatically increasing. Thus, the objective of this study was to summarize the overall clinical outcomes of this high-risk cohort and understand factors associated with perioperative complications.

Methods: Medical records of patients aged 80 or older undergoing spinal procedures from 2010 to 2015 in a single-center were retrospectively reviewed, which included 133 patients. Baseline characteristics such as age, sex, preoperative diagnoses, and co-morbidities as well as operative data including and 30-day perioperative medical (cardiac complications, respiratory complications, deep vein thrombosis, urinary tract infection) and surgical complications (reoperation, surgical site infection) (30D-MSC) were collected. Next, 133 patients were divided into the following two groups: 16 patients with 30D-MSC (Group 1, 12.0%) and 117 patients without (Group 2, 88.0%) and then statistically analyzed.

Results: With regards to baseline characteristics, statistically significant intergroup differences were noted in the average age (81.2 ± 1.8 (Group 1) versus 84.2 ± 3.0 (Group 2), $p < 0.0001$), the average operative time (566.6 ± 312.0 minutes versus 284.0 ± 222.5 minutes, $p < 0.0001$), and indications for operations (neoplastic pathologies: 25.0% versus 6.8%, $p = 0.04$). On the contrary, variables such as sex, estimated blood loss, the location of the operations, surgical approaches, and spinal fusion procedures were not correlated with 30D-MSC with statistical significance. In multivariate analysis, longer operative time ($p < 0.0001$) and younger age ($p < 0.001$) were independently associated with increased 30D-MSC.

Conclusion: Spine surgery in patients aged 80 or over resulted in an acceptable perioperative complication rate of 12.0%. This needs to be further investigated in future prospective studies to better address the safety feature and cost-effectiveness of spine surgeries in this high-risk cohort and facilitate judicious patient selection.

413 The Surgical Management of Giant-Invasive Spinal Schwannomas; Experience over 15 years from a Single Tertiary Spinal Referral Centre

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Introduction: Spinal schwannomas are the most common primary spinal tumour and are usually benign, slow-growing lesions that become symptomatic when compression of the neural elements occurs. 'Giant invasive' schwannomas (GIS), are a rare sub-type of these lesions, characterized by bony erosion and invasion through myofascial planes, that pose distinct surgical challenges.

Methods: An analysis of a prospectively collected series of patients with a histo-pathological diagnosis of spinal schwannoma was performed from 2003–2018 at a single tertiary spinal referral centre. Presentation, perioperative and recurrence data was compared between patients with GIS and those with non-GIS using chi-square and univariable logistic regression.

Results: 15 patients were judged to have 'giant invasive' schwannomas (type IV or V on the Sridhar scale) out of a total of 82 patients. The GIS group had a higher rate of urinary dysfunction at presentation compared to the non-invasive group (odds ratio (OR) = 4.29[95%CI: 1.14–16.20]; p=0.023). The mean largest diameter of tumour at presentation in the GIS group was 5.87[±1.4] cm. The likelihood of achieving a subtotal excision was similar in the GIS group (OR=0.99[0.19-5.13]; p=0.99), but the GIS group had a significantly higher rate of instrumented fixation (n=13; 87% versus n=17; 34%, p=<0.0001). One patient in the GIS group (7%) required a second operation within 30 days, compared to 0 patients in the non-invasive group. There was no radiological recurrence in the GIS group (mean follow up 53.8[±11.6] months), compared to 9% (n=6) in the non-invasive group (mean follow up: 42.3[±8.7] months). Two patients required revision surgery after radiological recurrence in the non-invasive group at 3 years and 8 years after index surgery.

Conclusion: Giant invasive spinal schwannomas are rare, and have a higher rate of urinary dysfunction at presentation. These lesions can be successfully managed with microsurgical resection which mandates instrumented reconstruction in most cases.

414 Validation of a Wireless, Non-Optical System for Measurement of Intra-Operative Spine Alignment

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Introduction: Sagittal alignment of the spine is closely related to quality of life scores and malalignment is a cause of pain and disability. Stabilization of the spine and restoration of normal posture and spine alignment using osteotomies and/or fusion is a major goal of spine surgery. Current methods of intra-operative measurements are inadequate for real-time measurement of segmental and overall spinal alignment.

Methods: The intra-operative spine alignment monitoring system, utilizes disposable, miniaturized wireless MEMS (micro-electromechanical) sensors, advanced signal processing, and error compensation algorithms to provide accurate dynamic measurement of sagittal plane intervertebral angles and overall spinal alignment. Each wireless sensing module (WSM) is battery-powered and communicates information wirelessly to the display unit. The goal was to provide continuous tracking of spine alignment without reliance on repeated imaging. Registration is performed with a single fluoroscopic image. The system accuracy was validated via benchtop and simulated use testing. Benchtop testing simulated motions that could be encountered during surgery using precision stages that allowed for accurate reference values for angular measurements. Simulated clinical use testing using radiopaque Sawbones® phantoms compared manual Cobb angle measurements of Lordosis and Kyphosis on lateral fluoroscopic images to the values measured by the spine alignment monitoring system.

Results: In benchtop testing, mean difference between the reference values and the GALILEO™ Spine Alignment Monitoring System measurements was 0.0 degrees with a standard deviation of 0.9 degrees (n= 90). In simulated use testing, mean difference between the cobb angle measurements and the spine alignment monitoring system measurements was 1.5 degrees with a standard deviation of 1.9 degrees (n = 30)

Conclusion: Benchtop and simulated use testing of the spine alignment monitoring system, a low cost, non-optical, disposable wireless system for dynamic measurement of intra-operative spine alignment demonstrated high accuracy and repeatability. This approach could provide surgeons with practical, real-time measurements of segmental and overall alignment, thus allowing attainment of sagittal balance.

415 The Timing and Management of Surgical Site Infections after Posterior Spinal Fusion

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Introduction: Surgical site infection (SSI) is a common complication after posterior spinal fusion (PSF). Management of SSI can include operative wound washouts, hardware revision including replacement or removal, as well as long-term antibiotics. Here, we examined the timing and management of SSI after PSF.

Methods: We performed a retrospective analysis of all patients who underwent posterior spinal fusion and developed SSI at a university-affiliated tertiary-care hospital from 2000 to 2015. Clinical and demographic data and outcome measures were collected. Regression analysis was performed using stepwise logistic regression.

Results: Time-to-infection was significantly lower for gram-negative infection than for gram-positive infection (16.0 v. 26.0 days, RR 1.63, $p=0.001$) or gram-negative polymicrobial infection (16.0 v. 28.0 days, RR 1.75, $p=0.035$). Gram-negative infections were less likely to delayed infection (infection occurring after postoperative day 30) (OR 0.19, $p=0.034$). Delayed infection was more likely when a higher number of levels were fused (OR 1.14, $p=0.025$). Gram-negative polymicrobial infections were more common with a higher comorbid disease burden (OR 1.49, $p=0.009$), and a higher number of levels fused (OR 1.17, $p=0.038$). Prolonged antibiotics use (>12 weeks) was associated with a higher comorbid disease burden (OR 1.47, $p=0.002$). Reoperation was associated with a higher number of levels fused (OR 1.18, $p=0.023$) and a higher comorbid disease burden (OR 1.66, $p=0.006$). Hardware removal was associated with a higher comorbid disease burden (OR 1.67, $p=0.005$) and smoking history (OR 10.03, $p=0.036$).

Conclusion: Gram-negative infections present more quickly than other SSI. Patients with larger fusion constructs are at higher risk of gram-negative polymicrobial infections, delayed infections, and infections requiring reoperation. Patients with a higher comorbid disease burden are more likely to have gram-negative polymicrobial infections requiring aggressive and prolonged management.

416 Surgical Site Infection in the Intensive Care Setting after Posterior Spinal Fusion

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Introduction: Posterior spinal fusion (PSF) is used to treat numerous spinal pathologies, but can be complicated by postoperative infection. Patients undergoing PSF who require postoperative ICU admission likely represent a high-risk subpopulation, and factors associated with complications for them may differ from other PSF patients. Identifying factors associated with such complications could help risk stratify patients and tailor clinical management.

Methods: We retrospectively analyzed all posterior spinal fusions performed at our institution from 2000 to 2015. Posterior spinal fusions were identified using Current Procedural Terminology (CPT) codes. Patients who were admitted to the ICU postoperatively were identified. Data was collected on patients' baseline patient clinical characteristics, procedural and intraoperative factors, and antimicrobial management. Multivariable analysis was used to identify factors independently associated with the outcomes of interest.

Results: 688 patients were identified. History of PVD (OR 2.62 [1.22, 5.61] $p=0.013$) and having a staged procedure (OR 5.87 [2.20, 15.64], $p<0.001$) both predicted having a postoperative infection, and BMI showed a trend toward significance (OR 1.04 [0.99, 1.08], $p=0.093$), and having more participants in the surgery was associated with gram negative infections specifically (OR 1.17 [1.01, 1.36], $p=0.026$). Patients were more likely to undergo reoperation within 30 days if their index surgery was staged (OR 3.90 [1.41, 10.80], $p=0.009$), the surgery was minimally invasive (OR 4.98 [1.22, 20.34], $p=0.025$), and there were people in the operating room (OR 1.09 [1.03, 1.17], $p=0.006$). Patients with diabetes were less likely to undergo reoperation within 30 days (OR 0.39 [0.15, 1.00], $p=0.049$). Patients were less likely to undergo washout if they were older (OR 0.96 [0.93, 0.99], $p=0.006$) or had a cervical surgery (OR 0.17 [0.04, 0.80], $p=0.024$).

Conclusion: There are specific risk factors for wound infection and reoperation for wound infection among patients admitted to the ICU after PSF. Staged procedures and comorbid conditions, such as PVD and obesity, put patients at higher risk for wound infection, but comorbid conditions may also persuade spine surgeons to pursue conservative management rather than surgical intervention for the management of wound infections.

417 Three Month Cost of Nonoperative Care in Patients with Symptomatic Lumbar Herniated Disc prior to Microdiscectomy

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Introduction: Patients diagnosed with a lumbar intervertebral disc herniation trial conservative therapies for symptomatic management prior to microdiscectomy. The cost of maximal non-operative therapy (MNT) in this population remains unknown. The purpose of this study was to characterize the utilization of MNT in patients diagnosed with a symptomatic lumbar intervertebral disc herniation 3-months prior to microdiscectomy.

Methods: Medical records from patients diagnosed with lumbar intervertebral disc herniation undergoing 1,2, or 3-level index microdiscectomy procedures between 2007-2017 were gathered from a large insurance database. Records were searchable by International Classification of diseases (ICD) codes, Current Procedural Terminology (CPT) codes and generic drug codes specific to Humana. Utilization of MNT 3-months after initial lumbar herniation diagnosis in adult patients was of interest. "Utilization" included cost billed to patients, prescriptions written, and quantity of units billed.

Results: A total of 13,106 of 571,754 (2.3%) eligible patients underwent lumbar microdiscectomy. Demographically, 25.5% of the population had type 2 diabetes and 15.8% were obese (BMI >30 kg/m²). MNT breakdown was as follows: 3,086 (23.5%) used NSAIDs, 7,822 (59.7%) used opioids, 5,024 (38.3%) used muscle relaxants, 3,744 (28.6%) received LESI, 2,146 (16.4%) attended PT/OT, 1,628 (12.4%) received chiropractor treatments, 12,227 (93.3%) received lumbar spine imaging and 636 (4.9%) presented to the ED. The total cost associated with all MNTs during the 3-month study

period was \$13,205,924. Lumbar imaging comprised the greatest percentage of the MNT total cost (\$8,289,398; 62.8%), followed by LESI (\$3,321,476; 25.2%), ED visits (\$591,657; 4.5%), and opioids (\$317,734; 2.4%). There were 34,610 prescriptions for lumbar spine imaging, 19,425 prescriptions for opioids, 11,703 prescriptions for LESI, 8,881 prescriptions for chiropractor visits, and 8,637 prescriptions for muscle relaxants. Our cohort billed for 1,050,953 opioid pills, 415,991 muscle relaxants, and 12,407 LESI during the 3-month study period.

Conclusion: Our findings emphasize the substantial resource utilization of MNT in the 3-months between initial lumbar intervertebral disc herniation diagnosis and index microdiscectomy.

418 Retrospective Analysis of the Relationship Between Post-Operative Delirium and Quality-of-Life Outcomes in Patients Who Underwent Spine Surgery

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Introduction: Post-operative delirium has a multifactorial etiology and is associated with poor hospital-based outcomes. Studies have identified risk factors associated with its development including environmental and patient-specific aspects. However, there is a paucity of literature investigating the relationship between post-operative delirium and quality of life (QOL) outcomes in spine patients. We examined the incidence and severity of post-operative delirium in patients undergoing spine surgery, and investigated the relationship between delirium and QOL metrics.

Methods: A retrospective cohort study was conducted among patients undergoing lumbar fusion, cervical laminoplasty, and cervical laminectomy with fusion from 2014-2018. Patients were identified as delirious by brief confusion assessment method (bCAM) and the confusion assessment method ICU (CAM-ICU) screening tools. Established risk factors for delirium were collected from the electronic medical record including comorbidities, lab values, and post-operative events. The Pain Disability Questionnaire (PDQ) and the Patient Health Questionnaire-9 (PHQ-9) assessed QOL. Data was analyzed using a combination of multivariable linear and logistic regressions.

Results: Of 4466 patients included, 123 (2.8%) were bCAM positive and 113 (2.5%) were CAM-ICU positive, yielding 219 (4.9%) patients that became delirious at all during their hospital course. The median number of days delirious was two. Age, ICU admission, elevated inflammatory markers, anemia and poor presurgical PDQ functional status scores were associated with development of delirium. At 3 months post-surgery, development of post-operative delirium was associated with less improvement in PDQ functional status scores.

Conclusion: Incidence of post-operative delirium in our population was lower than the 12.5%-65% quoted in the literature for orthopedic procedures, suggesting a difference between spine and other orthopedic procedures. Most episodes of delirium resolved within two days. Finally, the interaction between post-operative delirium and PDQ functional status appears to be bidirectional, suggesting a complex relationship and a possible role of functional status evaluation in assessing long-term impacts of post-operative delirium.

420 Utility of Patient Specific Rod Instrumentation in Deformity Correction: Single Institution Experience

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Introduction: Patient-specific instrumentation is an emerging technology with the promise of a better fit to patient anatomy. With the advent of deformity correction planning software, prefabricated rods can be created and mitigate the need to bend rods in the operating room.

Methods: A retrospective chart review was completed and all patients in which a Medicea UNiD rod was placed for a thoracolumbar fusion were included. A minimum of 3 week follow up upright 36 inch lateral radiograph was necessary for analysis. 21 patients had Medicea UNiD rods placed, 4 were excluded (1 for cervicothoracic fusion, 3 for incomplete follow up). Pelvic parameters were documented from the preoperative, surgical plan, and postoperative radiographs using Surgimap Spine (Nemaris Inc, New York, NY, USA). All radiographs in this study were upright 36 inch lateral radiographs and part of a formal scoliosis series. The parameters for the UNiD rods was based on the surgical plan created by one surgeon (PJH). Paired T-tests were completed to compare the preoperative with surgical plan pelvic parameters and surgical plan with postoperative pelvic parameters.

Results: Average lumbar lordosis, pelvic tilt, sacral slope and sagittal vertical axis in preoperative radiographs were 35.12 degrees, 24.82 degrees, 28.65 degrees, and 65.65 mm. In postoperative imaging, lumbar lordosis, pelvic tilt, sacral slope and sagittal vertical axis were 57.00 degrees, 18.00 degrees, 35.71 degrees, and 21.59 mm, respectively. There was a statistically significant difference in pelvic tilt, sacral slope, lumbar lordosis, and sagittal vertical axis between the preoperative film and surgical plan ($p < 0.001$). There was no statistically significant difference between the surgical plan and postoperative film for any pelvic parameter ($p > 0.05$).

Conclusion: Cases in which prefabricated rods were utilized demonstrated improved spino-pelvic alignment. Additionally, there was no statistical difference between the surgical plan and postoperative imaging in terms of pelvic parameters. There may be additional benefits to prefabricated rods which include decreased operative time and decreased rod fracture and these should be studied in the future. The prefabricated rod can be a vital tool in the deformity surgeon armamentarium.

421 The Use of Antibiotic-impregnated Poly-methyl Methacrylate (AI-PMMA) for Spinal Reconstruction in Pyogenic Spondylitis: Efficacy and Safety

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Introduction: Surgical treatment of spinal osteomyelitis and discitis remains challenging due to the risk of implant colonization. We sought to demonstrate the safety and efficacy of the use of antibiotic-impregnated poly-methyl methacrylate (AI-PMMA) in spinal reconstruction for pyogenic spondylitis.

Methods: We retrospectively analyzed prospectively collected data of consecutive patients who underwent AI-PMMA interbody fusion for pyogenic spondylitis from Dec 2011 to October 2016 at a single institution with multiple surgeons. We excluded patients <18-year-old and those who had previous spine surgery in the same area. PMMA cement was mixed with Tobramycin and Vancomycin powder. The AI-PMMA was introduced into the disc space as 5mm beads, then contoured to fit the disc space. The primary outcome was fusion as determined by the Suk's criteria. Secondary outcomes were PMMA-specific or infection-related complications, VAS, and ambulation pre- and postoperatively. We collected data on confounders for fusion and infection. The patients were followed up by phone, clinic visits, and XR or CT for at least 24 months. Descriptive statistics were used for fusion and complications outcomes. Univariate analyses for categorical data was used for clinical outcomes. $P < 0.05$ was considered significant.

Results: Sixty-five patients were included in the study. Patient demographics and perioperative characteristics were presented in tables 1 and 2. The mean follow-up interval was 22.2 ± 18.9 months. AI-PMMA levels fusion rate was 100% (table 3). There was no cement extravasation or embolism. Four patients (6.2%) developed a recurrent infection at the same or adjacent level requiring revision surgery. Five patients (7.7%) died on long-term follow-up due to non-PMMA/infection-related causes (table 4). There were significant differences in VAS and ambulation rate pre vs. postoperatively (table 5).

Conclusion: We demonstrate that the application of AI-PMMA for spinal reconstruction in pyogenic spondylitis is safe and efficacious. The study is limited by its retrospective design.

422 Improvement in Sexual Function Following Degenerative Lumbar Spendylolisthesis Surgery

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Introduction: There is a paucity of investigation on the impact of spendylolisthesis surgery on sexual function. We investigated factors predictive of improved sexual function following surgery.

Methods: This was an analysis of the prospective Quality Outcomes Database registry of surgery for grade 1 degenerative lumbar spendylolisthesis. 221 patients were included who were sexually active and had both baseline and two-year sexual function follow up. Data was collected at baseline and two-year follow up. Sexual function was assessed by Oswestry Disability Index question, "With regards to pain, how would you say your sex life is?" The six, ordinal responses ranged from "Normal and causes no extra pain" (no dysfunction, score 0) to "Not sexually active because of pain" (most dysfunction, score 5). Univariate and multivariate analyses were conducted.

Results: At baseline, 179 (81.0%) patients had sexual dysfunction. Of those with baseline dysfunction, 126 (70.4%) improved in sexual function at two years. Of the 42 patients with no baseline dysfunction, 12 (28.6%) experienced some dysfunction post-operatively. Those receiving fusions ($n=200$) had greater baseline sexual dysfunction (83.5% vs. 57.1% with dysfunction, $p=0.008$) and two-year dysfunction (51.0% vs. 23.8% with dysfunction, $p=0.02$) compared to those receiving decompressions only ($n=21$). Overall, patients improved significantly in sexual function following surgery (baseline 19% vs. post-op 51.6% with no dysfunction, $p < 0.001$). Both those receiving fusions (baseline 16.5% vs. post-op 49% with no dysfunction, $p=0.008$) and decompressions only (baseline 42.9% vs. post-op 76.2% with no dysfunction, $p=0.03$) improved significantly at 24 months. In multivariate analyses, leg pain predominant presentation ($OR=7.6$, 95% CI [1.6-59.7], $p=0.02$; reference=back pain), baseline NRS back pain ($OR=1.3$, 95% CI [1.04-1.6], $p=0.02$), and surgeries utilizing MIS techniques ($OR=3.9$, 95% CI [1.6-10.1], $p=0.003$) were associated with improved sexual function at two-year follow up.

Conclusion: A majority of patients presenting with sexual dysfunction improved following surgery. Both fusion and decompression patients significantly improved their sexual function with spendylolisthesis surgery. Leg pain predominant presentation, magnitude of baseline back pain, and MIS were significant predictors of improved sexual function following spendylolisthesis surgery.

423 Dynamic Magnetic Resonance Imaging Parameters for Objective Assessment of the Magnitude of Tethered Cord Syndrome in Patients with Spinal Dysraphism

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Introduction: Dynamic magnetic resonance imaging (MRI)-based criteria for diagnosing magnitude of tethered cord syndrome (TCS) in occult spinal dysraphism are proposed.

Methods: In this prospective, case-control design study, MRI lumbosacral spine was performed in 51 subjects [pilot group(n=10) without TCS (for defining radiological parameters); control group(n=10) without TCS (for baseline assessment); and, study group (n= 31) with spinal dysraphism (thick filum terminale[n=12]; lumbar/lumbosacral meningocele[n=6]; and, lipomyelomeningocele[n=13]). The parameters compared in control and study groups included: Oscillatory frequency(OF), difference in ratio, in supine/prone position, of distance between posterior margin of vertebral body and anterior margin of spinal cord (oscillatory distance,OD), with canal diameter, at the level of conus as well as superior border of contiguous two vertebrae above that level; delta bending angle(DBA), difference, in supine/prone position, of angle between longitudinal axis of conus and that of lower spinal cord; and, sagittal and axial root angles, subtended between exiting ventral nerve roots and longitudinal axis of cord were assessed. An outcome assessment at follow-up was also done.

Results: In the study group (cord tethered), significantly less movement at the level of conus(OF0, p=0.013) and one level above(OF1, p=0.03); and, significant difference in DBA(p=0.0), were observed in supine and prone positions, compared to controls. Ventral nerve root stretching resulted in sagittal/axial root angle changes. MedianOF(0.04) in the lipomyelomeningocele group was significantly less than that in control group(0.23). Median OF was also lesser in patients with thick filum terminale or meningocele. Difference in median sagittal and axial root angles among study and control groups was statistically significant(p=0.00). Follow-up outcome after detethering did not correlate with either OF or DBA

Conclusion: New dynamic MRI-based parameters to establish the presence and magnitude of TCS have been defined. OF measured extent of loss of translational cord displacement in supine and prone positions; DBA defined the relative angulation of conus with lower spinal cord; and, sagittal and axial root angles represented ventral nerve root stretching. The difference in OF or DBA was minimum in the group with thick filum terminale and progressively increased in the groups with lipomyelomeningocele and meningocele.

424 Outpatient Posterior Lumbar Fusion May be Associated With Higher Reoperations: Insights from a National Surgical Registry

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Introduction: Outpatient spine surgery has recently been increasingly employed as a way to drive down inpatient cost and maximize access. However, concerns regarding the safety of outpatient surgery have recently emerged. In the current project, we sought to compare 30-day outcomes between inpatient and outpatient surgery for Posterior Lumbar Fusion (PLF), a common lumbar spine procedure.

Methods: The National Surgical Quality Improvement Program (NSQIP) database was queried for patients undergoing PLF between 2012 and 2016. Only patients with an American Society of Anaesthesiology (ASA) grade of 1 or 2 were selected with the objective to have a homogeneous cohort. Predictor of interest was the setting of surgery: outpatient vs inpatient. Outcomes of interest included 30-day postoperative complications, reoperations, and readmissions. Univariate analysis and multivariable logistic regression models were fitted using the unique set of predictors for each outcome.

Results: A total of 29,830 patients were identified of which, 3.4% (n=1,016) were performed in an outpatient setting while 96.6% (n=28,814) were performed inpatient. Patients undergoing outpatient surgery were more likely to be younger (Age 18-40: 16.5% vs 13.3%, p=0.008), more likely to be males (53.9% vs 45.4%, p<0.001) and more likely to be diabetic (10.4% vs 8%, p=0.005). On multivariable analysis, after adjusting for an array of patient factors, outpatient surgery was associated with higher reoperations (OR 1.6, 95% CI 1.1-2.4, p= 0.02) while readmissions and complications were found to be similar between the two groups.

Conclusion: Our results indicate that PLF performed in an outpatient setting might be associated with higher reoperation rate even in low-risk patients. As trend towards outpatient surgery continues to increase, these results should help caution surgeons and policy advisors further in prioritizing patient selection when opting for outpatient setting.

425 Nuchal Thickness and Risk of Surgical Site Infection in Posterior Cervical Spine Operations

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Introduction: Surgical site infections (SSI) are a common post-operative complication which increase cost, length of stay, and morbidity. Many risk factors have been identified including body mass index (BMI). However, BMI itself may be less important than the distribution of tissues. Several studies have found that lamina to skin thickness is more important than BMI. The purpose of this study was to evaluate whether nuchal thickness increases risk for post-operative SSI in posterior approach cervical spine operations.

Methods: A retrospective review of 180 consecutive patients who underwent posterior cervical spine surgery from 2012-2014 at the University of Florida was performed. Nuchal thickness was measured from the ventral most point of the spinous process of C5 to the skin on mid-sagittal pre-operative imaging. Previously demonstrated risk factors for surgical site infections (SSI) were collected including diabetes status, BMI, smoking status, duration of anesthesia, prior operations, and subcutaneous layer thickness. Infections were identified according to the Centers for Disease Control (CDC) definitions for surgical site infections (SSI). Univariate and multivariate analyses were performed by a biostatistician.

Results: 180 patients were identified. Twenty patients (11%) had surgical site infections. Smoking status, nuchal thickness of greater than 55 mm or less than 29.8mm, and subcutaneous fat thickness were all associated with SSI. Age, diabetes, BMI and use of intraoperative antibiotic powder were not associated with infection. On multivariate analysis adjusted for smoking status, nuchal thickness, subcutaneous fat thickness and the ratio of subcutaneous fat to nuchal thickness all remained associated with SSI.

Conclusion: Nuchal thickness and subcutaneous fat thickness are associated with increased risk of SSI in patients undergoing posterior cervical spine surgery. Risk of infection increases with very thin and very thick nuchal measurements. This knowledge of this may assist surgical decision making and pre-operative optimization of patients.

426 Predictive Factors for Conservative Medical Management in Urban Population Patients Presenting with Spinal Epidural Abscess: A Retrospective Bi-Institutional Study

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Introduction: Despite rising incidence of Spinal Epidural Abscess (SEA) in recent years, there are few studies on predictive factors for failure of medical therapy, and none specifically examining the US urban populations.

