Abstracts of the 2012 Meeting of the Lumbar Spine Research Society April 26–27, 2012

(DOI: 10.3171/2013.1.FOC-LSRSabstracts)

Poster Abstracts

Poster 1. Transdiscal Fixation for High Grade Spondylolisthesis

Brett A. Braly, MD; Nicholas Spina, MD; W. T. Ward, MD; Joon Y. Lee, MD

University of Pittsburgh, Dept of Orthopedics, Pittsburgh, PA

Objective: Operative treatment of symptomatic high-grade lumbosacral spondylolisthesis has included in situ posterolateral fusion with or without pedicular instrumentation. Posterior pedicular fixation has

increased fusion rates, however, lack of anterior column support may predispose to increasing kyphosis, slip angle, and pseudoarthrosis. We report a technique and our series of thirteen patients with high-grade lumbosacral spondylolisthesis treated with bilateral posterior transdiscal screws as a method to provide anterior support in conjunction with posterolateral fusion.

Methods: The medical records and radiographs of thirteen patients treated by transdiscal posterior pedicle fixation were reviewed. A bimodal mean age was found at 13 and 50 years of age with a range from 10 - 68 years. All but one patient had pedicle fixation to include L4. Preoperative and most recent follow up radiographs (ranging

0.6 - 7 years) were assessed for slip angle, Myerding grade, pelvic incidence, evidence of progression, and evidence of fusion.

Results: No significant difference in pre- and post-operative slip angle or grade was found. No progression in lumbosacral kyphosis was seen. Two post operative neurological changes were encountered and two cases required re-operation for screw repositioning. One case of screw breakage was noted in a patient whose construct did not extend to L4. There were no permanent neurological deficits.

Discussion: Posterior transdiscal lumbosacral pedicular fixation provides good clinical results and high fusion rates for high grade lumbosacral spondylolisthesis. Anterior support is achieved without the need for anterior exposure in this difficult patient population. Patients fused without decompression may be at risk for neurological deficit post-operatively. Re-enforcing the fusion mass with more proximal pedicular fixation may help avoid increased stress and screw breakage at L5-S1.

Conclusions: Transdiscal fixation is a viable option and care must be taken to follow the technique to avoid potentially serious complications.

Key words: Spondylolisthesis, Posterior Fusion, Pedicle Fixation, Transvertebral Fixation

Poster 2. Comparison of clinical outcomes following Interspinous Process Distractor (X-STOPTM) Implantation or Interlaminar Lumbar Instrumented Fusion (ILIFTM) for lumbar spinal stenosis

Charles Milchteim, MD; Joseph R. O'Brien, MD, MPH; Michael T. Benke, MD; Matthew R. Livingood; Warren D. Yu, MD

George Washington University, Orthopedic Surgery, Washington, DC

Study Objective: To determine the differences in validated clinical outcomes following indirect lumbar decompression using an interspinous device or an interlaminar allograft combined with fusion.

Figure 6: A. Pre-operative lateral radiograph; B. Lateral radiograph showing complication with the L4/5 graft rotated 90 degrees within the interspinous space (white arrow). The L5/S1 graft appears well placed (black arrow); C. Lateral radiograph after removal of implants and subsequent pedicle screw placement and fusion

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

Summary of Background Data: Indirect lumbar decompression for neurogenic claudication has been previously described as a safe and viable technique. Although there are several reports describing the clinical success of interspinous distracting devices, there is a paucity of literature on a new technique using an interlaminar allograft.

Methods: Sixty-four patients were prospectively followed between 2008 and 2011 after undergoing the X-STOPTM or ILIFTM (Interlaminar Lumbar Instrumented Fusion) procedure. Validated clinical outcomes including Oswestry Disability Index, Zurich Claudication Questionnaire, SF-36 and Visual Analog Scale were administered to patients pre-operatively, at 6 weeks, 6 months and 1 year post-operatively. Baseline characteristics and post-operative complications were recorded.

Results: Six patients in the X-STOP group and 2 patients in the ILIF group were excluded from the final analysis, leaving a total of 28 patients in the ILIF group and 28 in the X-STOP group. Baseline clinical scores were similar and both groups had significant improvement in scores during all post-operative time points. Overall, 15/28 (53.6%) patients in the ILIF group and 13/28 (46.4%) patients in the X-STOP group were considered a "clinical success" based on pre-defined ZCQ criteria.

Conclusion: Indirect decompressive techniques for neurogenic claudication offer equivalent clinical outcomes when compared to a novel technique using interlaminar allografts. The addition of direct decompression with a laminotomy and interlaminar fusion does not appear to yield significant clinical benefits at least in the short to mid-term follow-up periods. Longer follow-up is needed to determine whether significant clinical differences will develop.

Poster 3. Use Of Recombinant Human Bone Morphogenetic Protein-2 (rhBMP-2) Without Iliac Crest Bone Graft In Posterolateral Lumbar Spine Fusion (PLF)

Daniel K. Park, MD; Sung Soo Kim; Scott Boden, MD

William Beaumont Hospital, Orthopedic Surgery, Southfield, MI

Background: Previous reports have shown higher fusion rates (>95% versus 77%) when adding rhBMP-2 to iliac crest autograft (ICBG) in PLF. We compared the fusion rates between rhBMP-2 delivered with ICBG versus local bone graft/bone graft extenders.