Methods: Retrospective review was performed of medical records in two large institutions in underserved urban areas in the US. First, we compared patients who underwent surgery with those who were managed medically first; second, we compared patients who failed conservative medical management and required surgery to those who were managed only medically. Demographics, pre-operative lab values, comorbidities, locations of SEA, and pre-operative and postoperative Frankel grades were reviewed. Univariate analysis followed by multivariate logistic regression was used to identify predictors of patients requiring surgery and predictors of failing medical therapy.

Results: We identified a total of 103 patients with SEA between 2 large institutions. Average age was 58.2 and 57.3% were male. Out of 103 patients, 52 were managed medically initially. Of those 21 (40.4%) failed medical management and required surgery. Those who were older and with a Frankel grade B or better (had no or mild neurologic deficit) were more likely to be managed conservatively at first. Significant predictors of medical therapy failure on multivariate analysis were a history of diabetes (OR 12.1 95% CI: 1.6-89.9, $p=0.015$) and an abscess in the cervical spine (OR 8.7 95% CI: 1.1-66.7, $p=0.038$). Interestingly, a history of alcohol abuse was protective against medical therapy failure (OR 0.01 95% CI: 0.001-0.300, $p=0.006$).

Conclusion: Older patients with milder neurologic deficits are likely to be managed conservatively first. However the ones with diabetes, and cervical abscesses are likely to fail that management and require surgery. An unexpected finding was that alcohol abuse seems to be protective against failing medical therapy in this population. Further studies are warranted to further validate these findings in underserved urban populations.

427 Maximizing Sacral Chordoma Resection with Augmented Intra-operative Navigation

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Introduction: The primary treatment modality for reducing recurrence and optimizing outcomes in patients with sacral chordomas is en bloc surgical resection with wide, negative margins. Here we describe our use of intra-operative neuronavigation (IONN) coupled with MRI-CT fusion superimposed on 3D CT reconstructions to intra-operatively identify both bony and soft tissue margins for maximal tumor resection.

Methods: A single institution retrospective chart review was completed from 2016-2017 to encompass our experience of six consecutive patients who had sacral lesion resections using our described navigation protocol. We collected data on patient demographics, previous surgeries, radiation therapy, pre-operative exam, spinal levels involved, dural involvement, EBL, surgery time, tissue diagnosis, follow up, post-operative exam, complications and recurrence. Primary outcome was gross total en bloc resection with negative margins. Secondary outcomes were tumor residual or recurrence at follow up.

Results: Gross total, wide, en bloc resection was achieved in all patients. The average age was 56.7 ± 5.2 years (4M:2F). Four patients (66.7%) had prior surgical resections. One patient (16.7%) had previous proton beam radiation therapy. Negative surgical margins were achieved in five (83%) of the six patients. In the remaining one patient, dissection planes were close to the lateral tumor margins to preserve S3 nerves. MRI after 1 year revealed no residual or recurrence. The most common levels involved were S4-S5. All patients had a stable or improved neurologic exam after en bloc surgical resection. The average follow up was 5.4months + 84.6 days. No patient had residual or recurrent tumor at follow up.

Conclusion: MRI-CT fusion and 3-D reconstruction techniques to aid intra-operative surgical resection of sacral chordomas are not well represented in the literature. The safety and feasibility of this application is demonstrated and can be used for confirming tumor margins intra-operatively, which may improve progression free survival and overall survival.

428 Human Mesenchymal Stem Cell Morphology, Migration, and Differentiation on Micro and Nano-Textured Titanium

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Introduction: Early attachment, rapid migration, and improved differentiation of osteoblasts are necessary to colonize the surface of biomedical implants, preventing biofilm formation and implant-associated infection. This study characterized the morphology, migration and differentiation of human mesenchymal stem cells (hMSCs) on smooth (Ti6Al4V and PEEK), specifically engineered macro-micro rough (MM) and macro-micro-nano rough (MMN) topographies.

Methods: hMSCs were cultured following established methods. Epifluorescence microscopy was used to quantify morphology from 2 -72hrs (data not shown) and migration over a 10-hour window beginning at 6hrs post seeding. Differentiation was assayed through expression of early marker alkaline phosphatase, ALP, and mature marker osterix, OSX. Significance was determined via ANOVA.

Results: hMSCs demonstrated shifting morphologies, Figure 1, with smooth surfaces moving towards elongated morphologies typical of fibroblasts indicated by low roundness and high aspect ratios. In contrast, hMSCs on MM surfaces demonstrated low roundness and low aspect ratios typical of cuboidal osteoblasts. Finally, hMSCs on MMN surfaces demonstrated the highest roundness coupled with low aspect ratios typical of stellate morphologies observed in mature osteoblasts/osteocytes and reached a steady-state stellate morphology by 24hr, whereas the other surfaces didn't demonstrate steady-state morphology until 72hrs. An evaluation of the migration revealed hMSC velocity was highest on MMN surfaces coupled with low directionality indicating rapid random migration, Figure 2.A.&B. Finally, differentiation outcomes correlated well with morphology results showing significantly higher expression of early osteoblast marker, ALP, at 3 days and maturing osteoblast marker, OSX, at 10 days on MMN surfaces as compared to all other surfaces, Figure 2.C.&D.

Conclusion: These outcomes demonstrate the combined macro-micro-nano topography of the MMN surface results in rapid random migration necessary to colonize a surface, the evolution of a stellate morphology typical of mature osteoblasts/osteocytes, and a rapid progression through the early and mid-osteogenic differentiation markers, ALP and OSX respectively.

429 A Retrospective Cohort Analysis of the Effects of the Renin-angiotensin System Inhibitors on Spinal Cord Dysfunction and Imaging Features of Spinal Cord Compression in Symptomatic Cervical Spondylosis

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Introduction: Cervical spondylosis may lead to spinal cord compression, poor vascular perfusion, and eventually cervical myelopathy. Studies suggest a beneficial effect of renin-angiotensin system (RAS) blockers in the brain, but there is limited data on their effects in the spinal cord. We investigated whether RAS blockers and other antihypertensive drugs are correlated with preoperative clinical/functional status and radiological markers of cord compression in patients with symptomatic cervical spondylosis.

Methods: Retrospective chart review of 121 symptomatic degenerative cervical stenosis patients. Demographic data, comorbidities, antihypertensive medications, and functional status (including modified Japanese Orthopedic Association (mJOA) and Nurick grading scales) were collected. We evaluated % canal compromise, % cord compromise, surface area of T2 signal cord change, and pixel intensity of signal cord change compared to normal cord on T2-weighted MRI sequences.

Results: Of the 121 patients, 35.5% were female and 64.5% male; median age=57.7 years; 53.7% smokers; 24.8% diabetics. 70 patients (57.9%) had hypertension, of which 68 took anti-hypertensive medications: 21 angiotensin II receptor blockers [ARBs], 22 angiotensin-converting enzyme inhibitors [ACEIs], and 25 other medications). Patients treated with ARBs exhibited a higher signal intensity ratio (i.e., a lower signal intensity in the compressed cord area) compared to those untreated ($p=.03$). Patients receiving ACEI's or diuretics had lower preoperative mJOA (i.e., worse functional status) compared to non-hypertensive patients ($p=.003$, $.01$, $.01$). Hypertensive patients and those receiving calcium antagonists or diuretics had higher preoperative Nurick scores (i.e., worse functional status) compared to non-hypertensive patients ($p=.01$, $.02$, $.01$).

Conclusion: In cervical spinal cord compression patients, RAS inhibitors were associated with higher SIR (or less signal intensity changes) than untreated patients. We observed that cervical stenosis patients with hypertension and treated with ACEIs/diuretics/calcium antagonists displayed worse preoperative functional status compared to non-hypertensive patients. Further studies are needed to elucidate a neuroprotective effect of the RAS inhibitors for spinal cord damage.

430 Use of SPECT Imaging for Hypermetabolic Facet Identification in Diagnosis of Axial Pain

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Introduction: Many studies have examined hybrid SPECT/CT in evaluating bone lesions of infectious or malignant nature. However, few have used SPECT/CT to identify degenerative facet joint disease. We aimed to determine the

incidence of hypermetabolic facet joints on SPECT/CT imaging in patients with axial neck or back pain to further elucidate the value of SPECT/CT imaging in identifying the etiology of pain generators.

Methods: A retrospective chart and imaging study of adult patients (age>18 years) who reported axial neck or back pain from the senior author (MYW) was conducted. 188 patients underwent high-resolution SPECT/CT imaging using a standardized spine-bone protocol between January 2010 and April 2018. Facet joints with increased radionuclide uptake on SPECT imaging were characterized as hypermetabolic. The number, level, and laterality of hypermetabolic facets were recorded for each patient based on a review of the nuclear medicine radiologist's report.

Results: Female gender was slightly more prevalent (51%) and the average age was 58 years (SD 12.9). 93 patients (49.5%) had evidence of hyperactive facets on SPECT study. 58 patients had multiple involved facets when compared to single level disease (35). Of those who had several facets affected, the majority had bilateral hypermetabolic signal (65.5%). Lumbar facets were the most commonly affected (66.6% of patients) followed by cervical (23.6%) and thoracic regions (9.6%).

Conclusion: In our series, half of all patients with axial neck or back pain were found to have hypermetabolic facets on SPECT/CT imaging, establishing degenerative facet joint disease as a common pain generator. The results support identification of sites for potential treatment in these patients, which has previously been challenging to elucidate. Therefore, SPECT/CT may be used to identify a treatable pathology less invasively than with facet joint injection or surgery and thus may also decrease the number of unnecessary interventions performed on patients.

431 Radiographic Implications of Anterior Column Reconstruction at the Upper Instrumented Vertebra

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Introduction: Treatment of adult spinal deformity (ASD) is with minimally invasive surgical (MIS) techniques are becoming increasingly more common. Sagittal plane deformities that were previously addressed with open posterior approaches are now successfully treated with MIS strategies. With limited morbidity, anterior column realignment (ACR) can offer segmental lordotic correction that rivals that of posterior osteotomies. The dogmatic approach is that an ACR cannot be performed at the upper instrumented vertebra (UIV) for fear of proximal junction kyphosis (PJK) is challenged. We present a series of patients who underwent MIS correction of ASD with an ACR at the UIV.

Methods: A retrospective review of the author's experience with lateral lumbar interbody fusion (LLIF) with ACR was conducted and all patients with ACR at the UIV were included. Spino-pelvic parameters were measured in standard fashion. Statistical significance was set a priori at $p < 0.05$.

Results: A total of 12 patients (7/12 Female, Average Age: 58) underwent ACR at the UIV during LLIF during the study period. ACRs were either single-level (7/12, 58.3%) or double-level (41.7%) and all rod instrumentation was singlet in nature. There were no rod fractures. Respectively, mean, minimum, and maximum changes were noted for SVA (-1.4, -6.4, +4.3), LL (+13.2, -2.0, +32), PI (+0.9, -1.0, +3.4), PT (-4.9, -12.5, +0.3). Excellent correction of PI-LL mismatch was noted (-9.5, -28.0, +1.2) for this procedure. An increase in SVA was associated with the tendency to develop PJK in these patients (2/12 patients, $p = 0.04$).

Conclusion: ACR at the UIV is durable option for addressing sagittal balance deformities with MIS techniques. PJK is significantly associated with a gain in SVA compared to pre-operative imaging. When contemplating ACR at the UIV, restoration of SVA is paramount.

432 Management Dilemmas in Congenital Craniovertebral Junction Anomalies and their Addressal

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Introduction: In craniovertebral junction (CVJ) anomalies, mechanical factors such as inadequate canal decompression, torticollis, and/or scoliosis, and occipital condylar-C1 lateral mass hypoplasia and atlantan stenosis may lead to lack of improvement following the primary surgery; implant-related factors, require implant revision/removal of the implant; and, the presence of surgical site infections may result in management difficulty. This study highlights the management related dilemmas encountered during surgery for craniovertebral junction anomalies.

Methods: The data of patients included their clinicoradiological assessment and operative records. The inclusion criteria included persisting respiratory compromise and/or neurological deterioration, failed primary procedure, repeat procedure for construct failure, infection at the surgical site, or wound dehiscence. Pure CM patients without bony anomalies were excluded from the study.

Results: 58 out of 504 patients with CVJ anomalies were recorded as having either a failed procedure, construct related problem, respiratory failure, neurological deterioration or wound related complication. Oral wound dehiscence, velopharyngeal insufficiency and inadequate decompression formed the main issues related to transoral surgery. A very high basilar invagination, torticollis and scoliosis resulted in overdistracted and torsion on the cord often leading to neurological deterioration and inadequate decompression of the cervicomedullary junction. Occipital condylar and C1 lateral mass assimilation, asymmetry and/or atrophy led to failure to adequately place the C1 lateral mass screws. Anomalies of vertebral artery course also led to management dilemmas. Atrophy of C2 isthmus is a lesser known cause of vertebral artery compromise during surgery in this region. Patients with preoperative severe respiratory compromise often persisted in this state following their successful surgery and required intermittent and prolonged ventilatory support.

Conclusion: Awareness regarding the likely difficulties encountered during the management of congenital craniovertebral junction anomalies will have a lasting effect on the long-term outcome of these patients

433 An Overlooked Cause of Neck Pain: Calcific Tendinitis of the Longus Colli

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Introduction: Acute calcific tendinitis of the longus colli muscle is a rare clinical entity that causes severe neck pain. This entity is not well recognized due to its non-specific presentation such as acute neck pain, neck stiffness, odynophagia or dysphagia. The importance of this disease with a review of the literature is presented.

Methods: We retrospectively reviewed the clinical data, radiological features, and laboratory reports of eight patients who were diagnosed with acute calcific tendinitis of the longus colli muscle presented in this article were seen at our institution between April 2008 and March 2015. We describe the clinical presentation, diagnosis, and treatment of acute calcific tendinitis of the longus colli muscle.

Results: There were 5 men and 3 women who ranged in age from 41 to 49 years (mean age: 44.5 years). The associated symptoms included neck pain, stiffness, odynophagia, and headache. The duration of symptoms varied from 2 days to 1 week. All patients showed calcific deposition inferior to the anterior arch of the atlas, and prevertebral effusion extending from C1 to C4. All patients were treated with NSAIDs and immobilization with a cervical brace, and most patients showed complete resolution of symptoms within 1 week.

Conclusion: We report eight cases of acute calcific tendinitis of the longus colli, and describe the symptoms and radiological findings in detail. Awareness of this rare, benign and self-limiting disease entity with characteristic radiologic findings is essential for early diagnosis and to avoid unnecessary medical and surgical interventions.

434 Predictive Model for Return to Work After Lumbar Spine Surgery in Canada

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Introduction: Work absenteeism after spine surgery is a significant contributor to financial and societal burden of spinal disorders. Identifying predictors for return to work (RTW) will help surgeons have a substantive personalized discussion with patients and promote realistic expectations prior to surgery. Our objective was to create a predictive model for RTW after elective lumbar spine surgery in Canada.

Methods: Data from a prospective multicenter registry (Canadian Spine Outcome and Research Network CSORN) was used to assess RTW after lumbar spine surgery. Inclusion criteria were: being employed at the time of enrollment, between 20–65 years-old, diagnosed with lumbar disc herniation, stenosis, spondylolisthesis, or disc degeneration. RTW was assessed using survival analysis, calculated by the method of Cox proportional hazards regression to find the best multivariable model predicting outcome using a backward selection procedure.

Results: A total of 1076 patients were included in the study. The median time to RTW was 58 days (range: 0–571 days, mean 82.5 ± 76.1). After adjusting for all other covariates in the model, shorter times to RTW were associated with patients that did not have WCB/insurance claims (hazard ratio (HR) = 1.43), were males (HR = 1.55), had light (HR = 1.33) or sedentary (HR = 1.50) lifting requirements at work, had no need for help at work (HR = 1.15), had duration of symptoms less than 1 year (HR = 1.24), did not have fusion (HR = 1.62), had a single level operation (HR = 1.38), had lower depression scores (HR = 0.97), and were not from New Brunswick (HR = 1.46) or Quebec (HR = 1.45). The model presented adequate internal validity in the validation sample.

Conclusion: We present a novel predictive model for RTW after lumbar spine surgery in Canada. Canadian spine care providers can use this model to educate patients and encourage them in shared decision-making regarding RTW after lumbar spine surgery.

435 Diagnostic and Therapeutic Values of Intraoperative Neuro-Monitoring for Resection of Spinal Tumors: Meta-Analysis and Systematic Review Encompassing 26 Articles and 1563 Patients

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Introduction: While several guidelines and meta-analyses support the use of intraoperative neuromonitoring (IONM) for spinal surgeries and other neurosurgical procedures with class A recommendations, clinical evidence on its diagnostic and therapeutic value particularly in spinal tumor (ST) resection is surprisingly sparse and not well-summarized. Here we aimed to conduct a meta-analysis and systematic review regarding this controversial topic.

Methods: A web-based literature search (1970-2018) on Pubmed in compliance with the PRISMA guidelines was performed, utilizing the keywords, spinal tumor intraoperative monitoring, which yielded 341 articles. Inclusion criteria were: English-language clinical articles 1) reporting clinical outcomes of ST resection with the use of IONM and 2) documenting information necessary to calculate the diagnostic values of IONM to predict neurological deficits. Exclusion criteria were 1) non-human research and 2) studies including < 10 patients. Consequently, 26 articles encompassing 1563 patients were included, and the pooled diagnostic values of IONM were calculated.

Results: There were 10 articles reporting intramedullary-ST (IMST), six articles describing intradural-extramedullary-ST (ID-EM-ST), and four articles including extradural-ST (EDST), whereas six articles included miscellaneous STs, all of

them being retrospective. Thresholds for MEP ranged from 50% declines to 100% declines. Only eight articles (30.8%) assessed the therapeutic value of IONM. The pooled diagnostic value of IONM was a sensitivity of 80.8%, specificity of 88.9%, PPV of 65.0%, NPV of 95.0%. PPV was lowest in EDST (EDST:31.6%, ID-EM-ST:57.9%, IMST:71.5%, $p=0.15$), whereas NPV was lowest in IMST (EDST:96.6% versus ID-EM-ST:96.0% versus IMST:92.8%). The overall diagnostic accuracy (area under the curve) was 0.893.

Conclusion: The substantial heterogeneity of 26 articles with regards to types of STs, thresholds for IONM, and the quality of clinical evidence was identified. IONM for ST resection was deemed an excellent diagnostic modality, while its therapeutic value remained to be investigated. IONM should be carefully interpreted in EDST due to its lowest PPV.

436 Who Needs Detailed Radiographical Evaluations in Freehand S2-Alar-Iliac Screw Insertion?: S2AI Screw Difficulty Index as a Novel Predictor

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Introduction: With recent advancement in spinal surgery such as robotic assistance, instrumentation in the lumbosacropelvic spine has become increasingly safer. In our institution, however, we preferentially had performed S2-alar-iliac (S2AI) screw instrumentation via a freehand technique based on anatomical landmarks. Here we aim to identify which patient cohort is at risk for S2AI screw breach, proposing a novel index, S2AI screw difficulty index (SDI).

Methods: From 2010 to 2016, 102 patients received 204 S2AI screws with more than one-year follow-up periods. The screw starting point was approximately 25 mm inferior to the superior aspect of S1 and 22 mm lateral to the midline on the coronal plane. S2AI screws were routinely directed toward 40-50° lateral on the axial plane and 20-40° caudal on the sagittal plane. Given the starting point and screw length/width selected for each patient, SDI (Figure 1) was calculated as $10000/((\text{axial safety margin angle}) \times (\text{sagittal safety margin angle}))$, which represents difficulty of each S2AI screw placement. Clinical data regarding SDI, S2AI screw breach, patient baseline characteristics were collected and statistically analyzed.

Results: Overall, there were 8 S2AI misplaced screws (3.9%). The average SDI was significantly different between breached screws versus screws successfully inserted (112.6 versus 44.3, $p<0.0001$). $\text{SDI}>110$ yielded a positive predictive value of 72.7% and negative predictive value of 98.3% to predict S2AI screw breaches. In a multi-regression model, longer/wider S2AI screws, female, and deep-seated L5 (the entire L5 VB is below the Jacoby's line) were independently predictive of higher SDI with statistical significance, while age, BMI, and preoperative diagnoses were not associated with SDI.

Conclusion: There was less margin of error for S2AI screw insertion in females and patients with deep-seated L5. The length and width of S2AI screws and their trajectories need to be cautiously selected in these patient cohorts, which may warrant adjunctive techniques including robotic assistance.

437 Pedicled Omental Flaps for Complex Wound Reconstruction for Chordoma of the Mobile Spine and Sacrum

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Introduction: Soft tissue reconstruction following en bloc resection for chordoma of the mobile spine and sacrum is a challenge given the wide excisional nature of these operations. When local flaps or free tissue transfers are inadequate or limited, a pedicled omental flap with its rich vascular supply is a viable option. We present our series on using pedicled omental flaps for soft tissue reconstruction when treating chordoma of the mobile spine and sacrum.

Methods: We conducted a retrospective search through an institutional database of patients with a diagnosis of spinal chordoma who underwent tumor resection and reconstruction using a pedicled omental flap at our institution between 2010 and 2017. Patient demographic information, operative data, and post-operative complications were recorded.

Results: Twenty-eight patients met criteria for the study. Omental graft occurred either during the time of the chordoma resection ($n = 11$) or in staged fashion up to 12 months after the initial surgery ($n = 17$). The mean total operative time was 527 ± 26 min. The mean estimated blood loss was 2100 cc (range, 1700-3100 cc). Two patients died prior to their first follow-up, 1 from a cardiac arrest on postoperative day 10, and the other from undetermined causes (an autopsy was declined). The median follow-up time for the remaining 25 patients was 30 months (range 1–132 months). Most patients reported mild abdominal or back pain at follow-up, and few reported mild paresthesias or mild weakness in the expected distributions, given resection of nerve roots. All patients were ambulatory at follow-up. The rates of incidental durotomy was 11%, wound complications 36%, pulmonary embolism 7%, and gastrointestinal complications including ileus and bowel obstruction 32%.

Conclusion: Pedicled omental flap is a safe and viable option for reconstruction after en bloc resection of chordoma in the spine and sacrum, which provides good functional outcomes with manageable complication rates.

438 Intraneural Lipomas: Institutional and Literature Review

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Introduction: Adipose lesions of nerve can be envisioned as a spectrum ranging from intraneural/extraneural lipomas to lipomatosis of nerve (LN). We have noticed that intraneural lipomas are not as homogenous group as previously thought and demonstrate differences which have clinical implications. To better understand intraneural lipomas, we conducted a search of cases at our institution and published cases in the world's literature.

Methods: Mayo Clinic's database was searched between years 1994-2018. Published cases were identified using PubMed and Google Scholar databases. Following terms were used: intraneural lipoma, lipoma and nerve, lipoma and neuropathy, lipofibroma and nerve, fibrolipoma and nerve and neural lipoma as well as lipofibroma and fibrolipoma alone. Only cases that could be clearly identified as intraneural lipomas by the location of the lipoma within the epineurium were included for analysis. These cases were then sub-classified as encapsulated intraneural lipomas or hybrid intraneural lipomas (demonstrating features of both intraneural/extraneural lipomas and LN) based on their characteristics.

Results: We identified 12 cases at our institution (8 encapsulated, 4 hybrid) and 24 published cases (21 encapsulated, 3 hybrid). The most commonly affected nerve was median both at our institution and in the published cases. Encapsulated cases were found to be relatively easy to resect. Hybrid cases demonstrated variable degree of interdigitating fat between the fascicles and were relatively difficult to resect.

Conclusion: Intraneural lipomas exist as two separate entities with distinct clinical implications. Although rare, this should be taken in account when planning surgery. Terminology should be clarified to prevent ambiguity and confusion.

439 Osteosarcoma Survivors have a Higher Rate of Second Primary Malignancies of the Bones, Joints, and Spine

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Introduction: Second primary malignancies (SPMs) are a documented and serious long-term event in osteosarcoma survivors. The aim of the current study was to investigate the risk of SPM development, especially of the bones, joints, and spine, in survivors of osteosarcoma relative to the general population.

Methods: The National Cancer Institute's Surveillance, Epidemiology and End Results (SEER) 18 database was queried for all documented histological subtypes of osteosarcoma in children and adults for 2000-2015. Summary statistics, standardized incidence ratio (SIR), 95% confidence interval (CI), and absolute excess risk (AER) per 10,000 person-years were calculated for this population using the SEER*stat application.

Results: In total, 3,438 patients with osteosarcoma were identified. The mean age of osteosarcoma diagnosis was 37.3 years (range: 7.7-88.0 years), with a mean follow-up of 9.5 years. There were 79 (2.3%) SPMs observed across 119 sites, which was more likely than expected (SIR 2.84, CI 2.35-3.39, $p < 0.0001$). Of the 119 SPM sites represented, 85 (71%) were solid tumors (SIR 2.31, CI 1.83-2.86, $p < 0.0001$) and 33 (28%) were lymphatic or hematopoietic (SIR 7.65, CI 5.26-10.74, $p < 0.0001$). When corrected for multiple comparisons, the trends for overall SPMs and lymphatic and hematopoietic disease remained significant. Significant corrected solid tumor SPM sites were bones and joints (SIR 73.07, CI 38.90-124.94, $p < 0.0001$) and soft tissue including heart (SIR 15.19, CI 5.58-33.07, $p < 0.0001$). In absolute terms, all malignancies were more common in osteosarcoma patients (AER 44.96), especially tumors of the bone or joint (AER 7.48), soft tissue including heart (AER 3.27), and lymphatic and hematopoietic disease (AER 16.74).

Conclusion: The overall incidence of SPMs was significantly higher than expected in osteosarcoma survivors. In particular, standardized absolute and relative incidence of malignancies in the bones and joints including spine, soft tissue including heart, and lymphoid and hematopoietic malignancies were significantly higher than expected.

441 The Incremental Value of Magnetic Resonance Neurography to the Neurosurgeon

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Introduction: When attempting to visualize and diagnose neurological lesions involving peripheral nerves and spine, conventional MRI can identify large structural neural problems but is inadequate for distinguishing nerves tissue from soft tissue. Magnetic Resonance Neurography (MRN) is an evolving imaging modality that can visualize peripheral nerves including spinal nerve roots in great detail when compared to traditional MRI. Alterations in signal intensity, fascicular pattern, continuity, and size can be detected with MRN. Although MRN has been described previously, few have addressed the additional value of MRN in assisting management of challenging cases, specifically for neurosurgeons and spine surgeons. It is still an underutilized resource in neurosurgery, and our paper highlights specific categories of disease where MRN can significantly impact clinical and surgical decision making.

Methods: We performed a retrospective review of 206 (129 female, 77 male) cases where MRN was used for preoperative or postoperative evaluation. The impact of MRN (compared to standard MRI or CT) was determined through correlation with clinical information and specific categories were identified.

Results: MRN lead to a significant change in diagnosis or care of 44 patients (21.4% -27 female, 17 male). Through further analysis of those cases, we identified five diagnostic categories out of the 44 patients, which included: Trauma (13.6%- 6 patients), Post-surgical evaluation (11.4%- 5 patients), Compressive/Degenerative conditions (15.9%- 7 patients), Tumors (29.5%- 13 patients), and Neuritis/Inflammation (29.5%- 13 patients). We have selected

representative cases from each category to discuss the specific radiographic findings that can be seen on MRN imaging.

Conclusion: MRN has proven to be a valuable tool for the neurosurgeon when utilized for the variety pathologic conditions listed in this poster. We advocate for further widespread use of MRN, which can significantly lower the socioeconomic burden of many diseases that can be difficult to treat and detect with traditional radiographic methodology.

442 Thoracic Ossification of Ligamentum Flavum Caused by Skeletal Fluorosis: Breaking the Etiopathological Barrier - Answer to the Crippling Disease of the Society.

Shivanand Reddy K V Mch; Mudumba V. Saradhi

Introduction: Thoracic ossification of ligamentum flavum (OLF) caused by skeletal fluorosis is rare¹. Only six patients had been reported in the English literature. This study is the second study to the best of our knowledge in literature

Methods: This is a prospective study of patients with thoracic OLF due to skeletal fluorosis who underwent surgical management at the NIMS hospital. Imaging showed OLF together with ossification of interosseous membranes, including interosseous membranes of the forearm (14/16 patients 87.5%). Urinalysis showed a markedly high urinary fluoride level in 15 of 16 patients (93.75%). Ossified ligamentum flavum sent for estimation of fluoride levels in 16 patients showed high fluoride level in the bone ash prepared from the oyl in 15 patients and other structures sent as control were spinous process, interspinous ligaments didn't show any fluoride deposition.

Results: Out of 16 patient 15 patient had fluoride levels more than 6000mg/kg. 7 patient had values between 6,000 7,000 mg/kg, 5 patient had values between 7,500 9,000 mg/kg and 3 patients had values > 8400 mg/kg. Controls were sent as spinous processes had normal fluoride level between 500-1000 mg/kg and interspinous ligaments sent showed no fluoride levels. Out of 16 patients 9 patients had multiple level dorsal OYL both contiguous and non-contiguous, contiguous in 4 patients and non contiguous in 5 patients. 7 patients had single level dorsal OYL. Most common segment involved in OYL is T9 and D10 level

Conclusion: This is the largest series of ossification of dorsal yellow ligament due to fluorosis. Fluorosis as one of the important etiological cause for OYL to be kept in mind and all patients with OYL to be screened for Fluorosis and would also help as a preventive measure for the people around the surroundings of the affected person and would help the society from a crippling disability.

443 Development of Machine Learning Algorithm to Increase Accuracy of Anatomic Diagnosis for Spinal Pain Conditions

Michael Verdon DO

Introduction: Treating spinal pain is expensive, costing the US health care system an estimated \$90 billion annually. Additionally, spinal pain effects American productivity as it is the most common cause for missed work days. Oftentimes, patients who suffer from spinal pain undergo treatments with no or incomplete symptom resolution.

Methods: We retrospectively reviewed and evaluated 250 consecutive patient records from an interventional pain management physician and a spinal neurosurgeon. The patients were then separated into the following diagnosis categories: lumbar radiculopathy, lumbar spondylosis without myelopathy, post laminectomy syndrome, and sacroiliitis. We manually entered information from the records regarding visual acuity scores, Oswestry disability index scores, pain location, duration, symptom descriptors and several other data points. Approximately 80 unique data points were entered into the system. We also tracked treatment interventions such as physical therapy, injections, or surgery and the patient reported outcomes regarding those interventions.

Results: We have created a "clinically relevant" data set for machine learning algorithms to identify patterns in patient reported data and to provide treating physicians with suggested therapeutic options. The results are enhanced decision making by the physician, therapy targeted to optimize patient outcomes and elimination of treatments which are ineffective and costly.

Conclusion: There are many different ways to treat spinal conditions such as: spinal manipulation, physical therapy, therapeutic injections, oral medications and surgical options. We identified data points from the diagnosis, patient reported complaints and other inputs to utilize the computing power of machine learning algorithms. We believe this will produce improved patient reported outcomes and clinical decisions for treatment which would be most efficient and effective.

444 Autocorrect: Using Text Messaging to Improve Enhanced Recovery After Surgery (ERAS) Behaviors for Patients Undergoing Spine Surgery

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Introduction: Enhanced recovery after surgery (ERAS) protocols have emerged to meet the demand for improving value in surgical care. A novel ERAS protocol for spine and peripheral nerve surgery was created by the authors and includes multiple elements including preoperative skin washing to reduce the risk of wound infection and preoperative glucose loading. Text messaging can facilitate patient adherence to such preoperative instructions. The goal of this

study was to examine the use of a text messaging platform, Way to Health, for patients undergoing spine or peripheral nerve surgery who were enrolled in an ERAS protocol at an academic medical center.

Methods: One hundred and nine consecutive patients were prospectively enrolled into our neurosurgical ERAS pathway (1) and counseled and consented for text messaging reminders through the Way to Health (WTH) application. Enrollment in WTH was voluntary for those patients with mobile telephones, and all patients were required to sign a consent form prior to participation

Results: Of 109 patients who were selected to participate in the WTH application, 79% of patients (n=86) engaged with the text messaging platform. Twenty-one percent of patients did not interact with the text messaging platform at all. Of the patients who interacted with the text messaging platform, only a small minority (10%) did not provide compliance data on use of skin prep or carbohydrate load. Thirty-nine percent of patients sent compliant data for only one behavior and thirty percent sent compliance data for both behaviors. Among patients who responded to both behavior questions, 100% compliance was recorded

Conclusion: Preventing avoidable postoperative complications requires innovation and participation from all members of the healthcare team. ERAS pathways aim to improve patient outcomes by utilizing a multi-modal, multi-disciplinary approach to patient care in which the patient becomes a powerful stakeholder in his or her care.

445 Effect of Spinal Decompression on Back Pain in Lumbar Spinal Stenosis: A Canadian Spine Outcomes Research Network (CSORN) Study

Shreya Srinivas FRCS; Charles Fisher MD; Greg McIntosh MSc; Nicolas Dea MD, MSc, FRCSC

Introduction: Surgical decompression is offered for improvement of neurogenic claudication in patients with symptomatic lumbar canal stenosis. These patients often have associated low back pain (LBP) and little is known about the effect of decompression on this symptom.

Methods: This is a multicenter, ambispective review of consecutive spine surgery patients enrolled by the Canadian Spine Outcomes and Research Network (CSORN). Consecutive patients (2014-2017) who underwent surgical treatment for symptomatic lumbar spine stenosis without instability were included. Primary outcome was change in low back pain on the Numeric Rating Scale recorded at baseline and at 3, 12 and 24 months after surgery. Multivariable logistic regression was used to model the relationship between the outcome and potential factors associated with achieving minimal clinical important difference (MCID) in back pain using a backward selection procedure.

Results: 1221 patients were included in the analysis. Mean age was 64 years and 58% were males. Baseline back pain scores were available in 1133 patients and follow up evaluations were available in 968/1133 (85%) patients at 3 months, 649/903 (72%) patients at 12 months and 331/454 (73%) at 24 months. LBP significantly improved 3 months after surgery and the improvement was sustained at 24 months ($P < 0.001$). We found that 74% of patients reached the MCID in back pain. Predictive factors for sustained improvement (12 and 24 months) in LBP after surgical intervention were absence of narcotic usage or compensation claims and increased severity of LBP prior to surgery (high NRS).

Conclusion: Alleviation of clinically significant LBP was observed at 3 months after lumbar decompression surgery for neurogenic claudication and this was maintained at 12 and 24 months after surgery in the majority of patients.

446 Optimizing Biomechanics of Anterior Column Realignment (ACR) Constructs: A Cadaveric Study of Rod Strain and Construct Stability

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Introduction: Anterior column realignment (ACR) is a powerful minimally invasive technique for sagittal realignment. To achieve clinical success, the optimal construct should provide sound biomechanics without limiting lordotic correction. The goal of this study was to evaluate the impact of ACR construct design on both segmental lordosis and construct stability/rod strain in a cadaveric model.

Methods: Seven human cadaveric T12-S1 specimens underwent ACR at L3/4 with a 30° implant, followed by grade 1 (G1) and 2 osteotomies (G2); a single screw into L3 vertebral body (1XLP) or single screw into both L3 and L4 vertebral bodies (2XLP) were used for anterior fixation to determine impact on lordosis. Next, nondestructive flexibility tests (7.5 Nm) were performed to assess range of motion stability (ROM) and rod strain (RS) at L3/4 in flexion, extension, lateral bending (LB), and axial rotation (AR). Conditions included: 1) intact, 2) intact + pedicle screw fixation and 2 rods (+2R), 3) ACR+1XLP+2R, 4) ACR+2XLP+2R, 5) ACR+1XLP with 4 rods (+4R), 6) ACR+2XLP+4R. Order of testing was randomized. Data were analyzed using RM-ANOVA or ANOVA ($p < .05$).

Results: Segmental lordosis was similar between ACR+1XLP and ACR+2XLP ($p > .28$). ACR+1XLP+2R was significantly less stable than all other conditions in flexion, extension, and AR ($p < .014$); however, adding an extra screw (ACR+2XLP+2R) improved stability to levels equal to 4R conditions ($p > .36$). Adding 4R to ACR+1XLP reduced RS in all directions of loading ($p < .048$), whereas adding a second screw did not ($p > .12$). There was no difference in strain between ACR+1XLP+4R and ACR+2XLP+4R ($p > .55$).

Conclusion: For maximum stability, ACR constructs should contain either fixation into both vertebral bodies (2XLP) or accessory rods (4R). Two fixation screws can be used without compromising the maximal achievable lordosis, but do not provide the same rod strain reduction as 4R. Combining these two techniques (2XLP and 4R) did not provide any additional benefit.

447 Facilitated Growth of Cortical Neurons Using a Dorsal Root Ganglion Bridge

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Introduction: Spinal cord injury (SCI) remains a devastating problem. One treatment option is the formation of a cellular bridge through the lesion, guiding surviving axons across the site of injury. (1) Neurons with cell bodies within the motor cortex send axonal projections to lower motor neurons in the spinal cord, serving as a target for long-distance regeneration. The present study utilizes dorsal root ganglion (DRG) cells to send axonal projections as a bridge for facilitated growth of cortical neuron aggregates (CNA) axons. All procedures in the study were completed in accordance with the Institutional Animal Care and Use Committee. Primary cortical neurons and DRGs were obtained from rat embryos. CNAs were plated with and without DRG bridges and axonal growth was recorded. (Figure 1)

Methods: All procedures in the study were completed in accordance with the Institutional Animal Care and Use Committee. Primary cortical neurons and DRGs were obtained from rat embryos. CNAs were plated with and without DRG bridges and axonal growth was recorded. (Figure 1)

Results: Plating two populations of DRG neurons on a single surface, DRG axons formed robust axonal connections spontaneously up to a distance of 10 mm, growing at approximately 1 mm/day. (Figure 1C) Two populations of CNAs plated in a similar fashion were unable to bridge a 3mm gap when plated without a DRG scaffold after 12 days. (Figure 2A) When CNAs were plated at a 4mm distance with DRG axons, CNA axons extended across the 4mm gap, following the DRG scaffold. (Figure 2 B-G)

Conclusion: In the present study, we demonstrate the feasibility of using elongated DRG axons as a bridge in SCI using an in vitro model of SCI. Our results show that compared to the negative control CNAs without DRG bridges, the CNAs plated with DRG axons demonstrated facilitated growth along the DRG axon bridge.

448 Histologic Analysis of Human NP-like Cells Regeneration Derived from Umbilical Cord Stem Cells to Treat Degenerative Disc Disease.

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Introduction: The regeneration of intervertebral disc (IVD) using umbilical cord (UC) mesenchymal stem cells (MSCs) is a promising field for restoring the nucleus pulposus (NP) for the biologic management of degenerative disc disease (DDD) spinal disorder that manifests with low back pain.

Methods: Using a rabbit DDD model we investigated the efficacy of NP-like cells (NPCs) derived from the UC-MSCs in restoring degenerated IVDs. We used differentiation medium (DM) for two weeks to induce UC -MSCs into NPCs by using differentiation medium labeled with PKH26 and then injected into the degenerated IVDs.

Results: Structure and cellularity of the NP improved significantly in the IVDs that received NPCs at eight weeks post-transplantation analysis. The histology of NPCs transplanted disc contained cellular content that was similar to normal control disc (NCD). However, histologic analysis of transplanted NPCs cells appeared notochordal like representing less differentiated cells than end differentiated chondrocytes seen in NCD. Transplanted IVDs also had higher glucosaminoglycan (GAG) and water content compared to the sham and degenerated IVDs. Indicating that NPCs appear responsible for the production of GAG. The transplanted cells survived, integrated, and dispersed in the damaged areas of the NP and were functionally active as they expressed human genes, SOX9, ACAN, COL2, FOXP1, KRT19, PAX6, CA12 and COMP as well as human proteins, SOX9, ACAN, COL2 and FOXP1 implicated in NP biosynthesis. NPCs were capable of homing to regenerate NP. The molecular mechanism for NP regeneration was proposed to be regulated via the TGF β 1 pathway.

Conclusion: Understanding the cellular histologic regeneration of the NP in a model of DDD is critical to providing effective biologic disc regeneration therapies. UC derived NPCs appear effective in restoring DDD.

449 Long-Term (72 month) Radiographic Results of Cervical Disc Arthroplasty Utilizing a Restrained Compressible-Core Prosthesis

Holger Bang MD; Avinash G. Patwardhan PhD

Introduction: This study presents the longest follow-up to date (up to 72 months) of cervical disc arthroplasty (CDA) utilizing a restrained, compressible-core disc prosthesis (M6-C). The results of two cohorts were compared: 65 patients operated in a private German clinic; and 30 patients operated in an FDA-controlled U.S. pilot study. We asked: (1) how does the index-level mobility change over time? and (2) how do outcomes from the two cohorts compare?

Methods: Sixty-Five patients underwent CDA in a German center: 1-level, N=52; 2-level, N=13. All patients were examined 1 month postoperatively, 39 patients up to 60 months, 27 patients up to 72 months, and 1 patient at both 60 and 72 months. The US Pilot included 30 patients: 1-level, N=12; 2-level, N=18. All patients were examined 6-weeks postoperatively and at 42 months for the last follow-up. Global and index-level ranges of motion (ROM) and disc heights were assessed radiographically at each follow-up.

Results: Global ROM increased over the follow-up periods in both cohorts ($p < 0.01$); the increases in two cohorts were similar. Index-level ROM, averaged over all levels in the German cohort, was maintained at 7.1° over 60+ months. ROM in 1-level patients tended to be greater than 2-level patients (Table 1). Index-level ROM was also maintained over

the 42-month follow-up in the US cohort, but the ROM tended to be smaller than the German cohort (Table 1). Index-level disc heights were maintained over the follow-up periods in both cohorts. Proportion of index levels with less than 2° of motion was smaller in the German cohort (7/78) compared to the US cohort (6/48).

Conclusion: CDA utilizing restrained compressible-core (M6-C) disc prosthesis yielded outcomes that were similar whether performed in a private surgery center or in the FDA-controlled US pilot study. Results showed index-level mobility and disc heights were maintained over the 72-month follow-up.

450 The Effect of Sacroiliac Fusion and Pelvic Fixation on Rod Strain in Thoracolumbar Fusion Constructs: A Biomechanical Investigation

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Introduction: Hardware failure is a multifactorial and challenging problem encountered by spinal surgeons. Increased rod strain can lead to instrumentation failure and rod fracture. Here, we investigated the effect of sacroiliac joint (SIJ) fusion and iliac fixation on distal rod strain in thoracolumbar fusions.

Methods: Seven fresh frozen human cadaveric specimens (T9 Pelvis) were used in this investigation. Six operative constructs were tested to investigate changes in rod strain at L5-S1 and S1-Ilium rods: posterior pedicle screws and rods from T10-S1 (PS), PS + bilateral iliac screw fixation, PS + unilateral iliac screw fixation, PS + unilateral iliac screw fixation + 3 unilateral SIJ screws, PS + 3 unilateral SIJ screws, and PS + 6 bilateral SIJ screws. Uniaxial strain gauges were used to measure surface strain of the rods during flexion-extension motion.

Results: In flexion-extension, bilateral iliac screws added significant strain to L5-S1 when compared to PS alone ($p < 0.05$). Unilateral iliac fixation exhibited the highest strain to the L5-S1 ipsilateral rod and was significantly more compared to the bilateral iliac fixation + PS construct. Unilateral and bilateral SIJ fusion did not significantly change L5-S1 rod strain compared to PS. When measuring S1-Ilium rod strain, unilateral pelvic fixation had the highest reported rod strain and approached significance when compared to bilateral iliac screws ($p = 0.054$). The addition of contralateral SIJ fusion did not affect rod strain at S1-Ilium on the side with unilateral fixation.

Conclusion: This biomechanical study examined the effect of pelvic fixation and SIJ fusion on distal rod strain in thoracolumbar fusions. We showed that additional fixation below S1 to the pelvis added significant rod strain. Unilateral pelvic screws had the highest rod strain while SIJ fusion did not affect rod strain. We believe these findings can help guide surgeons when associated risk of rod failure needs to be considered.

451 Anterior vs. Posterior Cervical Decompression and Fusion in Patients with Multi-Level Degenerative Cervical Myelopathy

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Introduction: The optimal approach for surgical decompression in degenerative cervical myelopathy (DCM) is unclear, and there is significant variation in practice patterns globally. We sought to compare the inpatient complications and costs of anterior (ACDF) versus posterior cervical decompression and fusion (PCDF) using a national administrative healthcare dataset.

Methods: Patients who underwent multi-level ACDF or PCDF for DCM were identified from the HCUP National Inpatient Sample (NIS) for 2004-2014 using ICD-9-CM codes. Propensity score matching (1:1 ratio; nearest-neighbor) was performed with age, sex, number and type of comorbidities, hospital bed size, and use of intra-operative monitoring as covariates. Outcomes, including hospitalization charges and costs, length of stay (LOS), discharge disposition, and inpatient complications and mortality, were compared between matched ACDF and PCDF groups.

Results: A total of 17,805 patients were eligible. Propensity score matching resulted in a cohort of 13,884 patients ($N = 6,942$ ACDF; $N = 6,942$ PCDF). PCDF was associated with greater LOS (MD +1.7 days, $P < 0.01$) and less frequent routine discharge home (OR 0.26, $P < 0.01$). With regard to complications, the PCDF group had a higher rate of MI (OR 1.6, $P < 0.01$), PE (OR 2.6, $P < 0.01$), DVT (OR 3.7, $P < 0.01$), neurological complications (OR 1.7, $P < 0.05$), hardware-related complications (OR 2.7, $P < 0.01$), wound infection/breakdown (OR 6.8, $P < 0.01$), and CSF leak (OR 1.7, $P < 0.05$). By contrast, the incidence of post-operative hematoma (OR 0.61, $P < 0.01$), hoarseness (OR 0.13, $P < 0.01$), and dysphagia (OR 0.20, $P < 0.01$) were significantly lower following PCDF. Mortality rate was comparable between ACDF and PCDF (0.29% vs. 0.26%, respectively; $P = 0.75$). Hospital charges (MD +\$26,259, $P < 0.01$) and costs (MD +\$7,728, $P < 0.01$) were significantly higher for PCDF than ACDF.

Conclusion: At a national level, we found anterior surgery for multi-level DCM to be associated with greater rates of post-operative hematoma, hoarseness, and dysphagia. However, posterior surgery exhibited a higher rate of general medical complications, length of stay, and in-hospital costs.

452 In Vitro and In Vivo Comparison of the Antibacterial Effect of Titanium and Cobalt-Chromium Alloys

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Introduction: Cobalt-chromium alloy (CC) and titanium alloy (Ti) have high corrosion resistance, wear resistance and fatigue strength. These properties cause them to be used widely for orthopedic implants. Previous studies have looked

at the biofilm formation of dental implants and the antibacterial agents of cobalt ions; however, there has not been a study to evaluate the bacterial proliferation difference between common spine implant materials.

Methods: The antibacterial effect of CC and Ti were evaluated using cultured mediums and animals. In the in vitro study, screw heads made of each material were incubated with one of the following bacteria, *S.aureus*, MRSA, *S.epidermidis*, MRSE, *E.coli*, *P.aeruginosa*. The collected bacteria were then spread on agar plates to determine the number of viable bacteria. The in vivo study used discs made of CC or Ti that were implanted into subcutaneous layer of BALB/c mice. After skin closure, a 0.05ml of *S. aureus* suspension (1×10^6 CFU) was directly inoculated on the implanted discs. Discs were retrieved and the number of viable bacteria was counted at 0.5, 1, and 3 days after inoculation.

Results: The mean number of viable *S.aureus* cultured with CC and Ti screw heads were 3.2×10^2 CFU/ml and 2.3×10^6 CFU/ml, respectively. There was a lower mean number of MRSA cultured with CC screw (6.1×10^2 CFU/ml) as compared to the Ti screw (2.5×10^6 CFU/ml). Similar reductions were obtained for the other bacteria. In the in vivo model, the number of viable *S.aureus* on Ti discs increased for each implantation period while it decreased on CC discs. Significant differences in the mean number of viable *S.aureus* between CC and Ti were observed at all time points ($p < 0.01$).

Conclusion: These data demonstrate that CC suppressed bacteria proliferation compared to Ti in both in vitro and in vivo studies. Robust clinical studies will be needed to draw clinical conclusions.

453 When to Abort the Transpsoas Lateral Lumbar Approach

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Introduction: The transpsoas lateral lumbar interbody fusion (LLIF) is a common skillset in the armamentarium of a spine surgeon. Complications can be significant with reported cases of vascular, visceral, and neurologic injuries. Vascular and visceral injuries are frequently noticed at the time of injury. However, neurologic injuries may not be immediately evident, particularly during the transpsoas dilation. The surgeon is tasked with the difficult decision to proceed or to abort when subtle intra-operative conditions are not optimal.

Methods: A retrospective analysis 42 consecutive L4-5 LLIF and a single case example of intraoperative suboptimal conditions for psoas dilation. A 67-year-old male with grade I L4-5 spondylolisthesis, severe stenosis with debilitating back and bilateral lower extremity pain. After standard positioning, left retroperitoneal access was obtained. A directional EMG probe was positioned on the psoas muscle with inconsistent readings of 1.5–2mA in all directions. When the EMG probe was repositioned more anteriorly, the readings suggested the femoral nerve was still anterior to the probe. The proximity of the lumbar plexus was such that dilation anterior to the lumbar plexus was not possible while maintaining an adequate docking site for the retractor.

Results: Forty-two consecutive cases with a surgical abort rate of 2.4% (1/42). No complications were encountered in the cases carried through fruition.

Conclusion: LLIF is safe at the L4-5 level as evidenced by the lack of complications in 42 consecutive cases. However, prior to performing L4-5 LLIF the surgeon must ensure the safety of the procedure at all pre- and intra-operative check points. Reliable, directional EMG is critical to identifying the relative location and proximity of the lumbar plexus when dilating the psoas muscle.

454 Accuracy of Modified Freehand Technique for Placement of Subaxial Cervical Pedicle Screws: A Cadaveric Feasibility Study

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Introduction: Subaxial pedicle screws provide superior fixation compared to other posterior cervical fixation strategies. High level of accuracy is required for safe application given proximity of critical neurovascular structures, and reported accuracy varies widely (20-97%). The purpose of this study was to evaluate accuracy of a modified freehand technique (FH) for placement of subaxial pedicle screws and compare with an established computed tomography (CT)-based neuronavigation (NAV) technique.

Methods: Six fresh-frozen cadaveric spines (occiput to T2) were prepared. Pedicle screws were placed from C3 to C7 on either side using either FH or NAV technique (alternating sides between specimens). Pedicles with diameter < 4 mm were excluded. For FH technique, 1) preoperative CT was used to evaluate anatomy and for intraoperative reference, 2) laminotomy was performed for direct visualization of the pedicle borders (superior, inferior, medial), 3) identification of the intersection of the medial pedicle wall with the posterior vertebral body was used to determine appropriate screw medialization (Figure 1). NAV screws were placed with CT-based navigation with reference frame mounted on C2 spinous process using standard technique. Screw position was evaluated using postoperative CT and breaches classified using the Neo classification.

Results: Fifty pedicle screws were placed at 25 levels in 6 cadavers (25 FH, 25 NAV). Three (12%) breaches occurred in FH group, and 9 (36%) in NAV group ($p = 0.10$; Table 1). Breaches were evenly distributed across all levels. There were no high-grade breaches in FH group and 1 (4.0%) with NAV ($p > 0.99$). Mean pedicle and medullary bone diameter were higher for levels with no breach ($p = 0.009$ and 0.02 , respectively).

Conclusion: This modified freehand technique with direct pedicle visualization achieves very high accuracy (100% grade 0-1 breach) in placement of subaxial cervical pedicle screws in cadavers. These results will need to be reproduced in the clinical setting.

455 A Biomechanical Investigation of the Sacroiliac Joint in the setting Lumbosacral Fusion: The Impact of Pelvic Fixation Versus Sacroiliac Joint Fixation

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Introduction: Randomized trials support sacroiliac fusion over conservative management for sacroiliac joint dysfunction. However, there are limited biomechanical studies to understand the effect of lumbosacral fusion on the sacroiliac joint. Here, we performed a biomechanical investigation to understand the effect of pelvic versus sacroiliac joint fixation on the sacroiliac joint. Furthermore, we studied the effect of lumbosacral fixation on the SI joint.