Methods: A retrospective, single institution, case-matched analysis of bone graft materials was performed in arthrodesis patients with radiographic evidence of degenerative spondylolisthesis (1-2 levels) with accompanying lumbar stenosis. RhBMP-2 was delivered on an absorbable collagen sponge (6 mg/side @ 1.5 mg/mL) with ICBG alone or with, local bone graft with or without a bulking agent inside the sponge (Grafton DBM Matrix, Osteotech). CT scans were assessed at 6 and 12 months by three blinded readers.

Results: Sixteen patients (30 levels) underwent PLF with ICBG with rhBMP-2. 35 patients (49 levels) received local bone graft with rhBMP-2. For the ICBG cohort, 80.0% and 93.3% of levels were either definitely or probably fused at 6 and 12 months. In contrast, for the local bone and rhBMP-2 cohort, 87.7% and 97.8% were fused at 6 and 12 months. As for fusion quality, 84.6% and 63.8% of the fused levels were rated good or excellent at 12 months in the ICBG and local bone cohorts. There was no evidence of heterotopic bone formation or psoas ossification.

Discussion: This study demonstrates that when using rhBMP-2 the substitution of local bone for ICBG can lead to comparable fusion rates of ~95% at one year. The fusion quality was not as mature with local bone and may take longer to equal ICBG.

Conclusion: This study validates the high fusion rates previously reported by adding rhBMP-2 to ICBG and shows that local bone may be safely substituted for ICBG in 1-2 level PLF. The avoidance of ICBG harvest has implications for operative time, blood loss, and morbidity. Lastly, this is the first study that directly compares the

fusion rate and quality for local bone and rhBMP-2 versus ICBG and rhBMP-2 at various time points.

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

Poster 4. Evaluation of Self Reported Functional Limitations Due to Lumbar Stiffness in Adult Spinal Deformity Patients

Warren Alpert Medical School of Brown University, Dept of Orthopedics, Providence RI

Robert A. Hart, MD; Alan H. Daniels, MD; Praveen V. Mummaneni, MD; Richard A. Hostin, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Bret Line; Virginie Lafage, PhD; Shay Bess, MD

Introduction: Sagittal balance is correlated with outcomes in adult deformity patients. The LSDI is a validated measure of functional impacts of lumbar spine stiffness. We correlated LSDI scores with other outcomes instruments and with sagittal balance in adult deformity patients.

Methods: LSDI, ODI, SF-36, and SRS-22 were completed by adult spinal deformity patients across 12 centers. Surgical vs. non-operative treatment, revision status were recorded. SVA and Pelvic Incidence - Lumbar Lordosis (PI-LL) were measured. Pearson correlation coefficients of LSDI with SVA, PI-LL, ODI, SF-36 PCS, and SRS-22 subscales were calculated. T-tests compared LSDI scores between operative and non-operative as well as between revision and primary patients.

Results: Of 479 patients, 170 underwent surgery and 309 were treated non-operatively. Operative patients had significantly higher LSDI scores than non-operative patients (29.1 vs. 16.9, $p < .001$). Revision patients had significantly higher LSDI scores than did primary fusion patients (33.1 vs. 25.9, $p = 0.01$). Significant correlations were found between LSDI and ODI, SF-36 PCS, and SRS-22 pain and function subscales ($r = .76, -.69, -.67$, and $-.71$, respectively), as well as with SVA and PI-LL ($r = .35$ and $.31$).

Discussion: Limitations due to lumbar spine stiffness correlate with pain related outcomes in adult deformity patients. Stiffness related limitations also correlate with sagittal imbalance. Surgical patients and those with prior fusions had higher baseline LSDI scores than non-operative and primary surgical patients, respectively. Adult deformity patients report substantial stiffness related disability even prior to surgical fusion.

Conclusion: Adult spine deformity patients report stiffness related disability even prior to surgical fusion, and limitations due to lumbar spine stiffness correlate with pain related outcomes.

Poster 5. Functional Limitations Due to Lumbar Stiffness Correlate with Age and SRS-22 Scores in Asymptomatic Volunteers

Robert A. Hart, MD; Alan H. Daniels, MD; Praveen V. Mummaneni, MD; Bret Line; Virginie Lafage, PhD; Behrooz A. Akbarinia, MD; Gregory M. Mundis, MD; Shay Bess, MD

Warren Alpert Medical School of Brown University, Dept of Orthopedics, Providence RI

Introduction: Among asymptomatic volunteers, significant correlation exists between Lumbar Stiffness Disability Index (LSDI) scores and advancing age, as well as SRS-22 pain and function subscales. Spine outcomes research has primarily assessed proposed benefits of surgery including impacts of pain, function, and deformity. Validated outcomes tools such as the SRS-22 do not seek

Figure 1: Relationship of LSDI score to decade of life among asymptomatic volunteers

information regarding functional limitations due to lumbar stiffness. The LSDI is a validated outcome questionnaire to specifically assess functional impacts of lumbar spine stiffness. Normative data for the LSDI have not been reported.