Methods: Seven fresh-frozen human cadaver specimens were used. There was one intact and six operative constructs: (1) posterior pedicle screws and rods from T10-S1 (PS), (2) PS + bilateral iliac screw fixation (BIS), (3) PS + unilateral iliac screw fixation (UIS), (4) PS + UIS + 3 contralateral unilateral SIJ screws (UIS + 3SIJ), (5) PS + 3 unilateral SIJ screws (3SIJ), and (6) PS + 6 bilateral SIJ screws (6SIJ). There were three bending modes: flexion extension (FE), lateral bending (LB), axial rotation (AR). Range of motion was recorded at the L5-S1 and sacroiliac joint.

Results: All operative constructs had significantly reduced ROM at L5-S1 compared to the intact specimen in all three bending modes. In FE, BIS had significant reduction in L5-S1 ROM compared to all specimens. SIJ ROM was greatest in FE bending mode. PS construct had the highest SIJ ROM. BIS construct reduced bilateral SIJ ROM by 44%. BIS and 6SIJ showed nearly equal reduction in SIJ ROM compared to PS. UIS and 3SIJ showed appreciable reduction in the unfused SIJ compared to PS.

Conclusion: This study adds biomechanical evidence to the literature showing adjacent segment stress in the SIJ in fusion constructs to S1. Unilateral pelvic fixation or SIJ fusion, led to appreciable but non-significant reduction to the unfused contralateral SIJ. Finally, bilateral pelvic fixation showed the greatest significant reduction of movement at L5-S1 and was equivalent to bilateral sacroiliac fusion in reducing SIJ motion.

456 Minimally Invasive Technique for Intradural Spinal Tumor Resection and other Pathology

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Introduction: Minimally invasive techniques have become increasingly popular for common spine pathologies and complex spine indications. Their benefits are well-described and include less blood loss, shorter hospital stay, less pain, fewer infections, and less cost. The same benefits have now been described for intraspinal tumors and extraspinal peripheral nerve sheath tumors.

Methods: A single surgeon retrospective review of a series of 24 patients with clinical, radiographic, and outcomes is reported.

Results: A total of 24 patients are reported, 14 women and 10 men, with an average age of 64 years. The average time to presentation was 14 months. Typical presentations included: pain (83%), sensory (83%), motor (50%), bladder (38%). Locations included cervical (2), thoracic (12), and lumbar (10). Pathologies included meningioma (8), Schwannoma (7), metastasis (3), AV fistula (1), lipoma (1), teratoma (1), ganglioneuroma (1), arachnoid cyst/syrinx (1), and tethered cord (1). Patients remained stable or improved in 88%. Gross total resection was achieved in 100% of patients. There were no complications related to the procedure/technique including CSF leak. No lumbar drains were used. Average length of stay was 2.2 days. Average time of surgery was 149 minutes. Average blood loss was 23 cc. Average follow-up was 2.9 years.

Conclusion: Minimally invasive techniques are now more commonly applied to complex spine procedures, including intraspinal and extraspinal tumors and other pathologies. Traditional microsurgical techniques performed through tubular retractors with minor modifications to surgical approach, retractor, dural retraction, and dural closure techniques can be performed with a high degree of efficacy and minimal complications.

457 Cost and Outcomes Associated with Stereotactic Navigation in 2 and 3-6 Level Lumbar Fusions: A Propensity Matched Database Analysis

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Introduction: It is of increasing importance to examine the healthcare value provided by neurosurgical procedures and associated technological adjuncts. Stereotactic navigation is increasingly used in spine surgery, but its effect on outcomes and costs remain controversial, with several payers not reimbursing its use.

Methods: A commercially available longitudinal database was used to identify patients undergoing conventional or navigation based lumbar fusions between 2007-2015 restricted to one year of continuous enrollment and excluding trauma, tumor or anterior procedures. Propensity matching was performed to normalize differences between demographics and comorbidities in the two cohorts. Outcomes, complications and cost were subsequently analyzed with multivariate logistic regression.

Results: We stratified the cohorts into 1117 conventional and 1117 navigated cases of 2-level instrumentation and 804 conventional and 804 navigated matched 3-6-level cases. There were no significant differences in baseline demographics between groups after propensity matching. In 2-level lumbar fusion, there was no difference between navigated and conventional groups in length of stay nor the rates of medical or surgical complications within 30- days. Similarly, there was no difference in 30 or 90-day readmission or revision rates between groups. In 3-6-level lumbar fusions, the navigation group had a longer length of stay (3.85 versus 3.44 days; $p=0.0012$) and a significantly lower risk of having any medical or neurosurgical complication within 30-days for the navigation group (12.3 versus 14.2%; OR 0.48; $p=0.0186$). The navigation group also had a trend towards lower readmission rates within 180 days (not significant). In both cohorts, hospital payments were significantly higher for the navigated groups.

Conclusion: Our findings suggest that for multilevel instrumented lumbar fusion of six or fewer levels, use of stereotactic navigation may lead to improved outcomes and reduced long term costs. This was not seen for two-level lumbar fusions, suggesting that at a population level, the judicious use of this technology may improve overall value in spinal fusion.

458 Development of a Novel Technique for In-Vitro Biomechanical Testing to Allow Comparison of Surgical Interventions for Low Back Pain Due to Bertolotti Syndrome

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Introduction: Bertolotti Syndrome (BS) is a clinical entity in which low back pain is attributed to a pathological pseudo-articulation between the fifth lumbar transverse process and the ala of the sacrum – a lumbosacral transitional vertebra (LSTV).⁽¹⁾ LSTV have been shown to increase risk for further spine pathology.⁽²⁻⁵⁾ Acquisition of cadaveric specimens with untreated BS for in-vitro testing is challenging, so we aimed to develop a novel in-vitro model of LSTV that incorporated three dimensional (3D) printing with normal cadaveric spines. Once validated, this model will permit researchers to ask biomechanical questions about BS, improve our understanding of different surgical approaches^(6,7), and gain knowledge about how this condition may cause pain and further pathology.

Methods: CT imaging was used to reconstruct LSTV morphology from a representative BS patient and the morphology of the normal cadaver spine specimen. Cadaver specific cutting guides were created to allow for appropriate placement of the surrogate LSTV on the normal spine, and the installation process was validated. In addition, tissue samples of an LSTV were acquired from a BS patient. Biomechanical testing of the bone and cartilage were undertaken to establish biomechanical tissue parameters that will be used to guide the design of the 3D printed material selection and geometry to be representative of the LSTV in the BS patient.

Results: Figures 1-3 show the novel LSTV model and actual LSTV specimen stiffness data.

Conclusion: The development of an in-vitro model of BS will allow for further biomechanical testing of this condition that sets a precedent for the ability to develop similar models for other spinal conditions. Future work will include a spinal biomechanics study using the simVITRO robotic testing system. Testing will include native spine, in-vitro LSTV spine, surgical resection spine model, superior level fusion spine model, and combined fusion and resection models.

459 Effects of Radiographic Disc Health on Cervical Spine Biomechanics

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Introduction: The effect of disc grade assessed radiographically on biomechanics is unknown. In this study, cadaveric cervical spinal specimens were graded radiographically and tested biomechanically to determine the effect of disc degeneration on range of motion.

Methods: 18 cadaveric cervical spines (C3-T1) were dissected. Cranial and caudal vertebrae were potted in high strength resin. Specimens were imaged fluoroscopically and assessed radiographically at each level by three fellowship-trained surgeons, on a 4 point scale, with 0 indicating a "normal or healthy" disc and 4 indicating "disc space obliteration with fusion and facet arthrosis". These grades separated discs into healthy (=1) and degenerated (>1) groups. All specimens were instrumented and tracked using an optoelectronic motion measurement system, loaded into a six degree-of-freedom kinematic testing machine, and tested up to 2 Nm for three cycles in axial rotation (AR), lateral bending (LB), and flexion/extension (FE). Motion and moment data from the loading phase of the third cycle to a logarithmic curve. Best fit model constants were calculated for each disc level and mode of motion. Maximum range of motion values were also calculated.

Results: Discs at the C5-C6 and C6-C7 levels graded significantly higher than C3-C4 discs overall ($p<.01$ and $p=.01$ respectively). No significant differences were seen between healthy and degenerated discs in maximum range of motion for flexion, FE, RLB, LB, and total LB across all levels. In extension, LAR, RAR, and total AR, a significant difference was calculated between healthy and degenerated discs only at C5-C6 (E: $p<.01$, LAR: $p=.01$, RAR: $p<.01$, AR: $p<.01$).

Conclusion: Although significant differences were detected between healthy and degenerated discs at each level, these differences did not translate into consistent differences in biomechanics of the cervical spine. In addition, although disc degeneration was identified at all levels, it did not appear to affect biomechanics equally.

460 Assessment and Comparison of Insertional Torque and Insertional Energy with Pull-Out Strength of Pedicle and Cortical Bone Screws

James L. West MD; Wesley Hsu MD

Introduction: Biomechanical measurements of screw fidelity, such as peak insertional torque, have been evaluated, but have not been shown to be clinically relevant. Recent studies have failed to demonstrate correlation between screw insertional torque and radiographic failure of the screws. Torque itself is a technically suboptimal number representing only one point in time. Insertional energy is the integral of torque over time and may provide a more complete picture of resistance to failure. Herein, we assessed pedicle (PS) as well as cortical (CS) trajectory screws for correlation between insertional energy and pull-out strength.

Methods: 12 cadaveric specimens from T12-Sacrum were obtained and divided into CS and PS groups which underwent L2-5 instrumentation. Specimens were cycled through 21 cycles of bending to 8Nm in flexion/extension, lateral bending, and axial rotation. The specimens were then sectioned and secured in a custom spherical clamp for pull-out testing.

Results: PS and CS had significant differences in mean insertional torque (0.21 ± 0.14 Nm, 0.38 ± 0.17 Nm) as well as peak insertional torque (1.13 ± 0.54 Nm, 1.68 ± 0.36 Nm). Insertional energy was similar between PS and CS (26.37 ± 21.70 W vs. 25.39 ± 9.48 W). During screw pullout tests, the CS group exhibited 25% higher elastic stiffness as well as higher pullout strength compared to PS (879 ± 306 N vs. 667 ± 397 N). Overall, PS pullout force had strong positive correlation coefficients with peak torque and insertional energy (0.94 and 0.91). For CS, the correlation coefficients with pullout force were 0.70 and 0.79 for peak torque and peak energy respectively.

Conclusion: Insertional torque has long been evaluated as a potential measurement, however because it is a discrete point in time, it does not capture the entire screw placement energy. Herein we evaluated insertional energy as well as peak torque and found them to be similarly effective predictors of linear pullout strength in CS and PS.

461 Anterior Lumbar Interbody Fusion for Salvage of Long-Segment Thoracolumbar Construct Pseudoarthrosis

James L. West MD; Keyan Peterson MS, MBA; Alexander K. Powers MD

Introduction: Long-segment corrections have been shown to improve quality of life in patients with poor spinal balance. Revision for pseudoarthrosis is technically demanding, with many authors reporting an increased complication rate. Herein, we report our experience, and the first description in the literature, of utilizing anterior lumbar interbody fusion (ALIF) to address pseudoarthrosis in long-segment thoracolumbar fusions.

Methods: This study represents a single-institution, retrospective review of patients who underwent ALIF to address lumbar pseudoarthrosis of long segment thoracolumbar fusions.

Results: Fifteen patients with an average age and BMI of $60.6 (+14.6)$ years and $29.0 (+4.5)$ kg/m² met inclusion criteria for this study. The average time from index surgery to ALIF was $65.5 (+111)$ months, and the average operative time, blood loss, and length of stay were $226 (+56.5)$ minutes, $265 (+197)$ mL, and $3.9 (+2.8)$ days. Overall there were no major complications and 3 minor complications including superficial wound infection, a delayed retroperitoneal hematoma that did not require intervention, and an iliac vein injury which was repaired primarily but did cause the ALIF to be aborted. On regression analysis, none of the collected variables including: BMI, smoking, diabetes, or previous abdominal surgery were found to be associated with an increased operative time or risk of complication. At follow-up, average $7.7 (+3.5)$ months, there were no significant changes in EQ5D outcomes scores and radiographs significantly improved segmental and lumbar lordosis as well as disc height.

Conclusion: ALIF is a reasonable and safe alternative to posterior revision of long-segment thoracolumbar fusions that develop lumbar pseudoarthrosis.

462 Headache Relief is Maintained 7 years after Anterior Cervical Spine Surgery: Post Hoc Analysis from Multicenter Randomized Clinical Trial

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Introduction: Cervicogenic headache (CGH) is a common symptom in patients with cervical spondylosis. While cervical disc arthroplasty (CDA) and anterior cervical discectomy and fusion (ACDF) have shown to improve CGH in the postoperative period and short-term follow-up, long-term studies are lacking.

Methods: To investigate the temporal trend in headache scores after CDA and ACDF and identify any difference between these patient groups over a 7-year period, we performed a post-hoc analysis of 575 patients who underwent CDA or ACDF between April 2006 and March 2008 as part of a prospective randomized clinical trial. Primary inclusion criteria were cervical spine degenerative disc disease with associated radiculopathy or myeloradiculopathy at one or two contiguous subaxial levels in patients aged 18 to 69 years. Assessment of pain and functional outcome was performed with the Neck Disability Index (NDI) in the trial. We used the NDI headache component to assess headache outcome.

Results: For both one- and two-level CDA and ACDF groups, there was significant headache improvement from preoperative baseline that was durable out to 7 years ($p < 0.0001$). For one-level surgeries, headache improvement was similar for both CDA and ACDF patients across all follow-up periods, including the 7-year follow-up time point.

However, for two-level treatment, CDA patients had significantly improved headache scores versus ACDF patients across all follow-up periods, including the 7-year follow-up time point ($p < 0.03$).

Conclusion: The headache improvement as noted at early follow-up was sustained over the long-term 7-year follow up period with ACDF and CDA populations. In the case of 2-level operations, CDA patients demonstrated significantly greater benefit compared to ACDF patients over the long-term. It is possible that improved cervical kinematics and preservation of range of motion with favorable mechanics at adjacent uncovertebral joints in the case of CDA may contribute to the observed difference between the CDA and the ACDF groups.

463 Differences in Cervical Sagittal Alignment Changes in Patients Undergoing Laminoplasty and Anterior Cervical Discectomy and Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) and laminoplasty (LP) are the most commonly performed procedures for degenerative cervical spondylosis. Cervical sagittal alignment (CSA) has recently been studied as an important predictor of clinical and radiological outcomes. The data from previous studies are insufficient for analysis using the recently designed CSA parameters, T1 slope (T1s), and T1s minus cervical angle (T1sCA).

Methods: We retrospectively collected data from patients who underwent ACDF and LP from January 2013 to May 2016. The CSA parameters included CA, sagittal vertical axis, T1s, and T1sCA. T1sCA values were used to evaluate the preoperative cervical balance ($T1sCA > 20^\circ$: imbalance). Clinical results were evaluated using the neck disability index (NDI) and recovery rate (RR) according to the Japanese Orthopedic Association scoring system.

Results: We analyzed the data of 72 patients (ACDF, $n=39$; LP, $n=33$). Imbalance on ACDF was associated with an increase in CA (balance: preoperative [PRE], 15.64° ? follow-up [F/U], 15.74° , $p=0.953$; imbalance: PRE, -1.14° ? F/U, 8.045° , $p=0.008$), whereas balance on LP was associated with a significant decrease in CA (balance: PRE, 16.26° ? F/U, 11.59° , $p=0.009$; imbalance: PRE, 5.36° ? F/U, 2.38° , $p=0.249$). No significant difference was found in the RR and NDI changes in the ACDF group based on balance, but a significant difference was found in RR in the LP group (balance: $61.65\% \pm 19.88\%$, imbalance: $46.90\% \pm 15.71\%$, $p=0.046$).

Conclusion: We found a significant difference in postoperative alignment in cases of ACDF and LP according to preoperative cervical sagittal balance. The postoperative clinical results of the LP group were more affected by F/U alignment than by the degree of alignment change.

464 Implantation of Freshly Isolated Adipose-Derived and Bone Marrow-Derived Stem Cells Achieves Successful Spinal Fusion in a Rat Model

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Introduction: Adipose-derived stem cells (ADSCs) offer clinical advantages in spinal fusion over bone marrow-derived stem cells (BMSCs), including larger available tissue volumes and decreased donor site morbidity. While pre-clinical studies have shown that ex vivo expanded ADSCs can be successfully used in spinal fusion, the use of freshly isolated cells will better enable clinical translation. We compared the efficacy of freshly isolated ADSCs and BMSCs in achieving successful spinal fusion in a rat model.

Methods: ADSCs were isolated from the inguinal fat pads, while BMSCs were isolated from the long bones of syngeneic 6-8 week old Lewis rats and combined with Vitoss (Stryker) bone graft substitute for subsequent transplantation. Posterolateral spinal fusion surgery at L4-5 was performed on 27 female Lewis rats divided into 3 experimental groups: [1] Vitoss (Stryker) bone graft substitute only (VO group, $n=9$); [2] Vitoss+ 2.5×10^6 ADSCs/side ($n=9$); and, [3] Vitoss+ 2.5×10^6 BMSCs/side ($n=9$). Fusion was assessed eight weeks post-surgery via micro-computed tomography (MicroCT) imaging and manual palpation.

Results: MicroCT imaging analyses revealed that fusion volumes and CT fusion scores in the ADSC group were significantly higher than in the VO group (19.75 mm^3 vs. 13.39 mm^3 , respectively, $p=.04$, and 1.5 vs. 1.0 , respectively, $p=.03$). CT volume and fusion score were not significantly different between the ADSC group and the BMSC group (19.75 mm^3 vs. 17.63 mm^3 , and 1.5 vs. 1.3 , respectively, $P>.05$). The average manual palpation score was highest in the ADSC group compared with the BMSC and VO groups (1.3 vs. 1.2 vs. 0.7 , respectively, $p>.05$).

Conclusion: In a rat model, ADSCs yielded increased fusion mass volume and rates of fusion when combined with a clinical grade bone graft substitute. ADSCs showed a trend towards higher fusion mass volume and rates of fusion compared to BMSCs. Ongoing histological studies will assess the quality of bone formed in the fusion masses.

465 The History of and Controversy over Kambin's Triangle: A Historical Analysis of the Lumbar Transforaminal Corridor for Endoscopic and Surgical Approaches

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Introduction: The transforaminal corridor in the lumbar spine allows access to the traversing and exiting nerve roots, the thecal sac, and the intervertebral disc space. Surgeons and interventional pain management physicians have routinely utilized this corridor. Surgeons performing traditional midline and minimally invasive approaches for lumbar interbody fusion access the interbody space within the boundaries created by the exiting root of a segment and the traversing root after a complete facetectomy, removal of the pars interarticularis and lamina. Endoscopic surgeons and

interventional pain management physicians approach the lumbar segment through a similar corridor, but with the bony anatomy intact. Although the boundaries of the corridor remain the same, the angle of the trajectory of the approach and the bone work between the two differ. The overlap between these two distinct access corridors has led to an openhanded application of the term Kambin's Triangle. Initially described for endoscopic approaches to the lumbar spine, the working triangle that Kambin first used in 1973, has found itself grafted into the transforaminal lumbar interbody fusion literature. Given the similarities between these corridors, it is understandable how the lines of this nomenclature have blurred. The result has been an interchangeable application of the term Kambin's triangle for a variety of procedures in the spine literature. The objective of the current work is to add clarity to the various lumbar transforaminal corridors. That clarity is best framed within the history of Kambin's triangle.

Methods: Literature review of all publications from 1973 to present containing keywords: Kambin's Triangle and TLIF

Results: No publication was identified where Kambin reports removal of the superior articular process.

Conclusion: Kambin's triangle should be limited to percutaneous access to the disc space for endoscopic approaches. The term "Kambin's triangle" should not be applied to TLIFs when the facet, pars interarticularis, and lamina have been removed.

466 Adipose-Derived Stem Cells Treated Ex Vivo with Low-Dose of Bone Morphogenetic Protein-2 Augment Their Efficacy in Spinal Fusion

Alexander Perdomo-Pantoja MD; Christina Holmes; Ethan Cottrill BS; Wataru Ishida MD; Sheng-fu L. Lo MD; Timothy F. Witham BS, MD

Introduction: Adipose-derived mesenchymal stem cells (ADSCs) have recently become of increasing interest in spinal fusion research. Several pre-clinical studies have demonstrated that ex vivo expanded ADSCs can achieve spinal fusion, particularly when combined with BMP-2. However, clinical delivery of rhBMP-2 often requires high concentrations and has been associated with various complications. We aimed to examine whether a brief period of in vitro pre-priming with low-dose of rhBMP-2 can enhance ADSC-mediated fusion in a rat model.

Methods: ADSCs were isolated from the inguinal fat pads of syngeneic 6-8 week old Lewis rats and cultured in vitro. When passage 1 (P1) ADSCs reached approximately 80% confluency they were pre-primed for 24 hours with 1 ng of rhBMP-2 (Medtronic). After pre-priming, 2×10^6 ADSCs were seeded onto Vitoss (Stryker) bone graft substitute scaffolds for subsequent transplantation. Dorsolateral spinal fusion surgery at L4-L5 was performed on 21 female Lewis rats divided into 2 experimental groups: [1] Vitoss+ADSCs pre-primed with rhBMP-2 (n=12); and, [2] Vitoss+non pre-primed ADSCs (n=12). Fusion was evaluated eight weeks post-surgery via micro-computed tomography (MicroCT) imaging and manual palpation.

Results: Preliminary microCT imaging data suggest that rhBMP-2 pre-primed ADSCs (n=11) yielded significantly higher fusion mass volumes than non-primed ADSCs (n=10) (14.97 mm^3 vs. 12.78 mm^3 , respectively, $p=.04$). However, preliminary CT fusion scores were not significantly different between groups (1.7 pre-primed vs. 1.5, non-primed, $p>.05$). Pre-primed ADSCs also yielded significantly higher manual palpation scores than non-primed ADSCs (1.9 versus 1.3, respectively, $p=.03$).

Conclusion: In our rat model, rhBMP-2 pre-primed ADSCs displayed an increased fusion mass volume and manual palpation score compared to non-primed ADSCs. Ongoing histological studies will evaluate the quality of bone formed within the fusion masses. Future studies will also compare whether these results are similar in pre-primed BMSCs.

467 Axillary Nerve Repair By Lower Subscapular Nerve In Upper Brachial Plexus Palsy

Pavel Haninec; Libor Mencel MD, PhD

Introduction: The possible utilization of lower subscapular nerve for use in brachial plexus surgery was suggested by many anatomical studies. To date, however, we know of no studies in the literature describing the use of separate lower subscapular nerve for axillary nerve reconstruction. The aim of this study was to examine the effectiveness of this nerve transfer in upper brachial plexus palsy.

Methods: Of 1340 nerve reconstructions performed by the senior author (P.H.) between 1993 and 2018 in 568 patients with brachial plexus injury, 17 involved axillary nerve repair by lower subscapular nerve. All 17 of these procedures were performed between 2011 and 2017. The mean age of these patients was 48 years and the mean time between trauma and surgery was 6.5 months.

Results: Thirteen patients completed a minimum follow-up period of 18 months. Successful deltoid recovery was defined with muscle strength MRC grade = 3, electromyographic increase in the amplitude and duration of motor unit action potentials and by evaluation of muscle mass increase. Axillary nerve reconstruction was successful in 9 of 13 patients, which represents a success rate of 69.2%. No significant postoperative weakness of shoulder internal rotation or adduction was observed after transecting lower subscapular nerve.

Conclusion: The lower subscapular nerve is possible to use as a neurotization tool for upper brachial plexus injury with success rate 69.2% in axillary nerve repair.

468 Impact of Hypothyroidism on In-Hospital Mortality for Cervical Spinal Fusions

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Introduction: The prevalence of hypothyroidism in the United States is 1-4% and is associated with an increased risk of developing many comorbidities including hypertension, cardiovascular disease, osteoporosis, peripheral neuropathy, and muscular weakness.¹⁻⁴ However, the impact of hypothyroidism on perioperative morbidity in patients undergoing cervical spinal fusion is limited. It was the aim of this study to elucidate this relationship.

Methods: We performed a retrospective analysis of the Nationwide Inpatient Sample between 2004-2014. Patients who had an ICD-9-CM procedure code indicating a cervical spinal fusion (81.01-81.03 and 81.31-81.33) were included. Patients in this cohort with an ICD-9-CM diagnosis code indicating hypothyroidism (244.x) were compared to euthyroid patients. Defined primary outcome measures were short-term post-surgical complications [neurological, respiratory, cardiac, gastro-intestinal, wound complication and infections, venous thromboembolism, and acute-renal failure (ARF)]. Patient, hospital and Elixhauser comorbidity variables were assessed in univariate analysis to test covariates predictive of specific complications and mortality. Factors predictive in univariate analysis ($p < 0.2$) were utilized to construct a multivariate logistic regression model to analyze the effect of hypothyroidism on complications and mortality.

Results: A total of 1,681,805 patients underwent cervical spinal fusion from 2004-2014 for which 138,495 (8.2%) carried a diagnosis of hypothyroidism. Although hypothyroid patients had increased risk of developing acute postoperative anemia (OR 1.162, 95% CI 1.114 to 1.212, $p < 0.0001$), they exhibited decreased in-hospital mortality (OR .606, 95% CI .506 to .720, $p < 0.0001$).

Conclusion: Hypothyroid patients undergoing cervical spinal fusion demonstrated lower rates of in-hospital mortality when compared to their euthyroid counterparts. This suggests that hypothyroidism offers protection against all-cause mortality in the post-operative cervical spinal fusion patient. The mechanism is poorly understood but may be secondary to either decreased oxygen demand and thus reduced cardiac workload in the hypothyroid-induced hypometabolic state or by the known antithrombotic effects of thyroid hormone supplementation.³

469 Transplanted Bone Marrow Stem Cells Treated With Bone Morphogenetic Protein-2: Tracking In Vivo Their Survival And Proliferation In A Murine Spinal Fusion Model

Alexander Perdomo-Pantoja MD; Wataru Ishida MD; Maritza Taylor; Colson Tomberlin; Sheng-fu L. Lo MD; Timothy F. Witham BS, MD; Christina Holmes

Introduction: Little is known about whether BMP-2 affects the proliferation or survival of transplanted cells in tissue engineering applications; therefore, we developed a mouse model for non-invasive in vivo tracking of transplanted bone marrow cells (BMSCs) over time during spinal fusion, to explore the role of BMP-2 on transplanted BMSC survival and proliferation post-implantation.

Methods: BMSCs were isolated from syngeneic transgenic FVB mice, which express the luciferase gene, and seeded at a concentration of 5×10^6 cells/sponge onto a collagen sponge (CS) pre-incubated with either high or low dose of rhBMP-2. FVB/NJ host mice underwent bilateral posterolateral lumbar spinal fusion surgery divided in four groups: (1) CS + Luc(+)BMSCs; (2) CS + low dose BMP-2 + Luc(+)BMSCs; (3) CS + high dose BMP-2 + Luc(+)BMSCs; and, (4) CS seeded with syngeneic BMSCs. Bioluminescence imaging was performed at different time points post-surgery. Fusion was assessed 8 weeks post-surgery via microCT imaging.

Results: All Luc(+)BMSCs groups showed an increase in bioluminescence flux signal over the first 12 days, suggesting early transplanted cellular proliferation. This was followed by a dramatic decrease in signal from day 15 onwards, indicating cellular death. Between day 6 and 15, the group treated with high concentration BMP-2 exhibited the highest flux signal intensity. From week 4 onwards, however, all groups showed similar, dramatically reduced flux signals. At 8 weeks, both groups treated with BMP-2 were found to fuse at similar rates via microCT, however, the higher dose yielded a higher fusion mass volume (5.80 ± 1.95 mm³ vs. 4.33 ± 1.65 mm³, $p = .01$).

Conclusion: BMP-2 appears to increase early transplanted BMSC proliferation in a dose-dependent manner, however, by week 4 post-surgery, this effect decreases and all groups exhibit a dramatic decrease in transplanted cell survival. Increasing concentrations of BMP-2 yielded higher fusion mass volumes. Ongoing immunohistochemistry will determine the fate of transplanted cells within the fusion mass.

470 Combined Annulus Fibrosus and Nucleus Pulposus Repair In An In-vivo Sheep Model

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Introduction: Objective of the current study is to assess the efficacy of combined annulus fibrosus (AF) using high-density collagen (HDC) gel and nucleus pulposus (NP) repair using a hyaluronic acid (HA) gel in an in-vivo sheep model.

Methods: We performed an anterolateral, retroperitoneal pre-psoas approach to access the IVDs L1-6 in a total of 8 skeletally mature Finn sheep. IVDs were randomized into 5 groups 1) intact, 2) injured via 3x10mm box annulotomy and removal of 200mg of NP; 3) injury and HDC gel patch for AF repair, 4) injury and injection of a HA gel into the NP and 5) injury and HDC AF repair and NP HA replacement. At 6 weeks postoperatively, sheep were sacrificed and underwent post-mortem 3T-MRI scans as well as gross anatomical and histological evaluation. Disc height index (DHI) analysis and Pfirrmann grading (PG) were performed on each segment using MR images.

Results: Intact control discs were not degenerated and had an average PG of 1 while injured, untreated discs had significant degeneration with an average PG of 3. Discs receiving the combined injection and collagen AF patch

individually showed fewer signs of degeneration than injured alone and the combined treatment resulted in the least amount of degeneration with PG not significantly different than the intact controls. DHI confirmed the trends seen in the PG, where injured discs lost 20% of the intact disc height, the individual NP and AF repairs restored 5-10% of intact disc height, and the combined repairs preserved 90% of the intact disc height (Figure 1 and 2).

Conclusion: PG and DHI results demonstrate that individual NP and AF repairs are able to prevent disc degeneration better than no treatment at all, however the greatest preservation of disc health was seen with combined AF and NP repairs.

471 Adenoviral Delivery of Botulinum Toxin Genes Inhibits Synaptic Activity in the Rat Spinal Cord: An Evaluation of Different Toxin Domains in Gene-Based Neuromodulation

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Introduction: Botulinum toxin is a potent synaptic inhibitor that is widely used to treat peripheral nervous system disorders, but it suffers from transient effects and central nervous system toxicity. Vector-mediated gene transfer has the potential for cell-specific, sustained neural inhibition. We tested the adenoviral vector-mediated expression of select botulinum toxin/A (subtype A) protein domains in focal central nervous system inhibition without cytotoxicity.

Methods: Adenoviral vectors encoding different botulinum toxin/A domains (light chain, light chain and receptor binding domain, and light chain and translocation domain) were injected into rat spinal cords at 4×10^4 transforming units to test their neural inhibitory effects. To assess for dosage dependency, vectors were also tested at 4×10^5 and 4×10^6 transforming units. Pre-surgical baseline and post-operative sensorimotor function was measured by Basso-Beattie-Bresnahan open-field locomotor scoring, grip strength, and rotarod performance. After 3-weeks of postoperative behavioral testing, rats were euthanized, and spinal cords were immunostained for cytotoxicity and transgene expression. Prior to injection, vectors were tested in vitro in HEK293 cells to control for differences in transduction efficiency.

Results: Animals injected with vectors encoding the light chain and receptor binding domain displayed the most consistent deficits between all treatment groups in open-field assessment, grip strength, and rotarod performance. These behavioral deficits were sustained for the entire 3-week testing period. Rats injected with adenovirus containing light chain showed spontaneous recovery at 16 days post-injection, coinciding with the cessation of adenoviral gene expression. Spinal cord neuron counts revealed no signs of cytotoxicity between treatment groups and controls at injection titers of 4×10^4 and 4×10^5 but not at 4×10^6 transforming units. In vitro testing showed no difference in transduction efficiency between vectors and there were no differences in neuron density compared to controls.

Conclusion: Our results suggest that viral vector-mediated gene transfer using botulinum toxin light chain and receptor-binding domain may be another approach to neural inhibition. These preliminary findings warrant further studies using alternate vectors and genetic promoters to target specific cell types for longer periods of time. With further development, focal gene-based neuromodulation may contribute to the treatment of neurological disease and the study of neural circuitry.

472 The National Prevalence and Characteristics of Opioid Use In Patients Undergoing Elective Spine Surgery

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Introduction: As local governments join ongoing medical efforts to minimize opioid dependence and begin regulating prescribing practices (including limiting prescriptions to 7-day volumes), it is essential to evaluate current prescribing practices to guide legislation and identify areas for improvement.

Methods: The MarketScan database, populated by national employer-sponsored health plans, was queried using CPT codes of common elective spine surgeries, and opioid prescribing data 365 days prior to and following surgery. Analysis was limited to patients aged 18-64, patients discharged home, and surgeries performed between 2010 and 2016.

Results: A total of 253,473 surgical cases were analyzed; before surgery, 24.4% were opioid-naïve, 60.0% filled 1-10 opioid prescriptions, and 15.6% had a diagnosis of opioid dependence or >10 prescriptions. Surgeries included anterior cervical discectomy/fusion (ACDF) (35.41%), posterior cervical laminectomy/fusion (PCF) (2.87%), lumbar decompression (LD) (46.29%), and posterior lumbar fusion (PLF) (15.42%). Cervical surgeries had the highest incidence of opioid-naïve patients (27.24% ACDF, 29.89% PCF), and PLF had the highest rate of preoperative opioid-dependence (25.31%). Post-operatively, refills were requested within 30 days by 26.9% opioid-naïve, 43% intermittent, and 86.5% opioid-dependent patients. Opioid-naïve patients required refills in 26.6% ACDF, 28.8% PCF, 20.8% LD, and 48.2% PLF. However, 87.0% ACDF, 85.0% PCF, 83.0% LD, and 91.2% PLF of opioid-dependent patients obtained a refill within 30 days. Oral morphine-equivalents per post-operative prescription also varied from 960 OME in opioid-naïve, 1009 OME intermittent, and 1738 OME opioid-dependent patients.

Conclusion: The majority of patients undergoing common elective spine surgeries are not opioid-naïve. Refill rates and OME's vary wildly among opioid-naïve, intermittent, and opioid-dependent patients. Opioid-naïve and intermittent-use patients represent an opportunity to prevent dependence, while acute postoperative pain control in opioid-dependent

patients remains challenging. Limiting prescribers to 7-day prescriptions in larger surgeries places an undue burden on prescribers and may result in unreasonable delays in pain control.

8:53 - 8:55 am

473 In Vitro Response to Implants with Internally Roughened Micron and Nano Features

Justin L. Brown PhD; Michelle B. Gallagher MS; Jennifer M. Schneider MS

Introduction: Recent research has focused on enhancing the endplate-contacting surfaces of spinal interbody fusion devices. The topography of the internal walls of interbody implants may play an equally important role during bone graft integration and fusion, however there is an absence of work investigating the effect of micro/nano-topography of internal implant surfaces on cellular response. This study evaluates whether uniform application of surface topography at the micro/nano level invokes a similar cyto/chemokine expression and phenotype when exposed to human mesenchymal stem cells (MSCs), regardless of location on the device.

Methods: MSCs were seeded homogeneously on spinal fusion devices, cultured 14 days and selectively lysed from each device face. Cyto/chemokine expression was assessed with PCR and analyzed using the NIH bioinformatics database, DAVID, to identify statistical groupings across interior/exterior device faces and three implant types; PEEK, smooth titanium, and a novel device with micro/nano-topography(MN) on both the macrotextured endplate-contacting and internal surfaces. Immunostaining at 24hrs examined MSC morphology on implant faces.

Results: Analysis of cyto/chemokines demonstrated expression varied across implant type (PEEK, smooth Ti, MN), but not between the exterior and interior surfaces of each device type. Functional analysis of the changes in cyto/chemokines using DAVID revealed MN surfaces upregulated bone formation relative to smooth titanium and PEEK, Fig.1. Furthermore, PEEK demonstrated increased inflammatory cyto/chemokines on all implant faces. Finally, the morphology of the MSCs on each MN face demonstrated a spread cell with multiple processes associated with osteoblastic phenotypes, which is in contrast to the spindle shaped cells on PEEK and smooth titanium associated with fibroblastic phenotypes, Fig.2.

Conclusion: These results demonstrate equivalent MSC gene expression and morphology on the interior and exterior faces of the devices examined, and further support the significance of engineered topography on all faces of interbody fusion devices to optimize cellular response and accelerate arthrodesis.

474 Influence of Lumbar Lordosis on Posterior Rod Strain in Long-Segment Pedicle Screws and Rods

Instrumentation and Anterior Column Realignment: Cadaveric Study

Bernardo D. Pereira MD; Jakub Godzik MD, MSc; Jennifer Lehrman BSE, MS; Anna Newcomb; Randall Hlubek MD; Juan S. Uribe MD, FAANS; Jay D. Turner MD, PhD; Brian P. Kelly PhD

Introduction: Restoration of lumbar lordosis (LL) is an essential element of spinal deformity correction surgery and it differs significantly between patients. Posterior rod strain (RS) monitoring during biomechanical testing is an effective method to infer the stresses on spinal implants and predict failure mechanisms. Yet, the geometry of the final construct may have significant impact on the resultant forces.

Methods: Seven fresh-frozen specimens underwent standard nondestructive tests in 7.5 Nm flexion (FL) 7.5 Nm extension (EX) and 400 N compression (C) in a robotic apparatus. Conditions tested were: 1) intact; 2) pedicle screws and rods at L1-S (PSR); and 3) anterior column realignment at L3-L4 (ACR) with 30° interbody device. The posterior right rod was instrumented with strain gauges oriented in line with the long axis of the rod between L3-4 and L5-S1 pedicle screws. Lumbar lordosis spanning different levels were measured from lateral x-rays in all different conditions before loading, using the Cobb method: L5-S1, L4-S1, L3-S1, L2-S1 and L1-S1. These angles were compared with peak recorded rod strains (RS) for each test condition. Data were analyzed using Pearson correlation analysis ($p < 0.05$).

Results: There were significant correlations between both intact ($R^2=0.74$, $p=0.028$) and PSR ($R^2=0.87$, $p=0.007$) L3-S1 angles and PSR L3-4 RS during FL, and between intact L3-S1 angle and PSR L3-4 RS during EX ($R^2=0.791$, $p=0.018$). Intact L3-S1 angle also correlated with ACR L5-S RS during C ($R^2=0.86$, $p=0.008$). Intact L2-S angle correlated with PSR L3-4 RS during FL ($R^2=0.86$, $p=0.007$) and EX ($R^2=0.93$, $p=0.002$), as well as PSR L5-S RS during FL ($R^2=0.71$, $p=0.030$) and ACR L5-S RS during C ($R^2=0.71$, $p=0.030$).

Conclusion: Lumbar lordosis in both the intact spine and PSR demonstrated strong correlations with in vitro posterior RS during various configurations. These relationships should be strongly considered when interpreting results of biomechanical testing in long segment fusion models.

475 Biomechanical Evaluation of a Corpectomy Device with Self-Adjusting End Cap

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Introduction: Reconstruction after a vertebrectomy or a corpectomy is a technically demanding procedure. Most expandable cages have a fixed angle endcap, and this can lead to point loading and cage subsidence. The goal of this study is to determine if a self-adjusting multi-planar endcap will increase the contact area of the cage.

Methods: A cadaveric study assessed the mechanical behavior of T2 Stratosphere™ Expandable Corpectomy System (T2S, Medtronic) compared to a representative fixed angle corpectomy cage (T2A). T2S includes a self-adjusting endcap with a multi-planar total range of motion of 16 degrees and optional extended endcaps (T2S+EE). Figure 1

shows an image of T2S. Two surgeons performed partial corpectomies on two spines each (T11-Sacrum) at L2 with posterior instrumentation from T12-L4. Each surgeon randomly placed each corpectomy device into their respective specimens. TekScan pressure films were placed between the corpectomy device and the endplates which recorded the contact area. Fluoroscopy (Figure 2) was used to finalize placement of the corpectomy systems. Figure 3 represents a contact area map generated post compression.

Results: Analyzing the data (Figure 4) using an ANOVA general linear model, the "Device" factor (T2A vs. T2S vs. T2S+EE) was statistically significant for L1/L3 post compression ($p=0.008$, 0.009 , respectively) while the device differences for L1/L3 pre-compression were not statistically significant ($p=0.323$, 0.112 , respectively). Pre-compression data indicate general trends that T2S and T2S+EE have larger values, on average, than T2A. Using a Tukey Pairwise Comparison on post compression data, T2S and T2S+EE were each significantly different from T2A, but there were no significant differences between T2S and T2S+EE.

Conclusion: Utilization of an expandable cage with a self-adjusting multi-planar endcap leads to a significant increased contact area after compression across the device; furthermore, even without compression, a trend of increased contact area was present at the vertebrae interfacing the self-adjusting endcap.

476 Spinal Cord High-grade Infiltrating Gliomas in Adults: Clinico-pathological and Molecular Evaluation

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Introduction: Primary high-grade infiltrating gliomas of the spinal cord (SCHGG) in adults are rare with prior series including limited numbers of cases and reporting poor outcomes. The molecular profile of SCHGG has not been well-characterized.

Methods: We identified 13 adult patients whose surgery had been performed at our institution over a 26-year-period. Detailed clinical information was abstracted from the electronic medical record. Existing slides were reviewed and, when sufficient tissue was available, immunohistochemistry and a targeted 150-gene Next Generation Sequencing (NGS) panel were performed.

Results: The 13 patients included 11 men and 2 women with a median age of 38 years. Histologically, all were consistent with an infiltrating astrocytoma corresponding to 2016 WHO grades III ($n=5$) and IV ($n=8$). By immunohistochemistry, 6 cases were positive for H3K27M. Next generation sequencing (NGS) was successfully performed in 10 cases. H3F3A K27M-mutant status was confirmed in 4 cases (the other 2 sequencing reactions failed). Additional recurrent mutations identified included those of TERT promoter ($n=3$), TP53 ($n=5$), PPM1D ($n=3$), NF1 ($n=3$), ATRX ($n=2$) and PIK3CA ($n=2$). No HIST1H3B, HIST1H3C, IDH1, IDH2 or BRAF mutations were detected. Ten patients have died since first surgery, with a median survival of 13 months, and 1-year of 46%. Median survival was 48.5 months for H3K27M-positive cases, compared to 1 month for those with TERT promoter mutation, and 77 months for those harboring neither ($p=0.019$).

Conclusion: Our findings suggest that SCHGG in adults represent a heterogeneous group of tumors, with variable outcomes possibly related to their molecular profiles.

477 Spinal Cord Stimulator (SCS) Trial Lead Placement Under General Anesthesia A Feasibility, Accuracy and Reliability Study

Tianyi Niu MD; Yevgeniy Freyvert MD; Daniel C. Lu MD, PhD; Irene Wu

Introduction: Epidural spinal cord stimulator (SCS) is a common strategy for treating medically refractory neuropathic pain. A trial lead is typically placed through a percutaneous incision to test a patient's response, and the permanent implantation is performed only if SCS is effective in relieving the pain. Generally, the trial is placed under awake, but sedated conditions, and the area of coverage is confirmed prior to lead placement. However, this technique is highly subjective and influenced by the patient's depth of sedation and cooperation. We present our experience with trial placement under general anesthesia (GA), while using spinal cord motor evoked responses (sMEP) to assess proper lead placement and coverage.

Methods: A single center, multiple surgeon, retrospective chart review was performed. 25 subjects underwent SCS percutaneous lead placement under GA (general anesthesia group). This was compared to 25 previous subjects who underwent SCS trial lead placement while awake (awake group). Pre- and post-SCS trial lead placement assessments were conducted that included visual analog scale (VAS, back and leg) and Oswestry Disability Index (ODI). Surgical time, and rate of successful trial (defined as lead placement that reduced pain by 50% or greater and subsequent permanent implantation) were also captured.

Results: Operative time was significantly shorter for GA group. There were no cohort differences in patient profile between the two groups (age, gender, BMI, co-morbidities, pain medication use, and chronicity of symptoms). Furthermore, there were no differences in the pre-operative metrics of VAS and ODI. After surgery, there were no differences in VAS or ODI scores between the two groups. Surgery time was significantly less for GA group, and the rate of successful trial favored the GA group, which trended toward significance (86% vs. 77% $p = 0.062$).

Conclusion: SCS trial under general anesthesia may have advantages to awake lead placement in decreased surgical time and increased success rate, possibly due to better placement using an objective measure (sMEP) of proper lead placement.

478 Inflammatory Mediators Modulate Mitochondrial Dynamics in Spinal Facet Chondrocytes

Logan Helland MD

Introduction: The pathological cascade of osteoarthritis includes molecular, cellular, and tissue level changes. Injury leads to inflammation and MMP expression followed by ECM breakdown and subsequent chronic inflammation from tissue loss. During this process, mitochondrial dysfunction develops leading to decreased ATP production and increases in ROS. Normal protection from dysfunction includes mitophagy and organelle repair. Chronic inflammatory states may lead to a decrease in the AMPK-SIRT pathway causing decreased mitophagy, decreased mitogenesis, and increased ROS. Without effective repair or protective mechanisms, mitochondrial dysfunction leads to chondrocyte cell death and overall tissue degradation.

Methods: Facet cartilage was harvested from healthy porcine spine and digested in protease and cartilaginase overnight. Cells were then plated and cultured in standard porcine media for five days until cells quiescent. Experimental cells were then exposed to TNF- α (10ng/mL) and IL-1 β (5ng/mL) for 48 hours while control cells were again cultured in standard media. Cells were then stained with calcein green and mitotracker deep red and fixed in formalin. Cells were then imaged via 100x confocal microscopy.

Results: Examination of fixed, stained chondrocytes from porcine facets show predominately a mitochondrial matrix in the fusion state, primed for ATP production and in a healthy state for the control cells. Cells exposed to cytokines showed a majority of cells with the predominate fission state of the mitochondrial matrix. The cells appeared dimmer with respect to intensity for both stains.

Conclusion: A trend towards mitochondrial fission with exposure to common inflammatory cytokines shows overall cell stress and loss of effective protection from mitochondrial dysfunction. The cells are primed for apoptosis given the mitochondrial stress. This shows inflammation could play a role in mitochondrial pathway of cell death and subsequent spondylosis as a result of tissue level degeneration.

479 Synergistic Inhibitory Effect of Anti-PD-1 Antibodies and LXR-623 Against Chordomas in an NSG-SGM3-BLT Humanized Mouse Model

Wataru Ishida MD; Alexander Perdomo-Pantoja MD; Betty Tyler BA; Michael Lim MD; Timothy F. Witham BS, MD; Sheng-fu L. Lo MD

Introduction: We previously established a humanized mouse model of chordomas, which enables us to study the interaction between human chordomas and human immune cells in vivo. To examine in vivo efficacy of immunotherapeutic agents on rare cancers such as chordomas, where murine equivalents are unavailable, this model is indispensable. The objective of this study is to study synergism between PD-1 blockade and LXR-623, a synthetic agonist of liverX receptors, a class of anti-neoplastic agents disrupting cancer cholesterol metabolism, using this model.

Methods: To achieve the humanization of the immune system, 24 NSG-SGM3 mice were engrafted with human thymus and CD34+ hematopoietic stem cells harvested from a fetus, whose HLA-types were partially-matched with those of the U-CH1 chordoma cell lines. The animals were divided into the four groups (n=6 for each): control (isotype Abs), anti-PD-1 Abs monotherapy (anti-human-PD-1-Abs (Clone: J116), 10 mg/kg, 3 times/week for 4 weeks, i.p.), LXR-623 monotherapy (isotype Abs + LXR-623 100mg/kg, daily for 4 weeks, i.p), and the combinatorial treatment (anti-human-PD-1 Abs + LXR-623). Anti-tumor activity was monitored via tumor size weekly and flow cytometric analyses one of tumor-infiltrating lymphocytes (TILs) one week after the treatment regimen, using the following Abs: anti-mouse-CD45, anti-human-CD3, anti-human-CD4, anti-human-CD8, anti-human-CD11b, anti-human-CD14, anti-human-CD33, anti-human-CD45, anti-human-PD-1, and anti-human-FoxP3.

Results: The synergistic inhibitory effect of LXR-623 and anti-PD1-Abs against chordomas was identified via synergistic volume reduction in the combinatorial group ($p < 0.05$ for each intergroup comparison except between control versus LXR-623). In the TIL analysis, the combinatorial group exhibited highest in human CD8+CD3+ cells and lowest human PD-1+CD8+CD3+ cells and human CD14-CD11b+CD33+ cells.

Conclusion: The synergism between LXR-623 and PD-1 blockade was observed potentially via reduction in CD14-CD11b+CD33+ (myeloid-derived suppressor cells) in the chordoma microenvironment. We are currently conducting multiplex cytokine analysis including TGF- β , IFN- γ , and IL-2 as well as multiplex immunohistochemistry (CD3, CD8, CD11b, CD33, PD-L1, Brachyury).

480 Leveraging microRNAs for Spinal Cord Injury Repair

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Introduction: Paralysis in spinal cord injury is largely due to loss of functional corticospinal motor neurons, the cortical neurons that control voluntary movement and do not spontaneously regenerate. Transplantation of stem cell-derived neurons is considered a potential therapeutic strategy¹⁻⁶. Unfortunately, stem cell-derived neuron populations are heterogeneous and comprised mainly of arrested immature neurons, placing limitations on their therapeutic potential. Progress requires an understanding of corticospinal motor neuron development. While several transcription factors

were recently implicated, the molecular controls that coordinately regulate these transcription factors to specifically generate - or regenerate - mature corticospinal motor neurons, are still unknown. microRNAs are small, non-coding RNAs that coordinately repress gene pathways and regulate transcription factors. microRNAs appear to contribute to early cortical development⁸, potentially providing the still elusive regulatory functions for CSMN development.

Methods: We profiled microRNA expression in pure populations of corticospinal vs. the highly related callosal projection neurons, obtained via retrograde labeling followed by FACS. Targets of lineage-restricted miRNAs were predicted using bioinformatic searches. Cortical and embryonic stem cell cultures were transfected with miR-CSMN1 gain-of-function, loss-of-function, and control reagents, followed by immunofluorescence analysis using established markers.

Results: We have identified microRNAs that are differentially expressed by developing corticospinal vs. callosal projection neurons. miR-CSMN1 is strongly expressed by corticospinal motor neurons during their development, and represses a transcription factor that regulates the callosal projection neuron development. miR-CSMN1 controls corticospinal cell fate in embryonic cortical culture and in embryonic stem cells, with overexpression increasing the % corticospinal motor neurons and knockdown decreasing it.

Conclusion: microRNAs play a role in corticospinal motor neuron development. miR-CSMN1 regulates adoption of the corticospinal motor neuron fate, and may enhance future stem cell therapies for spinal cord injury.

481 Association of Body Mass Index, Sagittal Vertical Axis Change, and Health-Related Quality of Life Outcomes following Adult Deformity Surgery

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Introduction: Obesity, a condition that is increasing in prevalence in the United States, has previously been associated with poorer outcomes following deformity surgery, including higher rates of perioperative complications such as deep and superficial infections. To date, however, no study has examined the relationship between preoperative BMI and outcomes of deformity surgery as measured by spine parameters such as the sagittal vertical axis (SVA), as well as health-related quality of life (HRQoL) measures such as the Oswestry Disability Index (ODI) and Scoliosis Research Society-22 Patient Questionnaire (SRS-22). To this end, we sought to clarify the relationship among BMI, postoperative SVA change, and HRQoL outcomes.

Methods: We performed a retrospective review of a prospectively managed multicenter adult spinal deformity database collected and maintained by the International Spine Study Group (ISSG) between 2009 and 2014. The primary independent variable considered was pre-operative BMI. The primary outcome was change of the sagittal vertical axis (SVA) at 1 year after deformity surgery. Postoperative ODI and SRS-22 outcome measures were evaluated as secondary outcomes. We used generalized linear models in order to model the primary or secondary outcomes at one year as a function of BMI at baseline, while adjusting for potential measured confounders.

Results: Increasing BMI was not statistically correlated with change of SVA at 1 year post-surgery. However, BMIs in the obese range were found to be statistically correlated with poorer outcomes as measured by the SRS-22 - a decline of 0.51 for BMIs 30-34.9 ($p = 0.03$) and a decline of 0.53 for BMIs > 35 ($p = 0.03$). BMIs > 30 were also found to be associated with poorer outcomes as determined by the ODI, but this correlation did not reach statistical significance.

Conclusion: Baseline BMI did not affect the degree of change achievable in SVA at 1 year post-surgery. However, baseline BMIs > 30 are statistically correlated with worsened health-related quality of life outcomes as measured by the SRS-22. Further validation of our results by future prospective studies remains warranted.

482 Risk Factors of Proximal Junctional Kyphosis in Neuromuscular Scoliosis

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Introduction: The development of PJK is a well documented complication after spinal fusion with strong correlations to poor health-related quality of life measures. However, PJK has not been well described in patients with neuromuscular scoliosis (NMS). As the pathology and treatment goals of NMS is vastly different from other forms of more prevalent scoliosis, the characterization of unique risk factors of PJK will aid in improving treatment.