Methods: The LSDI and SRS-22 were completed by normal adult volunteers. Exclusion criteria included prior spine surgery, back pain, scoliosis, traumatic spine injury, cancer, neurological disease, extremity amputation, or hip or knee surgery. Correlations of LSDI scores with age and SRS-22 subscales were calculated.

Results: 177 volunteers completed the LSDI and the SRS-22. Mean age of the cohort was 38.7 years (range 22-73). Mean LSDI scores were 3.4 +/- 6.3 (maximum score = 100). There was a statistically significant correlation between increasing age and LSDI scores ($r=.30$; $p=.0001$), as well as between LSDI scores and SRS-22 pain and function subscales ($r=.41$, $r=.42$; $p<.0001$ for both).

Discussion: Limitations due to lumbar spine stiffness were low among asymptomatic volunteers. A statistically significant relationship was noted between worsening LSDI scores and advancing age. Correlations between LSDI and SRS-22 pain and function subscales suggest that functional limitations due to lumbar stiffness occur in tandem with limitations from pain. Normative data for the LSDI will complement ongoing functional outcome measurements related to spinal stiffness following spinal arthrodesis.

Conclusion: Among asymptomatic volunteers, limitations due to lumbar spine stiffness were low. In addition, LSDI score worsened with advancing age.

Poster 6. Comparison Of Cortical Trajectory And Traditional Pedicle Screw Loosening In Lumbar Spine With Cyclic Loading

Erkan Alci, MD; Jonathan Gottlieb, MD

Jackson Memorial Hospital/University of Miami, Miami, FL

Objective: To compare the loosening rates and pullout strength of cortical trajectory screws (CS) to traditional pedicle screws (PS) in normal and osteoporotic bone

Methods: 10 lumbar VB were disarticulated, DEXA scanned. Traditional PS on one side, CS on the contralateral side are inserted. A 5.5 mm titanium rod was used to connect UHMWPE vertebral body model to simulate a corpectomy model.

Each construct was tested in flexion/extension by applying sinusoidal cyclic load in load control by the MTS858 Minibionics servo-hydraulic system for 5,000 cycles at 1 Hz. 5 N.m preload on one side of the lever arm, a 5 N.m cyclic compression load on the other side was applied via the MTS ram. 3 markers from the MaxPRO motion tracking system were attached to the pedicle, cortical screw heads and to the vertebral body SP. The MaxPRO system tracked the X, Y, Z motions and calculated the 6 degrees of freedom of motions of each screw head. Lateral view of the VB was monitored with Mini-C-arm. A video of 5 cycles was recorded at 0,100, 250, 500, 1000, 2500 and

5000 cycles. Relative motions of the screws in the bone were analyzed by ImagePro software.

Results: Samples with BMD<0.8 g/cm² are considered osteoporotic. >2 in screw motion are considered loose. Segments with BMD<0.8 g/cm²; in 4 samples, both CS and traditional PS loosened. Pull-out strength of the CS were 54% less than the traditional PS ($p<0.03$). In 1 segment, no loosening occurred. Pull out strength of the CS was 9% higher than the traditional PS. Segments with BMD>0.8 g/cm²; no loosening occurred at neither the CS nor the traditional PS. Pull-out strength of the CS were 29.2% greater than the traditional PS ($p=0.56$).

In comparison to each other, there was a 36% reduction in pullout strength of the traditional PS in osteoporotic bone compared to non-osteoporotic bone ($p=0.015$). CS had 69% reduction in osteoporotic bone compared to non-osteoporotic bone. ($p=0.003$). Once loosening took place after 5000 cycles, traditional PS had 56% reduction in their pullout strength in comparison to 81% reduction in CS ($p=0.004$ and $p=0.0001$).

Conclusion: Cortical trajectory screw loosening rates are overall equivalent to traditional PS during cyclic loading up to 5000 cycles. CS screws have better pullout strength than PS in both osteoporotic and good quality bone if there is no loosening during cyclic loading ($p=0.058$). Once loosening takes place in osteoporotic bone during cyclic loading, pull out strength of the CS are significantly inferior to traditional PS ($p<0.03$).

Poster 7. Analysis of the Techniques for Thoracic and Lumbar Level Localization During Posterior Spine Surgery and the Occurrence of Wrong Level Surgery: Results from a National Survey

Jillian E. Mayer, BA; Rajan P. Dang, BA; Guillermo D. Prieto, MD; Samuel K. Cho, MD; Sheeraz A. Qureshi, MD, MBA; Andrew C. Hecht, MD

Mount Sinai School of Medicine, New York, NY

Introduction: Of all the potential complications that can occur during spinal surgery, operating on the wrong spinal level is perhaps the most preventable. The reported incidence of wrong-level surgery varies in the literature between 0.14% and 15%. One of the possible contributing factors to wrong-level surgery is the variability in the way that surgeons confirm the appropriate spinal level intraoperatively. Currently, multiple imaging modalities and anatomic landmarks are used with little consensus amongst surgeons. The purpose of this study was to assess the various localization methods that surgeons are using and any associations between the method chosen and the likelihood of wrong-level surgery.

Methods: An eight-question survey was distributed nationally to members of North American Spine Society with 173 orthopedic surgeons and neurosurgeons responding (7.4% response rate).