Methods: This is a retrospective review of a high volume pediatric spinal deformity institution. All patients that underwent posterior spinal instrumented fusion for NMS were evaluated. Inclusion criteria were: complete x-rays preoperatively, immediate postoperatively and at last follow-up (minimum 6 months). Patients with missing imaging studies, incomplete follow-up or other causes of scoliosis were excluded. PJK was determined by a change in the proximal junctional angle of $\geq 15^\circ$ from immediate postoperatively to follow-up. Radiographic, demographic, and surgical factors were assessed for their relations to PJK.

Results: Of the 106 NMS patients who underwent surgery, 73 met inclusion criteria. Mean follow-up was 28.7 months and mean age 14.47 years. PJK incidence was 5.5% (4). Radiographic factors that correlated to increased rate of PJK were: increase in sagittal vertical axis postoperatively (-9.94 ± 70.44 mm in non-PJK vs 105.00 ± 12.73 mm in PJK; $p=0.029$); final sagittal vertical axis (0.68 ± 46.17 vs 57.25 ± 71.75 mm; $p=0.026$), reduction in lumbar lordosis (9.22 ± 17.27

vs -16.00 ± 4.24 degree; $p=0.048$); and shoulder imbalance ($p=0.038$). A lower implant density was associated with higher PJK (1.62 ± 0.26 vs 1.14 ± 0.73 ; $p=0.003$). PJK was not impacted by gender, age, cause of scoliosis (cerebral palsy, myelomeningocele, arthrogryposis, spinal cord traumatic brain injury), ambulatory status, presence of spasticity, fusion to pelvis, or pelvic obliquity.

Conclusion: The incidence of PJK after surgery for NMS is 5.5%. Postoperative increased positive sagittal alignment, reduced lumbar lordosis, shoulder imbalance, and low implant density are associated with health-related higher risk of PJK.

483 Supplemental Rods are Needed to Maximize Rod Strain Across the Lumbosacral Junction with TLIF but not ALIF in Long Constructs

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Introduction: Instrumentation across the lumbosacral junction (LS) is subject to significant strain and stresses, resulting in high rates of rod fracture during long segment fusion. Reduction of LS instrumentation strain may help reduce fracture rates. Clinical studies have demonstrated the benefit of multi-rod strategies in three column osteotomy constructs; however, use of multiple rods at the LS junction has not been extensively studied.

Methods: Standard nondestructive flexibility tests (7.5 Nm) were performed on 14 cadaveric specimens (L1-ilium) to assess range of motion stability (ROM), rod strain, and sacral screw bending moment (SS) of a supplemental 4-rod construction (4R) versus standard 2-rod construction (2R) (Fig. 1); specimens were equally divided into L5-S1 anterior lumbar interbody fusion (ALIF) or L5-S1 transforaminal lumbar interbody fusion (TLIF) groups. Three conditions were tested in each group: (1) No interbody+2R, (2) ALIF or TLIF+2R, and (3) ALIF or TLIF+4R. Data were analyzed using RM-ANOVA or ANOVA.

Results: No differences were observed between groups 1 and 2 for age, sex, bone mineral density, or baseline ROM ($p>0.09$). Overall, TLIF+2R demonstrated greater ROM than ALIF+2R in extension, lateral bending (LB), and axial rotation (AR) ($p<0.03$), with greater rod strain in flexion, extension, and compression ($p<0.001$, Fig 1), and greater SS in compression and AR ($p<0.04$). Compared to TLIF+2R, TLIF+4R resulted in reduced rod strain in flexion, extension, compression, and LB ($p<0.04$), as well as SS in AR ($p<0.001$); TLIF+4R improved the biomechanics compared to ALIF+2R; only ROM in LB ($p=0.03$) and SS in flexion, extension, compression, and AR remained elevated ($p<0.01$). ALIF+4R did not significantly improve ROM, rod strain, or SS ($p>0.11$).

Conclusion: The use of ALIF and adding accessory rods with TLIF significantly reduced lumbosacral rod strain in a long-segment cadaveric model with iliac fixation. Reducing strain could decrease the risk of failure associated with long-segment fixation.

484 Early and Late Complications in Surgical Correction of Proximal Junctional Kyphosis

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Introduction: PJK rates after adult spinal deformity (ASD) surgery have been reported as high as 34%. Previous studies have focused on the timing of and the factors predicting its occurrence. Techniques for correction have also been described. ASD procedures are known to be highly morbid, however there is some thought that PJK correction may have a distinctly higher complication rate.

Methods: After obtaining appropriate institutional review board approval, the electronic medical record was queried for patients who underwent spinal fusion surgery that included at least one thoracic segment between 2001 and 2016 at the University of Utah. Patients were identified and then further screened for the indication of fusion. The inclusion criteria were to have undergone spinal fusion for correction of PJK. Demographic information including gender, age at time of surgery, co-morbidities, smoking status, etc. in addition to information regarding surgical factors such as estimated blood loss, early and delayed complications after correction, amongst other data points.

Results: The initial screen yielded 765 patients. Of those, 49 met inclusion criteria which represented 50 cases of PJK that underwent surgical correction. The mean age at the time of surgery was 59.3 ± 16.0 yrs. The population was 30.6% male and 85.7% had significant comorbidities. The average follow-up was 3.0 ± 2.7 yrs. The rate at which there was at least one significant complication was 52% with pulmonary complications making up the largest grouping at 25.0%.

Conclusion: Surgical correction of PJK is a highly morbid undertaking. These procedures should be treated as a unique surgical fusion entity. All patients undergoing such procedures should be thoroughly counseled as to the significant risks that are much greater than many other surgical fusion procedures. Given these increased risks, extra measures should be implemented to reduce the more common complications.

485 Transforaminal Versus Anterior Lumbar Interbody Fusion at L5-S1 in MIS Treatment of ASD: Effect on Spinopelvic Parameters and Outcomes in Degenerative Scoliosis

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Introduction: Two approaches to arthrodesis at the lumbosacral junction have demonstrated high rates of fusion with satisfactory outcome: anterior lumbar interbody fusion (ALIF) and transforaminal lumbar interbody fusion (TLIF). There are advantages and disadvantages regarding approach, sagittal alignment, and neural decompression.

Methods: Retrospective ASD database with inclusion criteria: >18 years of age, a component of MIS surgery (posterior percutaneous screws and/or MIS interbody fusions), and at least PT>20, SVA>5cm, PI-LL>10, or scoliosis>20 was queried. Patients with TLIF or ALIF at L5-S1 and minimum 2 year follow-up were included. Radiographic, clinical and surgical parameters were compared.

Results: 82 pts were identified. No differences in preop spinopelvic sagittal parameters, EBL, OR Time or clinical outcome measures. Multivariate analysis resulted in greater LL with ALIF than TLIF (49.7° vs 40°, p=0.015), but no differences in other spinopelvic parameters or HRQOL measures (see table). Major complications (COMP) occurred with similar rates after ALIF (16.7%) and TLIF (28.8%; p=0.166), but minor COMP occurred more frequently after TLIF than ALIF (53.8% v. 30%; p=0.037). Infection was more common after TLIF (15.4% v. 0%, p=0.024) as were implant COMPs (26.9% v 3.3%, p=0.008). 1 ALIF patient had rod fracture and screw loosening. TLIF had 3 rod fractures, 8 interbody migration, 1 subsidence, 3 screw breakage, and 1 screw malposition. Reoperation rate was similar (10% ALIF v. 26.9% TLIF; p=0.069). TLIF required 11 reops for implant COMPs and 1 implant related revision for ALIF (p=0.028).

Conclusion: ALIF and TLIF at L5-S1 resulted in similar HRQoL, OR time and EBL. ALIF resulted in fewer minor COMP than TLIF when performing MIS correction of ASD. ALIF at the lumbosacral junction was also associated with fewer implant-related COMP and reoperations when compared to TLIF.

486 Operative Correction of Adult Spinal Deformity Is Not Associated with Reduced Risk of Persistent Opioid Prescribing

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Introduction: We sought to characterize the prevalence and risks of opioid prescribing among adult patients with spinal deformity treated with operative versus non-operative strategies.

Methods: We identified patients who had a single spinal osteotomy operation between 2002 and 2012, based on claimed Current Procedural Terminology (CPT) code. Searching by the most common diagnosis codes associated with those procedure claims, we assembled a non-operative control population and assigned each a random date of simulated surgery. Continuous insurance coverage from at least 90 days before through 2 years after actual or simulated procedure was mandated. Opioid prescriptions were quantified by average daily morphine milligram equivalents, and prescribing risk was stratified per US Centers for Disease Control and Prevention (CDC) guidelines. Prescribing beyond an expected post-operative recovery period of 90 days was considered persistent.

Results: Of 1754 operative patients, 43% were opioid-naïve pre-operatively, while 24% were classified as high-risk. After osteotomy, 46% of non-naïve patients remained at the same risk category; 29% had reduced risk. This is less than the 35% spontaneous rate of reduction after simulated surgery for 2376 non-operative patients. Among operative patients, there was a significantly higher rate of persistent prescribing for non-naïve versus naïve patients by post-operative day 90 (90% vs 62%) and 2 years (75% vs 40%, p < 0.0001 by Fisher exact test for both).

Conclusion: A majority of adult patients undergoing spinal deformity correction are prescribed opioids pre-operatively, and prescribing risk level usually does not decrease after surgery. Persistent prescribing after an expected recovery interval is more likely in this cohort, including beyond 2 years after surgery.

487 The Role of the Fractional Lumbosacral Curve in Persistent Coronal Malalignment following Adult Thoracolumbar Deformity Surgery

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Introduction: Achieving appropriate coronal alignment is less reliable in adults with coronal malalignment due to trunk shift ipsilateral to degenerated thoracolumbar scoliosis' apex. The goal of this study is to compare radiographs/surgical techniques for thoracolumbar deformity with varying severity and direction of coronal imbalance.

Methods: Review of adults who underwent posterior spinal fusions to pelvis (=5 levels) for thoracolumbar scoliosis. Exclusion: revisions, no coronal deformity, thoracic Cobb>300, and anterior operations. Patients were divided into 3 groups, as proposed by Rao et al.: (1) Type A, CSVL<3cm; (2) Type B, CSVL>3 cm and C7 plumb shifted to scoliosis' concavity; (3) CSVL>3cm and C7 plumb shifted to scoliosis' convexity. Radiographic parameters and surgical techniques were compared.

Results: 144 patients (male-6; female-118; avg age 58±10 years; Type A-87; Type B-19; Type C-18). Type C had significantly greater lumbosacral fractional curves. 28% of Type C were treated with fractional curve TLIFs, while all, but one, Type B had TLIFs of the fractional curve. Deformity parameters after surgery were similar, except Type C had persistently greater fractional curves/coronal malalignment. All preop Type B were appropriately corrected postop. For preop Type C, 67% remained Type C and 33% became Type A postop. Compared to those who became Type A, persistently undercorrected and malaligned (Type C) patients had significantly greater preop lumbosacral fractional curves, greater preop coronal Cobb angles, and more commonly involved TLIFs of lumbosacral fractional curves.

Conclusion: In adults who underwent primary, posterior-only operations for thoracolumbar spinal deformity, the majority of Type C coronal deformities remained coronally undercorrected and malaligned postop. For these patients,

an alternative surgical strategy should be considered to more adequately correct lumbosacral fractional curves and maintain and/or restore coronal balance.

488 Quantitative Age-Adjusted Targets for Ideal Cervicothoracic Sagittal Alignment in Asymptomatic Adults

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Introduction: Increased C2-T3 angle has been identified as a risk factor for sagittal malalignment following thoracolumbar surgery. No ideal cervicothoracic alignment thresholds exist in the literature. As several studies have demonstrated a relationship between the normal aging spine and sagittal alignment, such ideal-alignment thresholds should also account for patient age.

Methods: Patients >18yrs with cSVA<4cm, available full-body stereographic x-ray imaging, and NDI data at baseline were included. Patients were stratified by age: <35, 35-45, 45-55, 55-64, 65-74. Linear regression modeling allowed for identification of NDI values corresponding to ODI US-norms, as previously published. Linear regression analysis established correlations between C2-T3 angle, age, and NDI. Normative NDI values were then used to establish age specific targets.

Results: Overall, 223 patients (50±20yrs, 65% F) met inclusion criteria, presenting with a mean sagittal vertical axis (SVA) of 17.8±47.7mm, cervical SVA 19.8±11.2mm, T1 Slope-C2-C7 lordosis 24.7°±16.2°, and C2-T3 of 2.1°±16.5°. At baseline, increased C2-T3 angle was significantly correlated with both NDI score (r=0.266, p<0.001) and patient age (r=0.458, p<0.001). Baseline NDI showed a significant correlation with ODI (r=0.751, p<0.001), permitting extrapolation of US-normative NDI scores. US-normative NDI scores increased with age: <35yr: 10.1, 35-45yr: 11.8, 45-55yr: 14.7, 55-64yr: 18.8, 65-74yr: 21.7, >75yr: 27.8. Linear regression analysis showed a significant relationship between NDI score, age, and baseline cervicothoracic alignment, as assessed by C2-T3 angle (r=0.497, p<0.001). Using US-normative NDI scores and mean age within each patient age group, this regression equation yielded age-specific ideal alignment targets for C2-T3, all of which increased with age: <35yr: -11.6°, 35-45yr: -4.7°, 45-55yr: -1.4°, 55-64yr: 1.8°, 65-74yr: 4.7°, >75yr: 6.7°.

Conclusion: Significant relationships exist between age, neck disability, and cervicothoracic alignment, suggesting broad measurements across the cervicothoracic junction may be clinically relevant in predicting postoperative outcomes of surgical spine deformity patients. This study offers a set of ideal age-adjusted alignment targets for C2-T3.

489 Grading of Complications Following Cervical Deformity-Corrective Surgery: Are Existing Classification Systems Applicable?

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Introduction: Validated for general surgery, the Clavien-Dindo complication classification system allows for broad comparison of postoperative complications; however, the applicability of this system is unclear in CD-specific populations.

Methods: Surgical CD patients>18yr with baseline(BL)/postop clinical data. Primary outcomes: complication type(renal, infection, cardiac, pulmonary, GI, neurologic, musculoskeletal, implant-related, radiographic, operative, wound), Cc grade(I, II, III, IV, V). Secondary outcomes: EBL, LOS, reop, HRQL score. Univariate analysis assessed impact of complication type/Cc grade on improvement markers and 1-year postop(1Y) HRQL scores.

Results: 153 patients(61±10yrs, 61%F) underwent surgery for CD(8.1±4.6 lvls; surgical approach:48% posterior, 18% anterior, 34% combined). Overall, 63% of patients suffered at least one complication. Patient breakdown by complication type:renal(2.0%), infection(9.1%), cardiac(7.8%), pulmonary(3.9%), gastrointestinal(GI; 1.9%), neurological(28.8%), musculoskeletal(0.0%), implant-related(3.9%), radiographic(21.5%), operative(7.8%), and wound(5.2%). Of complication types evaluated, only infection and operative complications were associated with increased EBL(p=0.003 and p=0.032, respectively); cardiac(p<0.001), GI(p=0.030), and neurological(p=0.044) complications were associated with increased LOS. Implant-related(p<0.001) and radiographic(p=0.011) were the only complication types associated with re-operation. Patients were also assessed by Cc grade: I(28%), II(14.3%), III(16.3%), IV(6.5%), and V(0.7%). Cc grade I was the only category associated with increased EBL(p=0.015) and LOS(p=0.023). Cc grades I(p=0.046), III(p<0.001), and V(p=0.008) were associated with increased rates of reoperation. At 1Y, there were no differences across Cc groups in HRQL outcomes: EQ-5D(p=0.329), mJOA(p=0.413), NDI(p=0.083). Cc III was the only grade associated with inferior 1Y HRQL score(mJOA, p=0.048). Types of complications associated with inferior 1Y HRQL scores were:radiographic(NDI, p=0.038) and neurological(mJOA p=0.047).

Conclusion: Increasing complication severity, assessed by the Clavien-Dindo classification system, was not associated with increased EBL, LOS, or inferior 1-year postop HRQL outcomes following CD-corrective surgery. By type, cardiac, neurological, and GI complications were associated with increased LOS, and operative complications

were associated with increased EBL. These results suggest a need for modification of the Clavien system to increase utility in CD-specific patient populations.

490 Development of a Novel Cervical Deformity Surgical Invasiveness Index

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Introduction: There has been a surgical invasiveness index for general spine surgery and adult spinal deformity, but a cervical deformity (CD) index has not been developed

Methods: CD was defined as at least one of the following: C2-C7 Cobb $>10^{\circ}$, CL $>10^{\circ}$, cSVA $>4\text{cm}$, CBVA $>25^{\circ}$. A modified Delphi approach was used to select weightings for each variable that went into the invasiveness index based from experienced spine surgeons and neurosurgeons. Linear regression was used to predict operative time, EBL, and length of stay using the newly developed CD-specific invasiveness index, controlling for age, sex, and Charlson Comorbidity Index score. Binary logistic regression predicted high operative time (>338 minutes), high EBL (>600 cc), or high length of stay (>5 days) based on the median values of operative time, EBL and length of stay. Significance was set at $P<0.05$.

Results: 85 CD patients were included (61.35 ± 10.7 years, 65.9% female). The variables included in the newly developed CD invasiveness index with their corresponding weightings were: revision status (3), ACDF (2 per level), corpectomy (4 per level), levels fused (1 per level), implants (1 per level), posterior decompression (2 per level), Smith-Peterson osteotomy (2 per level), three column osteotomy (8 per level), fusion to upper cervical spine (2), absolute change in TS-CL, cSVA, T4-T12 thoracic kyphosis and SVA from baseline to 1-year follow-up. The newly developed CD invasiveness index was a significant independent predictor of estimated blood loss ($R^2=0.132$, $P=0.042$). This CD-specific index was also a significant independent predictor of operative time ($R^2=0.171$, $P=0.004$). CD-specific invasiveness index strongly predicted a hospital length of stay greater than 5 days ($R^2=0.310$, $P<0.001$), high blood loss ($R^2=0.170$, $P=0.011$), and extended operative time ($R^2=0.207$, $P=0.031$).

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

491 Reciprocal Changes of Mild and Severe Cases of Proximal Junctional Kyphosis After Lumbo-Pelvic Spinal Fusions

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Introduction: Post-Operative reciprocal changes (RC) associated with PJK in ASD fusions of the lumbo-pelvic spine are poorly understood.

Methods: Inclusion: ASD patients >18 y/o, undergoing fusions from the thoracic spine (UIV: T6-T12) to the pelvis with 1Y and 2Y radiographic f/u data. ASD was defined as: Coronal Cobb angle $\geq 20^{\circ}$, Sagittal Vertical Axis $\geq 5\text{cm}$, Pelvic Tilt $\geq 25^{\circ}$, and/or Thoracic Kyphosis $\geq 60^{\circ}$. PJK was defined as a $\geq 10^{\circ}$ measure of the sagittal Cobb angle between the inferior endplate of the UIV and the superior endplate of the UIV+2. Patients were grouped by mild (10° - 20°) and severe ($>20^{\circ}$) PJK at 1Y f/u. PSM controlled for CCI, age, PI and UIV. Unpaired and paired t test analyses determined difference between RC parameters change between time points (BL-1Y, BL-2Y). Pearson bi-variate correlations analyzed associations between RC parameters and PJK descriptors.

Results: 284 ASD patients with lumbo-pelvic fusions extending from the mid-thoracic spine into the pelvis were studied. The severe ($n=91$) v mild ($n=91$) PJK analysis consisted of 182 patients. Significant difference between groups was observed in 1Ydelta in TK (-16.8 v -22.8 , $P=.001$), TS-CL ($-.62$ v 2.8 , $P=.037$), cSVA (-1.8 v 1.9 , $P=.032$), C2S (-1.6 v 2.3 , $P=.022$), and 2Ydelta in T1S (1.9 v 5.5 , $P=.024$). Correlation between age and 1Ydelta in cSVA ($R=.153$, $P=.034$), and reop within 1Y and 1Ydelta in TK ($R=-.144$, $P=.029$) was found. Progressive PJK correlated with 1Ydelta in TK ($R=-.249$, $P=.002$). Severe PJK was found to correlate with 1Ydelta in TS-CL ($R=.142$, $P=.049$), cSVA ($R=.171$, $P=.018$), C2S ($R=.148$, $P=.040$), TK ($R=-.314$, $P<.001$), and 2Ydelta in T1S ($R=.256$, $P=0.003$).

Conclusion: RC in the unfused spine differed between mild and severe PJK. Patients with severe PJK experienced increases in TS-CL, TK, cSVA, and C2S between BL and 1Y, which differed from their mild PJK counter-parts. By 2Y, severe and mild groups exhibited similar amounts of change in cervical RC parameters coinciding with significant difference between the T1Sdelta2Y of these groups. In patients with severe PJK, proximal adjustment of the spine localizes on the cervico-thoracic junction over time.

492 Impact of Presenting Patient Characteristics on Surgical Complications and Morbidity in Early Onset Scoliosis

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Introduction: Early-onset-scoliosis (EOS) can be associated with significant comorbidity burden, complicating management decision-making. The rarity of this condition has resulted in a paucity of sufficiently powered studies describing comorbidity profiles and associated risks to the EOS population.

Methods: The KID database was queried for ICD-9 codes pertaining to congenital and idiopathic scoliosis from 2003, 2006, 2009, 2012. Patients <10 y/o (EOS group) were included. Demographics, incidence and comorbidity profiles were assessed. Comorbidity profiles were stratified by body systems (neurological, musculoskeletal, pulmonary, cardiovascular, renal). K-means cluster and descriptive analyses elucidated incidence and comorbidity relationships between frequently co-occurring comorbidities. Binary logistic regression models determined predictors of perioperative complication development, mortality, and extended length-of-stay (=75th percentile).

Results: 25,747 patients were included (Age: 4.34, Female: 52.1%, CCI: 0.64). Incidence was 8.9 per 100,000 annual discharges. 55.2% presented with pulmonary comorbidities, 48.7% musculoskeletal, 43.8% neurological, 18.6% cardiovascular, and 11.9% renal; 38% had concurrent neurological+pulmonary. Top inter-bodysystem clusters: Pulmonary disease(17.2%) with epilepsy(17.8%), pulmonary failure(12.2%), restrictive lung disease(10.5%), or microcephaly+quadriplegia(2.1%). Musculoskeletal comorbidities(48.7%) with renal+cardiovascular comorbidities(8.2%, OR: 7.9[6.6-9.4], $p<0.001$). Top intra-bodysystem clusters: Epilepsy(11.7%) with quadriplegia(25.8%) or microcephaly(20.5%). Regression analysis determined neurological+pulmonary clusters to have a higher odds of perioperative complication development(OR:1.28[1.19-1.37], $p<0.001$) and mortality(OR: 2.05[1.65-2.54], $p<0.001$). Musculoskeletal with cardiovascular+renal anomalies had higher odds of mortality(OR: 1.72[1.28-2.29], $p<0.001$) and extLOS(OR: 2.83[2.48-3.22], $p<0.001$).

Conclusion: EOS patients with musculoskeletal conditions were 7.9x more likely to have concurrent cardiovascular+renal anomalies. Clustered neurologic and pulmonary anomalies increased mortality risk by as much as 105%.

493 Is Frailty Responsive to Surgical Correction of Adult Spinal Deformity? An Investigation of Sagittal Re-alignment and Frailty Component Drivers

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Introduction: Frailty has been associated with adverse postoperative outcomes. Recently, a novel frailty index for preoperative risk stratification in patients with adult spinal deformity (ASD-FI) was developed. Components of the ASD-FI utilize patient comorbidity, clinical symptoms, and patient-reported-outcome-measures (PROMS).

Methods: Operative ASD patients =18 years old, undergoing multilevel fusions, with complete baseline, 6W, 1Y and 2Y ASD-FI scores. Descriptive analysis assessed demographics, radiographic parameters, and surgical details. Pearson bivariate correlations, independent and paired t-tests assessed postoperative changes to ASD-FI components, total score, and radiographic parameters. Linear regression models determined the effect of successful surgery (achieving lowest level SRS-Schwab classification modifiers) on change in ASD-FI total scores.

Results: 409 6 week, 696 1 year, and 253 2 year operative ASD patients were included. 6 week and 1 year baseline frailty scores were 0.34, 2 year was 0.38. Following surgery, 6 week frailty was 0.36 ($p=0.033$), 1 year was 0.25 ($p<0.001$), and 2 year was 0.28 ($p<0.001$). Of the ASD-FI variables, 17/40 improved at 6 weeks, 21/40 at 1 year, and 18/40 at 2 years. Successful surgery significantly predicted decreases in 1 year frailty scores ($R=0.273$, $p<0.001$), SRS-Schwab SVA modifier was the greatest predictor (Adjusted Beta: -0.291, $p<0.001$).

Conclusion: Improvement in sagittal realignment and functional status correlated with improved postoperative frailty. Additional research and deformity sub-group analyses are needed to describe associations between specific functional activities that correlated with frailty improvement as well as evaluation of modifiable and non-modifiable indices.

494 The Effect of Postoperative Sagittal Vertical Axis (SVA) on Discharge Disposition

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Introduction: Identification of factors which predict successful patient reported outcomes, including the need for time in a rehabilitation facility after surgery, are becoming more relevant as we transition to bundled payments and value-based care. Sagittal imbalance is associated with persistent patient-reported disability and development of adjacent segment disease.

Methods: In this study, a prospectively-collected surgical database of patient reported outcomes was queried for all posterolateral approaches to lumbar interbody fusion for degenerative spinal diseases at our institution. Preoperative demographic data, intraoperative parameters, and 90-day postoperative complications by a single-surgeon were

abstracted from the database from January 1, 2016–December 31, 2017. The primary outcome measure was the likelihood of discharge to a rehab facility. This data was correlated to an assessment of postoperative spinal sagittal parameters, with the assessor blinded to the discharge disposition.

Results: Eighty-two patients were assessed for sagittal parameters and discharge disposition. For patients with a discharge to home, Sagittal Vertebral Axis (SVA) averaged 3.6 ± 0.4 cm compared to 8.0 ± 1.3 cm for patients discharged to rehab ($p < 0.001$). Patient age ($p = 0.009$), ileus ($p = 0.010$), and deep vein thrombosis ($p = 0.010$) were also noted to be significantly associated with discharge to rehab. In a multivariable regression, the odds of discharge to rehab increased by 25% for every additional centimeter in the positive SVA ($p = 0.019$).

Conclusion: Undercorrection of positive SVA is associated with increased likelihood of discharge to a rehabilitation facility. Thus, presurgical counseling, optimization, and intraoperative correction of positive SVA would be modifiable factors which are associated with decreased length of stay and increased postoperative independence.