Results: Fluoroscopy was the most commonly used imaging technique for both thoracic and lumbar surgery (89.5% and 85.5% respectively), followed by plain radiographs (54.4% and 57.8% respectively). The facet joint with corresponding pedicle was the most commonly used anatomical landmark for localization of thoracic and lumbar surgery (69.7% and 61.6% respectively), followed by the spinous process (50.9% and 53.7% respectively). 35.8% of surgeons admitted to committing at least one wrong level surgery during their career, and

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

54.9% admitted to preparing the wrong level but then rectifying the error intraoperatively. 46.4% of these surgeons reported using plain radiographs and 37.5% used fluoroscopy when the error occurred. 94% of surgeons who admitted to performing a wrong level surgery explained the situation surrounding their error. Errors were caused by the use of poor counting methods, a lack of communication between surgeons, failure to recognize unconventional spinal anatomy, and failure to relocalize after exposure despite skin marking or the use of a needle. Furthermore, five surgeons described operating on obese patients as a contributing factor.

Discussion: Although surgeons used plain radiographs less often than fluoroscopy in general practice (55.9% vs. 87.3%), they used plain radiographs more often than fluoroscopy when errors occurred (55.2% vs. 36.2%).

Conclusion: This suggests that plain radiographs resulted in more errors than would be expected based on their general usage relative to fluoroscopy ($p=0.0015$). Considering that wrong level surgery is not an infrequent event, potential factors (such as the choice of the localization technique) must be further investigated.

Poster 8. Institutional Screening for Methicillin-Resistant *Staphylococcus aureus* in Patients Undergoing Spine Surgery

Leo Spector, MD; Lisa Kelly, MSN; Julie Jerman, BBA; Ruth Hallmark, BSN, RN, ONC, CIC; Susan Odum, MD; Rebecca Lark, MD; Bruce Darden, MD

OrthoCarolina Charlotte, NC

Introduction: Methicillin-Resistant *Staphylococcus aureus* (MRSA) surgical site infections (SSIs) are one of the most important preventable sources of morbidity and mortality associated with medical treatment. Epidemiologic studies have demonstrated that most cases of SSIs are caused by strains of MRSA that are brought into the hospital environment by patients themselves. On the average, SSIs are associated w/a two-week increase in hospital stay, double the rate of re-hospitalization, and triple the overall cost of treatment. The purpose of this study was to report the outcomes of an institutional MRSA screening program.

Methods: Beginning January 1, 2011 all patients undergoing spine surgery were to undergo pre-operative, day of surgery nasal screening for MRSA. Prior to implementation, patients were screened pre-op at the discretion of the surgeon. All patients who screened positive for MRSA were given a perioperative prophylactic dose of both Vancomycin and Ancef. All patients who screened positive at their pre-op visit were treated with Mupirocin and rescreened day of surgery.

Results: Of the 1386 patients undergoing spine surgery in 2011, 1310 (95%) were screened for MRSA. Of the 1310 patients screened, 69 (5%) patients tested positive for MRSA. None of the patients who screened positive and were subsequently decolonized, developed a MRSA SSI. In 2010, 104 (7%) of the 1366 patients undergoing spine surgery were screened at the discretion of the surgeon and 7 (7%) of the 104 tested positive for MRSA. Of the 1366 spine surgeries in 2010, there were five (0.37%) post-op MRSA infections compared to four out of 1386 (0.28%) in 2011. At our institution, the cost of screening was \$44 per patient and the average cost of treating a spine infection was \$40,000 per patient.

Conclusions: In this study, institutional nasal screening of MRSA in patients undergoing spine surgery resulted in a decreased rate of MRSA infection. The percent of patients who screened positive for MRSA was consistent with community based epidemiological studies. Selected MRSA screening by surgeons did not have a higher yield then screening of all patients. The average savings from the prevention of one infection paid for the screening of 915 additional patients.

Poster 9. Patient Impressions of Reimbursement for Orthopedic Spine Surgeons

K. Linnea Welton, MD; Mufaddal M. Gomberawalla, MD; Jeffrey S. Fischgrund, MD; Gregory P. Graziano, MD; Rakesh D. Patel, MD

University of Michigan, Dept of Orthopedics, Ann Arbor, MI

Introduction: The purpose of this study was to understand patients' impressions of reimbursement to orthopedic spine surgeons.

Methods: A survey was mailed to patients who underwent a spine procedure between 4/1/2010 and 4/1/2011 at an academic and private institution. Surveys were returned in an anonymous fashion. Data retrieved from the surveys was compared to the findings of the 2007 Medical Group Management Association Physician Compensation and Production Survey. Statistical significance was evaluated using chi square analysis.

Results: 103 surveys were completed. 76% of patients underwent a larger procedure (cervical fusion, lumbar fusion, or laminectomy with fusion), while others underwent smaller procedures (kyphoplasty, discectomy, or laminectomy without fusion). Of those who underwent smaller procedures, 62% of patients felt the reimbursement was between \$5,000 to \$10,000. In truth 100% of small procedures are compensated less than \$2,500 by Medicare. Of those who underwent larger fusion-based procedures, 84% of patients felt the reimbursement was greater than \$5,000, of which 28% believed the reimbursement was greater than \$15,000. Reimbursement for these larger procedures is actually less than \$5,000 regardless of the type (Figure 1). The differences between perceived and actual per procedure compensation was statistically significant for both smaller and larger procedures ($p = 0.002$ and $p < 0.0001$, respectively). Most patients (73%) believed procedural reimbursement should primarily be based on technical difficulty. Only a minority of patients felt that in-hospital rounding and outpatient follow-up in the first 90 days were included in the global billing period (38% and 26%, respectively). 41% of patients believed spine surgeons' annual salaries are between \$250,000 and \$500,000, and 22% believed it was between \$500,000 and \$750,000. This was quite accurate when in fact 68% of orthopedic spine surgeons make less than \$750,000 (p -value = 0.0003). The majority of patients (73%) believed spine surgeons are appropriately compensated.

Conclusions: A majority of patients believe spine surgeons are reimbursed a higher amount per procedure than factually true. Despite this, most patients feel that spine surgeons are appropriately compensated. Additionally, many patients are not aware that early post-operative inpatient rounding and outpatient clinical care are included within the global billing period.

Poster 10. Rates and Causes of Mortality Associated with Spine Surgery Based on 108,419 Procedures: A Review of the Scoliosis Research Society Morbidity and Mortality Database

Justin S. Smith, MD, PhD; Dwight Saulle, MD; Ching-Jen Chen, BA; Lawrence G. Lenke, MD; David W. Polly, Jr, MD; Manish K. Kasliwal, MD; Paul A. Broadstone, MD; Steven D. Glassman, MD; Alexander R. Vaccaro, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD

University of Virginia, Neurosurgery, Charlottesville, VA

Introduction. Despite the best of care, all surgical procedures have inherent risks of complications, including mortality. Defining these risks is important for patient counseling and quality improvement. Our objective was to assess rates and causes of mortality associated with spine surgery.

Methods. The Scoliosis Research Society morbidity and mortality database was queried for spinal surgery cases complicated by death from 2004-2007, including pediatric (<21 years) and adult (>21 years) patients. Deaths occurring within 60 days and complications within 60 days of surgery that resulted in death were assessed.

Results. 197 mortalities were reported among 108,419 patients (1.8 deaths/1,000 patients). Rates of death/1,000 patients for adult and pediatric patients were 2.0 and 1.3, respectively. Based on primary diagnosis (available for 107,996), rates of death/1,000 patients were: 0.9 for degenerative (n=47,393), 1.8 for scoliosis (n=26,421), 0.9 for spondylolisthesis (n=11,421), 5.7 for fracture (n=6,706), 4.4 for kyphosis (n=3,600), and 3.3 for other (n=12,455). The most common causes of mortality included: respiratory/pulmonary (n=83), cardiac (n=41), sepsis (n=35), stroke (n=15), and intraoperative blood loss (n=8). Death occurred prior to hospital discharge for 109 (79%) of 138 deaths for which this information was reported. The specific post-operative day (POD) of death was reported for 94 (48%) patients, and included POD#0 (n=23), POD#1-3 (n=17), POD#4-14 (n=30), and POD#>14 (n=24). Increased mortality rates were associated with higher American Society of Anesthesiology (ASA) score, spinal fusion, and implants (p<0.001). Mortality rates increased with age, ranging from 0.9/1,000 to 34.3/1,000 for patients aged 20-39 years and >90 years, respectively.

Conclusions. This study provides rates and causes of mortality associated with spine surgery for a broad range of diagnoses and includes assessments for adult and pediatric patients. These findings may prove valuable for patient counseling and efforts to improve the safety of patient care.

Poster 11. Long-term Clinical and Functional Outcomes After Laminectomy and Fusion for Degenerative Disease vs. Spondylolisthesis

Dennis Crandall; Jan Revella, RN; Kurt Crandall; Ryan McLeMore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: As insurance carriers increasingly turn to "evidence based guidelines" for authorizing arthrodesis, spondylolisthesis or instability must necessarily be present for fusion to be authorized. This is the first long-term study of surgical outcomes comparing laminectomy and fusion in spondylolisthesis(S) vs. degenerative disease(D) without instability.

Methods: Prospective data was reviewed on 267 consecutive adults(M-109, F-158) with back and leg pain and stenosis who underwent open laminectomy and instrumented fusion at 1-2 levels(average 1.6 levels) and TLIF(average 1.4 levels); S group- 139, D group- 128. Age averaged 59years(24-91years); 31 were smokers, 100 had prior surgery(D-71, S-29). Excluded: fusion for back pain alone, fusion>2

levels, tumor/trauma. Clinical(VAS, Oswestry(ODI) and radiographic outcomes were recorded preop, 1year, 2years, latest followup.

Results: Followup averaged 5 years(24-101months). Complications were similar in both groups. D group complications: Nonunion-1, infection-3, additional surgery(fusion-20, lami-8); S group complications: Nonunion-0, infection-1, additional surgery(fusion-31, lami-9). Clinical improvement was significant in both groups. D group VAS: preop-6.6, 1year-3.3, 2year-3.7 (p<0.001); ODI:preop-53.1, 1year-29.3, 2years-32.1 (p<0.001). S group VAS:preop-5.8, 1year-2.4, 2years-2.8 (p<0.001); ODI:preop-46.6, 1year-21.3, 2years-23.9 (p<0.001). Considering primary surgery only, D group VAS:preop-6.5, 1year-3.3, 2years-3.3 (p<0.001); ODI preop-51.2, 1year-25.6, 2years-28.5(p<0.001). Pain medication use also decreased in both groups. Change in the primary Spondy group was not significant for VAS (p=0.22), or ODI (p=0.073).