495 Incidence of Acute, Progressive, and Delayed Proximal Junctional Kyphosis over an 8-Year Period in Adult Spinal Deformity Patients

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Introduction: While previous literature have reported the incidence of PJK to range from 5%-46%, these studies are limited by small sample sizes.

Methods: Operative ASD patients (Coronal scoliosis $\geq 20^\circ$, SVA ≥ 5 cm, PT $\geq 25^\circ$, and/or TK $\geq 60^\circ$) > 18 y/o from 2009-2017 were included. PJK was defined as $\geq 10^\circ$ sagittal Cobb angle between the inferior endplate of the UIV and the superior endplate of the UIV+2. X2 analysis and post-hoc testing assessed annual and overall incidence of acute (6W follow-up(f/u)), progressive (increase in $^\circ$ of PJK from 6W to 1Y), and delayed (PJK development at 1Y, 2Y, or 3Y f/u) PJK development among operative (op) and re-operative patients(reop).

Results: 1005 patients were included (421 reop) (Age: 59.3, 73.5%F, BMI: 27.99, 92.9% white). No differences were observed between op and reop regarding acute, progressive, or delayed PJK at all f/u intervals($p > 0.05$). Overall incidence of any PJK from 2009-2016 was 59.1%, with lower annual rates observed in 2016 (50.9%, $p < 0.05$). Overall incidence of Acute PJK was 48.0%. Annual incidence of Acute PJK decreased from 53.7% in 2012 to 47.7% in 2016 ($p = 0.038$). Overall incidence of progressive PJK was 35.0%. Annual incidence of progressive PJK increased from 25.8% in 2009 to 35.7% 2016 ($p = 0.297$). Overall incidence of 1Y delayed PJK was 9.3%. Annual incidence of 1Y delayed PJK decreased from 9.2% in 2009 to 3.2% in 2016 ($p < 0.001$). Overall incidence of 2Y delayed PJK development was 5.0%. Annual incidence of 2Y delayed PJK decreased from 7.3% in 2009 to 0.9% 2015 ($p < 0.05$). No patients developed PJK at 3 years postoperative or greater.

Conclusion: Overall incidence of PJK was 59.1%, slightly above previously reports. While the progression of acute PJK is a challenge for physicians (exemplified by the recent increased incidence of progressive PJK), lower incidences of acute and delayed PJK development in recent years may indicate successful clinical implementation of preventative treatment strategies.

496 Anterior Column Realignment versus Pedicle Subtraction Osteotomy: Biomechanical Comparison of Stability and Rod Strain Distribution

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Introduction: Anterior column realignment (ACR) is a new minimally invasive approach for deformity correction. Limited data exist regarding long-term stability and complication profile. The ACR is similarly destabilizing to a pedicle subtraction osteotomy (PSO), which has a well-known complication profile. The goal of this study was to compare the biomechanical profiles ACR compared to PSO in terms of range of motion stability (ROM) and posterior rod strain (RS) to gain greater insight into the ACR technique and necessary surgical strategies to optimize longevity and stability.

Methods: Standard flexibility testing (7.5 Nm) was performed on 14 human cadaveric specimens, separated into two groups by L1-S1 intact ROM. For Group 1, a 30° hyperlordotic ACR was performed at L3/4; for Group 2, a 30° L3 PSO was performed. Flexion and extension pure moments were applied followed by compression. Conditions tested: 1) intact, 2) Pedicle Screw/ 2 rod (PSR) 3) ACR or PSO+2 rods (2R), 4) ACR or PSO+4R. Data were analyzed using RM-ANOVA or ANOVA ($p < 0.05$).

Results: No difference was observed between PSO and ACR in lumbar lordosis ($p = .83$) or focal bend ($p = .75$). While there were no differences in stability between ACR+2R and PSO+2R ($p > .065$), both were significantly destabilizing compared to PSR ($p < .032$). ACR+4R was more stable than ACR+2R in flexion and extension ($p < .022$), while PSO+4R was more stable than PSO+2R in flexion and extension ($p < .026$). RS between ACR+2R and PSO+2R was not significantly different ($p > .42$). 4R conditions in ACR and PSO had lower RS compared to the corresponding 2R condition in flexion, extension, and compression ($p < .008$). ACR+4R had lower RS compared to PSO+2R in flexion and extension ($p < .007$), but not compression ($p = .584$).

Conclusion: Both ACR and PSO are significantly destabilizing conditions. The 4R technique increases stability and decreases RS in both in ACR and PSO, but may be more effective in ACR.

497 Pilot assessment of OLIF/ATP in the Treatment of Adult Degenerative Scoliosis

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Introduction: Both optimism and skepticism exist regarding the application of OLIF/ATP to adult degenerative scoliosis. This technique allows for direct visualization of the anterior longitudinal ligament (ALL) and, therefore, has potential advantages in deformity correction.

Methods: Twenty-six consecutive patients with adult degenerative scoliosis underwent 2-staged reconstruction: OLIF/ATP from L1-S1, followed by T10-S1 minimally invasive pedicle screw instrumentation and fusion. PEEK interbody devices filled with bone morphogenetic protein and morselized allograft were used anteriorly without anterior instrumentation, except at L5-S1 where a single buttress screw was placed. Neuromonitoring was not used during the anterior stage. Facet decortication and morselized allograft were used at T10-L1 bilaterally. Standing upright scoliosis X-rays were obtained preoperatively; and postoperatively at day 1-2, 6 weeks, 3 months and 6 months. Correction was assessed using Cobb angles, lumbar lordosis (LL)/pelvic incidence (PI), and global sagittal and coronal balance.

Results: Twelve males and 14 females, ages 51-74 years were found to have mean preoperative lumbar Cobb 39°, thoracic Cobb 16°, LL 34°, and PI 46°. Mean preoperative coronal balance was -1.6 cm and sagittal balance +5.2 cm. Correction was maintained at 6 months postoperatively in all patients with the following means: Lumbar Cobb 4°, thoracic Cobb 2°, LL 49°, coronal balance -0.6 cm, and sagittal balance +1.4 cm. The mean LL:PI ratio after correction was 1.07. There was no blood transfusion, vascular injury, visceral injury, or perioperative cardiovascular event. The mean length of stay was 3.6 days and combined anterior/posterior blood loss 260 mL. No neurological injury was observed. A single patient was readmitted 2 months after surgery with Guillain-Barré Syndrome, and made complete motor recovery at 6 months with residual foot numbness.

Conclusion: Pilot assessment of OLIF/ATP for treatment of adult degenerative scoliosis shows satisfactory correction maintained at 6 months with low complication profile.

498 The Efficacy of Intraoperative Multimodal Monitoring in Pedicle Subtraction Osteotomies of the Lumbar Spine

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Introduction: Iatrogenic spine injury remains one of the most dreaded complications of PSOs and spine deformity surgeries. As such, IOM, which has the potential to provide real-time feedback regarding cord integrity, has become the gold-standard in such operations. However, while the benefits of IOM are well-established in PSOs of the thoracic spine, its utility in PSOs of the lumbar spine has not been robustly documented.

Methods: All adult patients who underwent lumbar PSOs at our institution from 2007 to 2017 were analyzed via retrospective chart review. Patients were categorized into one of two groups on the basis of IOM guidance. PDQ-39 quality of life (QOL) scores were gathered and multivariate analysis was performed for quantitative comparison of QOL scores. In addition, the proportion of patients who reached minimal clinically important difference (MCID), defined as an increase in PDQ-39 score of 4.72, was also determined, and statistical analysis was performed to determine whether IOM had a significant impact on achieving MCID.

Results: A total of 101 patients were included in the final analysis. Multivariate analysis shows that parameters with a statistically significant impact on achieving MCID included age (OR = 1.11, $p = 0.001$) and female sex (OR = 7.6, p -value = 0.005). Importantly, IOM usage was not correlated with a statistically significant increase in QOL scores ($p = 0.230$) or achievement of MCID 3 months after surgery ($p = 0.196$).

Conclusion: In our particular cohort, IOM did not lead to statistically significant improvement in outcomes in patients undergoing PSOs of the lumbar spine ($p = 0.230$). However, it is worthwhile to note that while statistical significance was not shown in this particular study, IOM is rapidly becoming the standard of care, and can be considered worthwhile if it prevents even one iatrogenic injury. The existing clinical equipoise, however, indicates future studies in this arena are necessary.

499 Thoracolumbar Junction Orientation: A Novel Guideline for Sagittal Correction to Reduce Proximal Junctional Kyphosis in Adult Spinal Deformity Patients with UIV at the Thoracolumbar Junction

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Introduction: This study aims to determine a predictive model for reciprocal thoracic kyphosis and proximal junctional kyphosis (PJK) based on the novel sagittal parameters of the thoracolumbar junction, thoracolumbar junction orientation (TLJO, thoracolumbar slope [TLS] and thoracolumbar tilt [TLT])

Methods: Review of adults who underwent posterior fusions extending from T10-L2 to the pelvis for spinal deformity with 2-year minimum follow-up. Sagittal alignment parameters (TK [T5-T12], PI, SS, PT and LL) and proximal junctional angle (PJA) were measured pre-operatively, 6 weeks post-operatively, and at final follow-up. TLJO was measured by TLS and TLT. Changes between time-points were determined (preop-6week = $(\Delta)Parameter[Pre-6wk]$ and preop-final follow-up = $(\Delta)Parameter[Pre-Final]$). SRS and ODI questionnaires were evaluated at final follow-up. Patients

were divided into two groups based on the presence of PJK ((Δ)PJA[Pre-Final]>15 degree). Independent T-Tests and ROC curves were used to investigate the significance of differences and cut-off values. Pearson correlations and linear regressions were used to analyze the entire cohort to determine the relationship between the changes in parameters.

Results: 127 patients (avg. age 58 $\pm$ 10 years; female 99) were included for analysis. Compared to patients without PJK (n=100; 78.7%), those with PJK (n=27; 21.3%) had significantly lower SRS scores [average (3.3 $\pm$ 0.8 v. 3.7 $\pm$ 0.7, p=0.015), pain (3.1 $\pm$ 1.0 v. 3.7 $\pm$ 0.9, p=0.022), mental health (3.4 $\pm$ 1.1 v. 4.1 $\pm$ 0.8, p=0.017) and significantly greater TK at final follow-up (20.9 $\pm$ 11.80 vs 8.6 $\pm$ 10.30, p=0.000), (Δ)LL[Pre-6wk] (-17.7 $\pm$ 13.40 v. -9.6 $\pm$ 11.3, p=0.002), (Δ)TLS[Pre-6wk] (14.9 $\pm$ 10.1 vs -7.1 $\pm$ 8.4, p=0.000). To be without PJK ((Δ)PJA[Pre-Final]<15 degree), ROC curves demonstrated a cut-off value of -9.4° for (Δ)TLS[Pre-6wk] (AUC: 0.712). PJK ((Δ)PJA[Pre-Final]) was significantly correlated with (Δ)TK[Pre-Final], (Δ)TLS[Pre-6wk]. To maintain a (Δ)PJA[Pre-Final]<15 degree, linear correlation revealed (Δ)TLS[Pre-6wk] needs to be >-25.3°.

Conclusion: As change of TLS reflects lumbopelvic realignment and influences reciprocal TK, reducing the change of TLS may be a new sagittal realignment guideline to reduce the risk of PJK.

500 Effect of Tobacco Smoking on Implant Failure Rate and Risk of Intra-Operative Bleeding: Analysis of 270 patients from the Prospective, Multi-center SCOLI-RISK-1 study of Complex Adult Spinal Deformity Surgery.

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Introduction: Smoking has been identified in as a predictor for complications after adult deformity surgery(1), however the effect on intra-operative complications, implant failure and other adverse events (AEs) has not been adequately described in prospective studies.

Methods: The Scolio-RISK-1 study enrolled 272 patients who had undergone complex adult spinal deformity surgery from 15 centers, with a minimum 2 year follow up. The outcomes and incidence of AEs in patients with a history of smoking (n=26) were compared to the non-smoking patients (n=244) using univariable analysis. Multivariable regression analysis was used to adjust for the effect of patient demographics, complexity of surgery and other confounders.

Results: No difference was observed in the number of levels or complexity of surgery in both cohorts. In the univariable analysis, the rates of implant failure were almost double (n=7; 26.9%; Odds Ratio 2.28; [95%CI 0.75 6.18]) that observed in the non-smoking group (n=34; 13.9%; p=0.088), but this was not statistically significant. Surgery related excessive bleeding was however significantly higher in the smoking group (n=5 vs n=9; 19.2% vs 3.7%; OR 6.22[1.48 22.75]; p=0.006). Wound infection rates were similar (n=3 vs n=17; 11.5% vs 7.0%; OR 1.74[0.30-6.70], p=0.422), as were rates of respiratory complications (n=1 vs n=13; 3.8% vs 5.3%; OR 0.71[0.02-5.13], p=1.000). In the multivariable analysis, the smoking group demonstrated a higher incidence of surgery related AEs over 2 years (n=13 vs n=95; 50.0% vs 38.9%; OR 2.12 [0.88-5.09]) (p=0.094), but this was not statistically significant.

Conclusion: Smoking significantly increased the risk of excessive intra-operative bleeding compared to the non-smoking group. The rate of implant failure was higher (but not significantly) in smokers, as was the rate of all post-operative surgery-related AEs. Even though this sub-analysis was likely underpowered, we recommend smokers undergo an active smoking cessation program prior to undergoing complex adult spinal deformity surgery.

501 Semi-automated Method for Calculation of Sagittal Alignment from CT Scans

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Introduction: Sagittal alignment of the spine is closely related to quality of life scores and malalignment is a cause of pain and disability. Stabilization of the spine and restoration of normal posture and spine alignment using osteotomies and/or fusion is a major goal of spine surgery. Current manual methods of measurement of sagittal alignment (Cobb, etc) on 2D sagittal radiographs have high inter and intra observer variability and are considered too time-consuming and complex for routine clinical use. Computerized measurements of sagittal alignment can reduce human variability and enable objective and consistent interpretation of images.

Methods: A semi-automated method for computerized calculation of sagittal plane alignment was developed. The method is based on processing and analyzing a CT scan of the spine. The CT scan is first segmented into individual vertebral bodies using a semi-automated algorithm with minimal human intervention. After segmentation, the algorithm analyzes the spatial relationship between the segmented vertebral bodies and calculates the spinal curvature and intervertebral alignment/angles. Lumbar Lordosis (L1-S1 angle) was calculated on the deidentified CT scans of 9 patients using two methods 1) Manual Cobb method and 2) Semi-automated computerized method. The mean difference, standard deviation, and coefficient and determination (R²) values were calculated.

Results: The mean difference in Lordosis calculated using the manual and computerized methods was 0.1 degrees with a standard deviation on 3.8 degrees (n=9). The R² value was 0.9526.

Conclusion: A semi-automated computerized method for measurement of sagittal alignment on CT scans demonstrated high accuracy and concordance with manual measurements and could provide surgeons with a consistent and objective method for evaluating sagittal alignment.

502 Characterization of Gait and Spinopelvic Alignment using Three-dimensional Kinematic Analysis and Support Vector Machine Regression

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Introduction: A variety of spinal pathologies can manifest with gait disturbance. Three-dimensional gait analysis provides quantitative information about trajectories, velocities, and angles throughout the spine and pelvis that could be applied in humans for diagnosing disease states and evaluating the efficacy of interventions. We sought to identify the kinematic changes during locomotion that best distinguished a neurodegenerative mouse model from their wild-type (WT) littermates.

Methods: A 3D motion capture system was used to track the coordinates of the thoracic spine, iliac crest, and hip while a neurodegenerative mouse model (J20) and WT mice stepped quadrupedally on a treadmill. Data regarding trajectory length, velocity, acceleration, and angle formation at the spine, iliac crest, and hip were collected. These variables were compiled in a support vector machine (SVM) regression that was used to identify their optimal combination for distinguishing between J20 and WT genotypes.

Results: Data from 16 J20 and 15 WT mice were included. The J20 mice demonstrated a significantly slower maximum velocity and greater number of steps with drag ($p < 0.001$ for both). The SVM regression selected a combination of angle maximum, angle standard deviation, maximum angle change rate, and average angle change rate of the hip, which was able to distinguish J20 from WT mice with 87.1% accuracy. Trajectory features of the iliac crest yielded 77.4% classification accuracy, while those for the thoracic spine produced 71.0% classification accuracy. The angle between the iliac crest and thoracic spine differed between genotypes, revealing a mean 2.5-degree tilt in this axis among J20 mice compared to WT.

Conclusion: By using the data obtained from 3D kinematic analysis in an SVM model, we were able to distinguish the quadrupedal kinematic patterns of J20 and WT genotypes. This approach could be applied to human gait testing for the evaluation, diagnosis, and monitoring of spinal pathology.

503 Readmission, Reoperation, and Infection after Long-segment Posterior Spinal Fusion

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Introduction: Posterior spinal fusions (PSF) can treat numerous spinal pathologies, but may be complicated by surgical site infections (SSI). Patients undergoing long-segment fusions may be at higher risk of SSI. Identifying factors associated with SSI and its sequelae could help risk stratify patients and tailor clinical management.

Methods: We identified and retrospectively analyzed all long-segment PSFs (7 or more levels) performed at our institution from 2000 to 2015. Data was collected on patients' clinical characteristics, procedural factors, and antimicrobial management, and multivariable analysis identified factors independently associated with the outcomes of interest.

Results: 628 patients were identified. SSI was associated with steroid use ($p=0.024$, OR=2.54), and using cefazolin ($p<0.001$, OR=4.37) or bacitracin ($p=0.010$, OR 3.49) for antibiotic irrigation, as opposed to gentamicin or other irrigants. Gram-positive infections were more likely with staged procedures ($p=0.021$, OR 4.91) and bacitracin irrigation ($p<0.001$, OR=17.98), and less likely with vancomycin powder ($p=0.050$, OR 0.20). Gram-negative infections were more likely with a history of peripheral vascular disease (PVD) ($p=0.034$, OR=3.21) or cefazolin irrigation ($p<0.001$, OR 25.47). Readmission within 30 days was more likely after staged procedures ($p=0.003$, OR=3.31), cervical spine surgery ($p=0.023$, OR=2.28), or cefazolin irrigation ($p=0.039$, OR=1.85). Any reoperation within 30 days was more common with more comorbid diagnoses ($p=0.022$, OR 1.09), staged procedures ($p<0.001$, OR=4.72), cervical surgeries ($p=0.013$, OR=2.36), more participants in the surgery ($p=0.011$, OR=1.06), using cefazolin ($p<0.001$, OR=3.12) or bacitracin ($p=0.009$, OR=3.15) irrigation, and higher ESR at readmission ($p=0.009$, OR=1.04). Washouts were more likely among patients with more comorbid diagnoses ($p=0.013$, OR=1.16), or who used steroids ($p=0.022$, OR=2.92), and less likely after cervical surgery ($p=0.028$, OR=0.24). Hardware removal was more common among patients who used bacitracin for irrigation ($p=0.013$, OR=31.76).

Conclusion: Whether a procedure is staged, and choice of antibiotic irrigation, affects risk of SSI and the subsequent management required.

504 Lumbar Spinal Segmental Curvature Changes Are Sex- and Level-Specific: A Controlled Upright MRI Study

Jamie Baisden MD; Karin R. Swartz MD; Joseph Avila Student; Narayan Yoganandan PhD; Frank A. Pintar PhD

Introduction: The objective of this study is to determine the effects of prolonged sitting on thoracolumbar spine curvatures using young healthy volunteers and MRI scans. This preliminary study explores differences between men and women, and implications of spine posture over time.

Methods: Upright lumbar spine T2-weighted MRI from 7 volunteers (4 -females, 3 -males, 29.7 ± 3.1 years, 69.8 ± 6.2 kg, 24.1 ± 1.7 BMI) were obtained. Volunteers seated in normal posture, Head Frankfort plane horizontal and upright torso, and pretest MRI obtained. Subjects were in the same monitored sitting posture for 4 hours and posttest MRI scans were obtained. Images were processed using 3D slice software, overall column (T12-S1) and segmental Cobb-angles were measured. Changes in Cobb-angle (CCA) between pre and post-sitting scans were obtained and compared between men and women.

Results: In women, CCA decreased across all spinal levels; in contrast, in men, decrease occurred only at the L4 -L5 levels while CCA increased at superior levels. The change was more pronounced in women than men (Figure 1).

Conclusion: This is the first study to determine the postural changes associated with prolonged sitting using upright MRI and volunteer subjects. While mechanical LBP is associated with structural and postural changes over time, and vibration loads are also factors, the present study shows differing response of the spine between men and women, and suggests different load paths in the spinal alignment. CCA in women showed similar patterns in sitting throughout the spine. In men increased segmental lordosis at T12-L3 accompanied by concomitant decrease CCA at the lower levels may predispose to more severe internal load-sharing at the lower levels and over time may accelerate the degeneration process. Additional loads due to material handling and vibration may accentuate this process in men. This study shows the spinal curvature changes are sex- and level-specific.

505 Lumbar Spine Stiffness and Motion as a Function of Sagittal Alignment Under Complex Loading

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Introduction: Sagittal alignment and biomechanical loading are interrelated. Aim: to determine the effects of spinal alignment and complex-combined loading on lumbar spine stiffness.

Methods: 7 male cadaveric spinal columns (T12-S1) (57 ± 10 years, 171 ± 10 cm, 68 ± 19 kg) were fixed at ends such that T12/L1 and L5/S1 joints were unconstrained. Six-axis loads cells at the ends were used to obtain force and moments. Specimens were fixated in custom device to change the positioning of S1 relative to T12 to induce different sagittal alignment conditions. Positions ranged from natural lordosis to a straight spine (parallel L5 and L1 endplates). Two intermediate alignment conditions were also selected. Axial loading was applied at each position using an electro-hydraulic piston. Three non-collinear retroreflective targets were inserted into each anterior bodies at each level to measure three-dimensional motions.

Results: Alignment-based stiffness was computed. Stiffness increased from the natural to the straight alignment condition for all specimens. Figure 1.

Conclusion: This study determines the role of spinal alignment and complex axial loading on lumbar columns. Stiffness and segmental motions were computed using this novel technique. Although follower loads can be applied, fixed end-conditions were used for alignment as the first step. Increasing stiffness from normal lordotic to straightened posture results from increased load-sharing of vertebral bodies and discs. Increased motions from the straightened to natural postures suggest the role of ligaments and posterior joints/ facet complex in the load sharing. It is likely that majority of change in the axial spine stiffness of the column was caused by increasing compression of L5/S1 disc as the posture transitioned to a straight sagittal alignment. The reduced sacral slope produces higher compression of the lumbosacral joint in a straightened spine resulting in increased stiffness. Changes in spinal alignment over time affect internal load sharing and may clinically alter the course of spinal degeneration.

506 Preoperative Chronic Opiate Use Associated with Lower Post-Surgical Clinical Outcomes After Complex Spinal Deformity Surgery

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Introduction: Pre-operative opioid use has been shown to be negatively associated with several outcome metrics in spine surgery(1-5). The purpose of this study was to evaluate the effect of pre-operative narcotic use on patient reported outcomes in the complex adult spinal deformity population.

Methods: All patients undergoing complex reconstructive spine surgery by the senior authors from the years 2015 and 2016 were identified. The cohort was divided into chronic opiate users and non-opiate users. Chronic use was defined as evidence of opiate use greater than 6 months in duration with a minimum morphine equivalent dose of 30mg/day.

Results: Of the 140 included patients, 30 (21.4%) were chronic opiate users. The opiate group demonstrated higher pre-operative SVA measurements at a mean of 8cm vs 6cm ($p=0.03$). Additionally, 80% of the opiate group had previously undergone spine surgery vs 48.2% ($p=0.01$). No differences were identified in pre-op HRQOL metrics. At both 6wks and 6mo post operatively, opiate users demonstrated worse mean VAS back pain scores relative to the non-opiate group (6wk: 6.25 vs 4.62, $p=.01$; 6mo: 5.4 vs 4.2, $p=.05$). At 6mo postoperatively and at the last known (LK) clinical follow up, ODI scores were higher in the opiate group (6mo: 42.8 vs 31.2, $p=0.04$; LK: 42.4 vs 31.5, $p=0.02$). There was no statistical difference in the rate of improvement in any HRQOL metrics between groups. There was also no statistical correlation between daily morphine equivalents and ODI scores. Lastly, the change in pre-op to LK follow up of HRQOL metrics was not statistically different between groups.

Conclusion: In this group of complex spine patients, chronic opiate users reported worse VAS back pain and ODI scores at multiple time points. Further work is needed to determine whether strategies to wean patients from opiates preoperatively could improve outcomes.

507 Lumbosacral TLIF Increases Proximal Junctional Motion in Long Segment Constructs

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Introduction: Proximal junctional kyphosis and lumbosacral pseudoarthrosis/instrumentation failure are relatively common complications following long instrumentation constructs to the sacrum. Methods to improve fusion rates and decrease instrumentation failure include lumbosacral anterior column support (ALIF or TLIF), iliac screw fixation, and accessory rods. The impact of these lumbosacral augmentation strategies on the proximal junction is not clear. The purpose of this study was to describe the impact of various lumbosacral constructs on proximal junction biomechanics.

Methods: Fourteen human cadaveric spine (L1-ilium) specimens were prepared and potted at L1 and ilium. Specimens were equally divided into either an L5-S1 ALIF or TLIF group. 4R conditions consisted of accessory rods spanning the L3-L4 and S1-ilium level. Compression (400 N) in combination with 7.5 Nm of flexion (FL), extension (EX), lateral bending (LB), or axial rotation (AR) was applied to all conditions. Proximal junctional range of motion at L1-2 (ROM) was measured. Specimens underwent testing in the following conditions: 1) Intact 2) L2-S1 Pedicle Screw Fixation (PSR) 3) L2-ilium (PSR-I) 4) PSR+ALIF (ALIF-S) or TLIF (TLIF-S) 5) PSR-I + ALIF (ALIF-I) or TLIF (TLIF-I) 6) ALIF-I + 4R or TLIF-I + 4R. Statistical comparisons were performed using one-way (RM) ANOVA ($p < .05$).

Results: PSR-I did not significantly change proximal junction ROM in any direction compared to PSR-S ($p = .069$). However, TLIF-I and TLIF+4R resulted in significant increase in L1-2 ROM in FL and right LB ($p = .038$) compared to PSR-I. TLIF-I+4R did not change ROM compared to TLIF-I in any direction ($p = .095$). ALIF-I did not change ROM in any direction compared to ALIF+4R or PSR-I ($p = .069$).