Discussion: Both S and D groups had similar complications and significant improvement after laminectomy and fusion at 1 - 2 levels. D group patients had more pain preop and postop, likely due to more than twice the patients with prior surgery.

Conclusions: For patients with stenosis and back pain, the presence of spondylolisthesis or instability is not required for successful long-term outcome. Insurance carrier policy of denying arthrodesis based purely on the absence of spondylolisthesis or instability appears unjustified.

Poster 12. Long-term Narcotic Usage Following Spinal Surgery

Daniel Gaffney, MD; Michael D. Daubs; Brandon D. Lawrence, MD; Darrel S. Brodke, MD; Alpesh A. Patel, MD; Thomas Higgins, MD

University of California San Francisco, Orthopedics, San Francisco, CA

Introduction: Spinal surgery is invasive and often necessitates the postoperative use of narcotics to achieve adequate pain control. Prolonged use of narcotics leads to physical addiction and the potential for abuse. The purpose of our study was to determine the number of patients who continued chronic narcotic usage (>3 months) following spinal surgery, and to evaluate the preoperative factors that predicted chronic use.

Methods: We evaluated 117 consecutive patients, 43 males, 74 females, with a mean age of 55 (range 22-86), that underwent spinal surgery at a single institution. Seventeen items of demographic data, clinical data, and narcotic prescription data were collected and analyzed, including the amount of preoperative narcotic usage. The narcotic usage data was collected from a mandated, state-wide, narcotic prescription database. High dose preoperative narcotic use was defined as >20mg morphine equivalents/day during the previous 30 days. In addition, all patients completed a preoperative psychological screening questionnaire (DRAM), a VAS, and an ODI or NDI.

Results: Sixty-two percent of patients had at least one narcotic prescription in the 30 days prior to surgery. Forty-four percent (52/117) of patients continued to receive narcotic prescriptions greater than 3 months following surgery. Chronic preoperative narcotic use (p<0.001), high dose preoperative narcotic use (p 1 year (p=0.06), and revision surgery (p=0.07) were not predictive but trended toward significance. Other factors including age, gender, and level of psychological distress were not predictive of prolonged narcotic use.

Conclusions: A significant percentage of patients (44%) continued narcotic usage greater than 3 months following spine surgery. Chronic preoperative narcotic use, high dose preoperative narcotic use, smoking, unemployed status, and fusion were found to be predictive of prolonged postoperative narcotic use.

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

Poster 13. Facet Joint Violation in Pedicle Screw Placement with Intraoperative 3-Dimensional CT (O-arm) Image-Guidance

University of Minnesota, Orthopedics, Minneapolis, MN

Sharon C. Yson, MD; Jonathan N. Sembrano, MD; Peter C. Sanders, MD; Edward Rainier G. Santos, MD; David W. Polly, Jr., MD

Introduction: Facet joint violation reportedly results in a higher rate of adjacent segment degeneration. Reported facet joint violation rates range from 11% to 100%. Image-guided techniques have enhanced pedicle screw placement accuracy. The aims of this study are to determine if 3-dimensional (3D) CT (O-arm) image-guided pedicle screw placement reduces cranial facet joint violation and to compare the rates of facet joint violation between open and percutaneous techniques.

Methods: We reviewed 188 cases of 3D image-guided lumbar pedicle screw instrumentation from November 2006 to December 2011. Surgeries were conducted at one institution by three fellowship-trained spine surgeons. The superior-most screws (ranging from L1 to L5) of each construct were graded according to the Seo classification (0 = no impingement; 1 = screw head in contact/suspected to be in contact with facet joint; 2 = screw clearly invaded the facet joint) on axial CT (O-arm) images. Grading was performed by three independent reviewers. If there is a difference in evaluation, a consensus was reached to arrive at a single grade for each screw. Student t-test was used to determine significance between the open and percutaneous group ($\alpha=0.05$).

Results & Discussion: A total of 370 screws (245 open, 125 percutaneous) were graded. Overall facet joint violation rate was 18.9% (Grade 1 = 16.2%, Grade 2 = 2.7%). Open technique (Grade 1 = 22.4%, Grade 2 = 4.6%) had a significantly higher violation rate than percutaneous technique (Grade 1 = 4%, Grade 2 = 0%) ($p<0.001$). Screws inserted percutaneously had more lateral entry points which tend to avoid the facet joint. There is a trend of an increasing percentage of facet joint violation from the upper to lower lumbar levels reflecting the difficulty of avoiding the facet joints at the lower levels due to facet orientation and presence of the iliac crests (see Graph).

Conclusion: The use of intra-operative CT (O-arm) image-guidance in lumbar pedicle screw placement resulted in a facet joint violation rate at the lower end of the reported range in literature. The percutaneous technique has a significantly lower superior-segment facet violation rate than the open technique. Moreover, none of the facet joint violations in the percutaneously inserted screws showed complete impingement of the joint (Grade 2).