Conclusion: In patients with pelvic fixation, lumbosacral TLIF results in increased ROM at the proximal junction while ALIF does not. Further augmentation of either ALIF or TLIF constructs with lumbosacral accessory rods does not impact proximal junctional ROM.

508 Evaluating the Need for Iliac Fixation in Long Segment Thoracolumbar Fusions

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Introduction: Long segment thoracolumbar fusions frequently incorporate iliac fixation to prevent distal nonunion and biomechanical failure of sacral instrumentation. However, greater utilization of interbody grafts, particularly within minimally invasive deformity correction strategies, may increase stress sharing across the fusion construct, and obviate the need for additional iliac fixation.

Methods: A retrospective review of a multicenter prospectively maintained spinal deformity database was performed. Inclusion criteria were age = 18, follow-up = 2 years, and one of the following criteria: coronal Cobb $> 20^\circ$, SVA $> 5\text{cm}$, PT $> 20^\circ$, PI-LL mismatch $> 10^\circ$. All patients had at least 4 instrumented levels with an upper level at L2 or above and lower level at the sacrum or ilium. Patients were dichotomized based on the lower instrumented level and statistical comparisons between the two groups was performed.

Results: A total of 98 patients, 45 with lower instrumentation ending in the sacrum, and 53 in the ilium were included for analysis. The iliac group had fewer patients treated with a minimally invasive strategy (32.1% vs 71.1%, $p < 0.001$), more treated levels (10.1 vs 5.7, $p < 0.001$), and fewer interbody instrumented levels (3.5 vs. 4.3, $p = 0.002$). A multivariate analysis comparing the two groups controlling for levels of instrumentation showed no statistically significant differences in VAS score changes for back pain (-3.3 vs -3.3, $p = 0.415$), leg pain (-3.0 vs -3.6, $p = 0.592$) and the Oswestry Disability Index (-21 vs -21, $p = 0.778$). Patients with iliac fixation continued to have fewer interbody fusion levels (3.4 vs 4.4, $p = 0.003$), increased blood loss (1695mL vs. 830mL, $p = 0.008$), and no significant differences in incidence of pseudoarthrosis ($p = 0.189$) or major complications ($p = 0.053$).

Conclusion: When controlled for levels instrumented, deformity patients with constructs ending in S1 had similar clinical outcomes, rates of major complications, pseudarthrosis and less blood loss than patients with pelvic fixation when more interbody fusion levels were used.

509 Intermittent Retraction of Great Vessels During Anterior Lumbar Interbody Fusion

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Introduction: Anterior retroperitoneal access to the lumbar spine is a valuable technique that requires mobilization of the aortoiliac great vessels. Adequate exposure can be accomplished by either fixed or intermittent vascular retraction. Although vascular injury is rare, it remains a potentially devastating complication that can occur during exposure. The aim of this study is to present the incidence of vascular injury in a large series of anterior lumbar interbody fusion (ALIF) cases that used intermittent vascular retraction.

Methods: A retrospective chart review was conducted from January 2001 to February 2017 to identify all patients that underwent anterior lumbar interbody fusion. Intermittent vascular retraction was used for all patients. Electronic medical records were used to gather data entered after 2008, while paper charts were used to collect data prior to that time period. Parameters including patient demographics, intraoperative vascular injury, operative levels, and prior surgery were recorded.

Results: 5,631 patients were identified in our cohort. The mean age of these patients was 53.02 years. Mean BMI was 30.2. 55.2% were female. 23.7% had underlying hypertension and 22.4% suffered from diabetes. There were 25 total cases of vascular injury, of which 23 were venous lacerations and 2 were arterial lacerations. No arterial occlusions occurred within this data set. We found no increased risk of vascular injury when accounting for sex, age, BMI, smoking, diabetes, hypertension, prior abdominal surgeries, prior lumbar surgery, or operative exposure level.

Conclusion: We present the first comprehensive study on intermittent vessel retraction during anterior lumbar interbody fusion. Vessel injury is a rare but devastating event. There was a 0.53 % incidence of venous laceration within our cohort, and overall our documented vascular injury rates were lower than previously reported literature. These results indicate intermittent retraction is a safe alternative to fixed retraction with a lower documented rate of vascular injury.

510 The Influence of Spinopelvic Parameters on Infection Rates Following Lumbar Spine Surgery

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Introduction: Surgical site infection (SSI) following lumbar spine surgery is a relatively common and serious complication, resulting in significant patient morbidity and mortality. While various patient and operative factors have been identified as risk factors for SSI, the impact of spinopelvic measures on this outcome has not been investigated. In this study, we have evaluated the effect of spinopelvic parameters on SSI risk following lumbar fusion surgery.

Methods: We retrospectively reviewed patients who underwent lumbar fusion surgeries between 2006 and 2008. Patients developing SSI were compared to a cohort of 120 consecutive patients who did not develop postoperative infections. Patient and operative factors analyzed included body mass index (BMI), number of operative levels, diabetes status, spine depth, and subcutaneous fat thickness. Spinopelvic parameters including pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and lumbar lordosis (LL) were also evaluated.

Results: Factors significantly associated with SSI included the number of operative levels ($p=0.0038$), depth of the spine ($p=0.014$), and the thickness of subcutaneous fat ($p=0.0083$). PI ($p=0.0094$), SS ($p=0.040$), and LL ($p=0.016$) were also significantly greater in infected patients compared to those in the uninfected group. PI, SS and LL also significantly correlated with spine depth. Multivariate analysis revealed the number of operative levels (OR: 2.051; 95% CI:1.31-3.20), depth of the spine (OR: 1.034; 95% CI:1.01-1.06), and LL (OR: 1.06; 95% CI:1.01-1.12) to be independent predictors of SSI.

Conclusion: Our findings suggest that a spinopelvic profile consisting of a higher PI, SS, and LL may increase the risk of developing SSI, primarily due to the associated increase in spine depth.

511 The Effect of More Interbody Fusion to Treat the Fractional Curve in Adult Scoliosis: Impact on Lordosis, Curve Correction, and Complications

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Introduction: Radiculopathy from the fractional curve, from L4-S1, often creates severe disability. However, treatment methods of the fractional curve vary. We wished to evaluate the effect of adding interbody fusion to posterolateral fusion in treatment of the fractional curve.

Methods: 78 adult scoliosis patients from 2006-2016 with fractional curves from L4-S1 $>10^\circ$ and ipsilateral radicular symptoms who received at least one interbody device at the level of the fractional curve were retrospectively studied. Patients either received one, two or three interbody devices at the level of the fractional curve. Primary outcomes included changes in fractional curve degree, lumbar lordosis, pelvic incidence-lumbar lordosis mismatch, scoliosis major curve, as well as rates of revision surgery and post-operative complications.

Results: There were no significant differences in age, gender, BMI, prior operation, fractional curve degree, pelvic tilt, pelvic incidence, pelvic incidence/lumbar lordosis mismatch, sagittal vertical axis, coronal balance, scoliosis major curve, proportion of patients receiving an osteotomy or average number of levels fused between the groups. Patients with less lumbar lordosis preoperatively trended towards receiving more interbody devices ($p=0.055$). Mean follow-up was 30.0 (range 12-101) months. Patients receiving more interbody devices (1 vs 2 vs 3 devices, respectively) had more fractional curve change (7.4 vs 12.3 vs 12.1 degrees, $p=0.009$), more increase in lumbar lordosis (-1.8 vs 6.2 vs 13.7 degrees, $p=0.003$) and more scoliosis major curve reduction (13.0 vs 13.7 vs 24.4 degrees, $p=0.01$). There were no significant differences among the groups with regards to post-operative complications (overall rate 44.8%, $p=0.97$) or need for revision surgery (overall rate 28.2%, $p=0.36$).

Conclusion: Additional interbody devices resulted in increased lordosis, scoliotic curve correction, and fractional curve correction without an increase in complication or revision surgery rates.

512 Hardware Complications in Adult Spine Deformity Correction when using Computer-assisted Rod Bending technology: A Single Institution's Experience

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Introduction: The goal of this study was to characterize the rate of hardware-related complications with the use of computer-assisted rod bending technology compared to manual rod bending techniques.

Methods: We conducted a retrospective review of all patients in whom computer-assisted or manual rod bending was used in complex spine surgery from 2015 to 2016. Patient demographics, postoperative complications, including proximal junctional failure, pseudoarthrosis and rod/screw fracture, were determined.

Results: Bendini was used in 88 patients compared to 54 patients with manual rod-contouring. There was no significant difference in the age (58.6 ± 16.3 vs 61.6 ± 12.2), number of fused levels (10.6 ± 4.1 vs 11.3 ± 4.8 , $P=0.4$), or length of follow up (1.4 ± 0.6 versus 1.7 ± 0.4 years, $P=0.6$). The overall rate of complication was similar between the two cohorts. In patients with prior surgery, overall complication rate in the Bendini group was 43.8% versus 25% in the manual rod counteracting group ($P=0.09$). In de novo operations, the rate of complications was almost identical (22.5% vs 22.7%, $p=0.98$). In those patients who underwent pedicle subtraction osteotomy and/or anterior column reconstruction, the combined rate of PJF and rod-fracture were more frequent in the Bendini group (36.4%) than in their counterpart (0%, $p=0.06$). With the use of Bendini, length of surgery was on average 33mins shorter ($p=0.16$) and estimated blood loss was 556ml less ($p=0.18$) requiring only one unit less blood product transfusion perioperatively ($p=0.23$), although these differences were not statistically significant.

Conclusion: The use of Bendini did not result in a statistically significantly difference in the rate of hardware failure when compared to manually contoured rods. However, in revision surgery or the use of PSO and/or ACR may predispose the patients to higher hardware-related complications when Bendini is used. This technology may allows for shorter operative time and less blood loss.

513 Mechanical Complications in Adult Spinal Deformity Surgery: Can the alignment explain everything?

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Introduction: Mechanical complications remain a challenge for the spinal deformity surgeon. It has been proposed that these complications are related to the postoperative spinal alignment. Recently, the Global Alignment and Proportional (GAP) Score was proposed as a predictive score for mechanical complications based on postoperative spinal alignment in ASD. It is suggested that setting patients to sagittal parameters according to the GAP score could decrease rate of mechanical complications. Our goal was to verify the accuracy of the GAP score in predicting mechanical complications in ASD.

Methods: Retrospective review of consecutive primary ASD cases that underwent deformity correction in the same institution over a 5-year period. Inclusion/exclusion criteria and definition of complications were similar to the original study describing the GAP score. Only primary (no-previous fusion) ASD (scoliosis >20degrees, SVA >5cm, PT >25degrees, and/or TK >60) who underwent 4 or more levels fusion were included. From 112 patients with primary ASD identified during the study period, 11 patients were excluded because of absence of adequate radiological assessment, and 17 patients without minimum follow-up of 6 months. 53 patients had at least 2 years follow-up.

Results: 84 were included (mean age $65.0[+-9.41]$, 69% female). First standing x-ray showed a matched PI-LL in 81% of patients. Mechanical complications occurred in 58.3% of patients, including PJK (45.2%), PJF (25%), rod breakage (10.7%), pseudoarthrosis at L5-S1 (21.4%), and other implant-related complications (20.2%). According to GAP score, 52.3% of patients were proportioned, 27.3% moderately disproportioned, and 20.4% severely disproportioned postoperatively. The incidence of mechanical complications was similar in each group (proportioned: 59.1%, moderately disproportioned: 56.5%, severely disproportioned: 58.8%; $P=0.979$). Risk factors for pseudoarthrosis at L5-S1 were absence of iliac fixation (Adjusted-OR: 6.19; $P=0.004$) and TLIF51 (Adjusted-OR: 4.18; $P=0.04$). Mechanical complications were associated with first x-ray showing PT >20 ($P=0.036$), and SVA >4cm ($P=0.011$).

Conclusion: This external validation study does not support the use of GAP score as a predictor for mechanical complication in ASD surgery.

514 Evidence of Impaired Pain Modulation in Adolescents with Idiopathic Scoliosis and Chronic Back Pain

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Introduction: Although 40% of AIS patients present chronic back pain, the pathophysiology and underlying pain mechanisms remain poorly understood in this population. We hypothesized that development of chronic pain syndrome in adolescent idiopathic scoliosis AIS is associated with alterations in pain modulatory mechanisms in these patients. The objective of this study was to identify presence of sensitization in nociceptive pathways and to assess the efficacy of the diffuse noxious inhibitory control in patients with AIS presenting chronic back pain.

Methods: Cross-sectional study with 94 patients diagnosed with AIS and chronic back pain. Quantitative sensory testing (QST) assessed pain modulation, and self-reported questionnaires were used to assess pain burden and health-related quality of life. Patients underwent a throughout pain assessment using standard and validated

quantitative sensory testing (QST) protocol. The measurements included mechanical detection thresholds(MDT), pain pressure threshold(PPT), heat pain threshold(HPT), heat tolerance threshold(HTT), and a conditioned pain modulation(CPM) paradigm. Altogether, these tests measured changes in regulation of the neurophysiology underlying the nociceptive processes based on the patient's pain perception.

Results: Efficient pain inhibitory response was observed in 51.1% of patients, while 21.3% and 27.7% had sub-optimal and inefficient CPM, respectively. Temporal summation of pain was observed in 11.7% of patients. Significant correlations were observed between deformity severity and pain pressure thresholds ($P=0.023$) and CPM ($P=0.017$), neuropathic pain scores and pain pressure thresholds ($P=0.015$) and temporal summation of pain ($P=0.047$), and heat temperature threshold and pain intensity ($P=0.048$).

Conclusion: Chronic back pain has an important impact in quality of life of adolescents with idiopathic scoliosis. Using a detailed pain assessment, we were able to demonstrate a high prevalence of impaired pain modulation in this group. The association between deformity severity and somatosensory dysfunction may suggest that spinal deformity can be the trigger for abnormal neuroplastic changes in this population contributing to chronic pain syndrome.

515 Back Pain in Adolescent Idiopathic Scoliosis: The Moderation Effect of Pain Catastrophizing

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Introduction: Back pain in a common complaint in patients with adolescent idiopathic scoliosis(AIS). Our goal is to define the relationship between 3D radiological features and psychological factors and back pain prevalence and intensity in AIS.

Methods: Cross-sectional study with 124 consecutive AIS patients selected for surgery at the Shriners Hospital for Children-Canada. Self-reported questionnaires included Numerical Rating Scale of Pain(NRS), back pain diagram (location of pain), SRS-30, pain catastrophizing scale for children (PCS-C), and State and Trait Anxiety Inventory for children (STAI-CH). Each participant underwent simultaneous posterior-anterior and lateral scans of the spine in EOS (EOS Imaging, Paris, France). From the 3D reconstructions, 10 parameters were assessed in the coronal, sagittal, and axial plane. Axial plane parameters included the apical vertebral axial rotation(AVR), axial intervertebral rotation(AIR) of the upper and lower levels of the main curve, and torsion index of the curve.

Results: Only 10% of AIS patients reported not having any back pain over the last 6 months and only 14.2% over the last 30 days. Location of back pain was associated with location of main curve ($P<0.05$). Pain at the low back was associated with higher lumbar apical AVR and lower lumbar lordosis ($P<0.05$). Independent risk factors for back pain in AIS were pain catastrophizing ($B=0.061, P=0.035$), mental health domain of SRS30 ($B=-0.872, P=0.023$), lower thoracic kyphosis ($B=-0.033, P=0.044$) and greater pelvic obliquity ($B=0.146, P=0.047$). There was a significant association between self-reported pain intensity in the last 24 hours and levels of catastrophizing. A moderation effect of PCS-C and main Cobb angle, AIR upper main curve, and torsion index were identified. In low catastrophizers, there is a significant association between greater deformity severity and higher pain levels.

Conclusion: Back pain prevalence was associated with psychological parameters, as well as thoracic hypokyphosis and pelvic obliquity. A significant association between deformity severity and pain intensity is moderated by catastrophizing.

516 Posterior Ligamentous Augmentation Prevents Acute Proximal Junctional Failure In Upper Thoracic Constructs But Not In Lower Thoracic Constructs

Randall Hlubek MD

Introduction: Posterior Ligamentous Augmentation (PLA) With Polyethylene Terephthalate Bands At The Upper Instrumented Vertebrae (UIV) -1 To (UIV) +1 Is A Proximal Junctional Kyphosis(PJK)/Failure(PJF) Prevention Strategy In Adult Spinal Deformity Patients. This Study Aimed To Understand The Effect Of PLA For Long Segment Constructs Terminating In The Upper Thoracic(UT) And Lower Thoracic(LT) Spine.

Methods: ASD Patients With Minimum F/U Of 6 Mos Who Underwent PLA Were Retrospectively Reviewed To Evaluate The Incidence Of PJK/PJF. Demographics, Operative Data, And Radiographic Parameters Were Recorded. Preop/Postop Measurements Included Pelvic Incidence (PI), L1-S1 Lumbar Lordosis (LL), Pelvic Tilt (PT), T1 Pelvic Angle (TPA), C7 Sagittal Vertical Axis (SVA), And UIV To UIV+2 Proximal Junctional Angle (PJA). PJK Was Diagnosed When: (1) PJA Was ≥ 10 Degrees (2) PJA Was 10 Degrees $>$ Than Preop. PJF Included Any Of The Following: Increase PJA Of $\geq 15^\circ$, Fracture Of UIV Or UIV + 1, Proximal Extension Of Fusion, And/Or UIV Fixation Failure.

Results: 27 Patients (74% Female) Were Identified With A Mean Age Of 67(42-81)Yrs, 13 Operative Levels, And F/U 12(6-18)Mos. UIV Was UT Spine In 19(70%) And The LIV Was The Ilium In 25(93%). Preop Mean SVA(8cm), PI-LL(28.3°), TPA(31.0°), And PT(31.7°) Improved To An Immediate Postop Mean SVA(2.8cm), PI-LL (10.8°), TPA(19.1°), And PT(24.5°). 5 Patients(19%) Developed PJF With 1/19(5%) Incidence With UIV In UT And 4/8(50%) Incidence With UIV In LT. Compared To UIV In UT, Odds Ratio Of PJF With LT UIV Was 4.41(95% CI, 1.64-11.76, $P=.01$). Failure Mode In LT Was Compression Fractures At The UIV In 3/4 Patients And Hook Failure Due To A Technical Error. No Patients Fit The Criteria For PJK.

Conclusion: PLA Resulted In A 19% Incidence Of PJF(50% LT; 5% UT). Osseous Mode Of PJF In LT Spine May Make This Technique Less Effective In Constructs That Terminate In LT Spine Vs UT Spine.

517 Surgical Treatment of Flat Back Syndrome with Anterior Hyperlordotic Cages

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Introduction: Traditional correction for flat back syndrome is performed with posterior based surgery or combined approaches in revision cases. Author's objective was to evaluate the outcome from anterior surgery with the use of hyperlordotic cages (HLCs) in patients with flat back syndrome.

Methods: All patients operated with or without prior posterior lumbar surgery were studied. Pre-to postoperative sagittal alignment was analyzed in all cases. Radiographic parameters were analyzed including T1PA, SVA, PT, PI, LL, SS, PI-LL, T4-12TK.

Results: All 50 patients (mean age of 58 years, 72% female with mean BMI of 28) demonstrated significant radiographic alignment difference in their spinopelvic and global parameters from pre- to postoperative standing: LL (-37.04° vs. -59.55°, $p<0.001$), SS (35.12 vs. 41.13, $p<0.001$), PI-LL (23.55 vs. 6.46), T4-12 TK (30.59 vs. 41.67), PT (28.22 vs. 22.13), SVA in mm (80.94 vs. 37.39), and T1PA (28.70° vs. 18.43°, $p<0.001$). Using linear regression analysis, predicted pre- to postoperative change in standing LL corresponded to a pre- to postoperative changes in standing PI-LL mismatch, T1PA, TK, , SS, PT, and SVA ($R^2=0.59, 0.38, 0.25, 0.16, 0.12$, and 0.17 respectively). 5 degrees of pre- to postoperative change in T1PA translate to -4.15° change in LL. (Figure 1)

Conclusion: Anterior surgery with hyperlordotic cages followed by posterior instrumentation is an efficacious to correct flat back syndrome. HLCs is an effective and reliable tool to maximize lumbar lordosis up to 30° which is equivalent in magnitude to a pedicle subtraction osteotomy, but associated with less blood loss, quicker recovery, lower complications, and good surgical outcome.

518 Reduced Impact of Obesity on Surgical Outcomes, Patient Reported Pain Scores and 30-Day Readmission Rates After Complex Spinal Fusion (>+7 Levels) for Adult Deformity Correction

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Introduction: The aim of this study was to determine whether obesity impacts surgical outcomes, patient reported pain scores, and 30-day readmission rates after complex spinal fusions =7 levels.

Methods: The medical records of 112 adult (=18 years old) spine deformity patients undergoing elective, primary complex spinal fusion (=7 levels) for deformity correction at a major academic institution from 2010 to 2015 were reviewed. Preoperative Body Mass Index (BMI) greater than or equal to 30 kg/m² was classified as obese. Patient demographics, comorbidities, intraoperative and postoperative complication rates were collected for each patient. Inpatient patient-reported pain scores and ambulatory status were also collected. The primary outcomes of this study were surgical outcomes, patient-reported pain scores, and 30-day readmission rates.

Results: Of the 112, 33 (29.5%) patients were obese (Obese: $n=33$ vs. Non-Obese: $n=79$). Patient demographics and comorbidities were similar between both cohorts, including age, gender, diabetes, hypertension and home narcotic use, Table 1. The median number of fusion levels operated, length of surgery, estimated blood loss, transfusion and complication rates were similar between both cohorts, Table 2. Moreover, the post-operative complication profiles between the cohorts were also similar, with a comparable length of hospital stay (Obese: 6.5 ± 4.6 days vs. Non-Obese: 7.0 ± 3.9 days, $p=0.5833$) and 30-day readmission rates (Obese: 12.1% vs. Non-Obese: 13.9%, $p=0.7984$), Table 3. Baseline ($p=0.6826$), First($p=0.9691$) and Last($p=0.9583$) post-operative patient reported pain scores were similar between cohorts, Table 4. Analogously, ambulatory status was similar between the cohorts, including days from OR to ambulation ($p=0.3471$), number of steps on first ($p=0.9173$) and last ($p=0.1634$) ambulatory day prior to discharge, Table 4.

Conclusion: Our study suggests that obesity does not significantly affect surgical outcomes, patient reported pain scores, and 30-day readmission rates after complex spinal surgery requiring =7 levels of fusion. Further studies are necessary to corroborate our findings.

519 Rate of Instrumentation Changes on Post-Operative and Follow-Up Radiographs After Primary Complex Spinal Fusion (≥5 Levels) for Adult Deformity Correction

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Introduction: There has been an excessive use of post-operative radiographs after spine surgery and has been a target for hospitals to reduce unnecessary costs. However, there is a paucity of data identifying the rate of instrumentation changes on radiographs after complex spinal surgery involving =5 level fusions.

Methods: The medical records of 136 adult (=18 years old) spine deformity patients undergoing elective, primary complex spinal fusion (=5 levels) for deformity correction a major academic institution from 2010 to 2015 were reviewed. Patient demographics, comorbidities, intra- and post-operative complication rates were collected for each patient. We reviewed the first five subsequent post-operative and follow-up radiographs, and whether revision of surgery was performed within five years after surgery. The primary outcome investigated in this study was the rate of hardware changes on follow-up radiographs.

Results: The majority of patients were female, with the mean $\pm$ SD age of 53.8 ± 20.0 years and BMI of 27.3 ± 6.2 kg/m². The median [IQR] fusion levels operated was 9 [7-13], with a mean $\pm$ SD length of surgery of 327.8 ± 124.7 mins and estimated blood loss of 1312.1 ± 1269.2 mL. The mean $\pm$ SD length of hospital stay was 6.6 ± 3.9 days with a 30-day readmission rate of 14.0%. Post-Operative and follow-up change in stability on radiographs (days from operation) included: Image 1 (4.6 ± 9.3 days) 0.0%; Image 2 (51.7 ± 49.9 days) 3.0%; Image 3 (142.1 ± 179.8 days) 5.6%; Image 4 (277.3 ± 272.5 days); and Image 5 (463.1 ± 525.9 days) 15.7%. The third-year after surgery had the highest rate of hardware revision (5.55%), followed by the second-year (4.68%), and first-year (4.54%).

Conclusion: Our study suggests that the rate of instrumentation changes on radiographs increases overtime, with no changes occurring at the first post-operative image. In an era of cost-conscious healthcare, reduction of early radiographs after complex spinal fusions (≥ 5 levels) may not impact patient care and can reduce overall healthcare resources.

520 Gender Does Not Influence Discharge Disposition After Spinal Fusion (≥ 4 Levels) for Adult Spine Deformity Correction: A National Study of 4,972 Patients

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Introduction: Gender has been shown to impact several aspects of spine surgical care. However, the influence of gender disparities on discharge disposition after adult spine deformity (ASD) is unknown. The aim of this study was to investigate the influence of gender on discharge disposition after elective spinal fusion involving ≥ 4 levels ASD correction.

Methods: The Nationwide Inpatient Sample database (2011-2014) was queried for patients with ASD (≥ 26 years-old) and elective spine fusion surgery involving ≥ 4 levels using ICD-9 codes. Patients were stratified by gender: Male or Female. Multivariate linear and logistic regressions were used to assess the impact of gender on length of hospital stay and discharge disposition.

Results: A total of 4,972 patients were identified of which 3,282 (66.0%) were Female. The median age for both cohorts was 66 years, with most patients being White and on Medicare. The Male cohort had a higher prevalence of comorbidities than the Female cohort. The number of fusion levels involved was significantly different between cohorts, with the Female cohort having less 4-8-level fusions (77.6% vs 86.8%) and more 9+-level fusions (23.0% vs 13.6%). The Female cohort had greater rates of postoperative UTI (5.5% vs 2.5%) and Hematomas (2.6% vs 1.3%), while the Male cohort had more postoperative MIs (5.4% vs 1.5%). The Female cohort spent slightly more time in the hospital than Male cohort (6.2 days vs. 5.9 days, $p=0.035$). While there was a difference in discharge disposition between cohorts, gender was not an independent predictor of discharge disposition when controlling for other factors ($p=0.69$).

Conclusion: Our study suggests gender disparities may not have a significant impact on discharge disposition after spinal fusion for ASD involving ≥ 4 levels. Further studies are necessary to understand risk factors for non-routine discharges in ASD patients, to better quality of patient care and reduced healthcare costs.