Poster 14. Arthrodesis and Pseudarthrosis Rates in 78 Studies Utilizing a Rabbit Posterolateral Spine Arthrodesis Model with Iliac Crest Autograft

Jason H. Ghodasra, B.S.; Erika L. Daley, B.A.; Erin L. Hsu, Ph.D.; Wellington K. Hsu, M.D.

Sonoran Spine Center, Mesa, AZ

Introduction. The rabbit posterolateral intertransverse spine arthrodesis model has been widely used to evaluate spinal biologics; however, the validity and reproducibility of performance of iliac crest bone graft has not been firmly established. We evaluated original research publications which utilized this model and identified which experimental conditions, outcome measures, and inhibitory compounds affected fusion rates.

Methods. A Medline search was performed for publications from 1960-2011 which utilized the rabbit posterolateral arthrodesis model to test iliac crest autograft. Study parameters—including strain, age, weight, vertebral level, volume, time point evaluation, and adjunct compounds—were recorded. Logistic regression analyses were performed to determine the effects of these variables on fusion rates as determined by manual palpation or radiographs. Treatments promoting pseudarthrosis were compared to autograft alone using Fisher's exact test. Statistical significance was accepted at $p<0.05$.

Results. Seventy-eight studies with a total of 1395 rabbits in 129 groups met the inclusion criteria. After excluding studies that measured fusion at 4 or fewer weeks or those that intentionally tried to decrease the fusion rate, 73 studies with 914 animals remained, and the overall fusion rate for autograft was 57.0% (Standard deviation of 17.4%) as determined by manual palpation and 66.3% (SD of 17.6%) by radiographs. Regression analysis demonstrated a difference between these measures with a trend towards significance ($p=0.09$). Longer time points and larger volumes of autograft resulted in significantly greater fusion rates ($p<0.01$ and $p<0.05$ respectively). Neither strain, age, weight, nor vertebral level significantly affected fusion rates. In comparison to untreated controls, the addition of nicotine, non-steroidal anti-inflammatory drugs, chemotherapeutic agents, and corticosteroids all significantly decreased fusion rates, whereas bisphosphonates did not (Figure 1).

Discussion. Although experimental conditions varied, time to outcome and autograft volume significantly affected fusion rates.

Increased pseudarthrosis rates can be induced through the administration of nicotine, non-steroidal anti-inflammatory drugs, chemotherapeutic agents, and corticosteroids.

Conclusion: Pre-clinical animal models are essential in demonstrating the safety and efficacy of spinal biologics. Utilizing historical controls, we established the expected arthrodesis rates in the rabbit posterolateral spinal arthrodesis model with varying experimental conditions.

Poster 15. The Impact Of Reduction Of Pain Following Lumbar Spine Surgery: The Relationship Between Changes In Pain And Changes In Function And Disability

Richard L. Skolasky, ScD; Stephen T. Wegener, PhD; Anica M. Maggard, BS; Lee H. Riley, III, MD

Johns Hopkins University, Orthopedic Surgery, Baltimore, MD

Objective: A prospective cohort study to characterize the relationship between changes in pain and changes in function and disability after lumbar spine surgery.

Summary of Background Data: Functional limitations and disability are common among those undergoing lumbar spine surgery. Little is known regarding the relationship between reduction in pain following surgery and the associated changes in physical function and disability.

Methods: 260 individuals undergoing lumbar spine surgery were assessed preoperatively and postoperatively (3 and 6 months). Assessment included pain [numeric rating scale (NRS)], function [Short Form 12 (SF12)], and disability [Oswestry Disability Index (ODI)]. Changes in pain, function, and disability were defined using minimum clinically important differences. Change in pain was associated with changes in function and disability using standard regression methods.

Results: Pre-operatively, mean pain intensity was 5.2 (standard deviation (SD) 2.4), mean function (physical health SF-12v2) was 27.9 (SD 9.2) and mean disability (ODI) was 40.1% (SD 16.8%). At three and six months, mean function was 34.5 (SD 9.6) and 36.4 (SD 9.8), respectively, and mean disability was 33.7% (SD 17.8%) and 33.4% (SD 18.1%), respectively.

While there was no association between reduction in pain and change in function, individuals that experienced an improvement in pain at three months (63%) were more likely to experience a reduction in disability (odds ratio (OR) 2.58, 95% confidence interval (CI) 1.89, 7.51) compared to those individuals that experienced no change (37%). A similar relationship was observed at six months (OR 1.95, 95% CI 1.32, 2.77).

Conclusions: A majority of individuals experienced clinically important reductions in pain following surgery (63% at three and six months). Individuals that experienced a reduction in pain intensity were more likely to experience a clinically important reduction in disability.

Poster 16. Lumbar Spinous Process Splitting Laminoplasty: A Novel Technique for Minimally Invasive Lumbar Decompression. Report on 27 Patients

Ahmad Nassr, M.D.; Charbel D. Moussallem, M.D., FEBOT; Bradford Currier, M.D.; Michael Yaszemski, M.D., PhD; Paul Huddlestone, M.D.; Peter Rose, M.D.; Mark Dekutoski, M.D.

Mayo Clinic, Orthopedic Surgery, Rochester, MN

Objective: To assess the safety and efficacy of a novel minimally invasive approach for lumbar decompression using the spinous process splitting approach

Materials and Methods: A retrospective review of prospectively

collected data was conducted on 27 patients with symptomatic lumbar spinal stenosis. The lumbar spinous process is split and detached from its base allowing for the paraspinal muscles to be preserved. Using microsurgical techniques a laminotomy is performed centrally and facet joints are undercut to effect a lateral recess decompression. The split spinous process is repaired with transosseous sutures together to allow for bony healing

Results: 27 consecutive patients all having symptomatic spinal stenosis were included in this study: 15 were males (55%) and 12 were females (45%) having a mean body mass index of 28 ranging from 15 to 38. The patient population ranged in age from 22 to 88 years with a mean of 65 years. 26 cases involved decompression of the lumbar spine on various levels and one case involved decompression of the thoracolumbar spine from T12 to L4. The average number of decompressed levels was 3 (range 1-6) and that of split processes was 2 ranging from 1 to 5. The mean operative time was 203 min (90-345 min) and the mean intraoperative estimated blood loss was 179 ml (25-650 ml) requiring blood transfusions in only 2 patients. The mean estimated post-operative blood loss was 63 ml (0-500 ml). The mean hospital stay was 3.9 days ranging from 1 to 12 days. The Mean Back pain VAS and leg pain VAS dropped from 6 (1-10) to 1.8 (0-5) and from 5.7 (1-9) to 1.8 (0-5) respectively after surgery. The mean Oswestry low back pain disability score dropped from 36.7 (8-68) to 17.3 (0-30) following decompression after a mean follow up of 7 months ranging from 1 to 24 months.

As for the complications: two patients had epidural hematomas that were evacuated with no neurologic injury after a mean follow up of 9 months. Both of them were done at the beginning of the series and no drains were used. A davol drain was inserted in all other cases. Two intraoperative dural tears were also noted and one late pseudomeningocele. All decompressions were deemed adequate clinically and no patients had to return for further decompression

Conclusion: The spinous process splitting laminoplasty is a novel approach that allows for a midline exposure and decompression of the lumbar canal while offering the advantages of decreased paraspinal muscle injury and preservation of the multifidus attachment to the bony spinous process for healing. Complication rates with this procedure are infrequent and justify further study into its use.

Poster 17. Improvement Of Sagittal Balance And Lumbar Lordosis Following Less Invasive Adult Spinal Deformity Surgery With Expandable Cages And Percutaneous Instrumentation

Michael Y. Wang

University of Miami, Neurological Surgery, Miami, FL

Introduction: The treatment of adult spinal deformity (ASD) remains a challenge for the spinal surgeon. While minimally invasive surgery (MIS) has many favorable attributes that would be of great benefit for the ASD population, improvements in lordosis and sagittal balance have remained elusive using MIS an approach. This report

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

describes the evolution of an MIS method for treating ASD with attention to sagittal correction.

Methods: Over an 18 month period 25 patients with thoracolumbar scoliosis were treated surgically. The mean patient age was 72 years, with 68% females. Patients were treated with multi-level facet osteotomies and interbody fusion using expandable cages (mean=3.2 levels) followed by percutaneous screw fixation (mean=5.3 levels). Seven patients had supplemental percutaneous iliac fixation.

Results: All patients underwent surgery without conversion to a traditional open technique. The mean operative time was 273 minutes and the mean blood loss was 416 cc. There were no intraoperative complications. Cobb angle over the scoliotic deformity improved from a mean of 29.2° to 9.0° ($p<0.001$). Lumbar lordosis between L1 and S1 improved from a mean of 27.8° to 42.6° ($p<0.001$). Sagittal vertical axis improved from 7.4 cm to 4.3 cm ($p=0.001$). Complications included: two patients returning to the operating room for hardware re-positioning, one case of screw pullout, an asymptomatic pedicle screw breach, prolonged hospitalization from constipation, and one patient with acute coronary syndrome three days after surgery without myocardial damage.

Conclusions: An expanding body of evidence suggests that sagittal balance remains a keystone for good outcomes with ASD surgery. An MIS approach using a combination of osteotomies, interbody height restoration, and advanced fixation techniques may achieve this goal in patients with less severe deformities. While feasibility will have to be proven with larger series and improved surgical methods, this technique holds promise as a means of reducing the significant morbidity associated with surgery in the ASD population.

• *The FDA has not cleared this drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an “off label” use). See inside back cover for full information.*

Poster 18. Long-Term Clinical, Functional, and Occupational Outcomes Following TLIF with rhBMP: Smokers vs. Non-smokers

Dennis Crandall, MD; Matthew Wilson; Jan Revella, RN; Dustin Revella, BA; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: Smoking impairs bone healing, is associated with pseudoarthrosis and back pain. This is the first report of long-term clinical, occupational, and functional outcomes from a large series comparing smokers to nonsmokers after posterior fusion and TLIF using BMP.

Methods: Consecutive cohort of 545 adults, age 61years(19-88) who underwent spinal fusion for spondylolisthesis(180pts, avg 3 levels), degenerative(193pts, avg 3 levels), or deformity(172pts, avg 9 levels); All were fused with BMP and local autograft: posterior only(98pts), TLIF(447patients) at average 1.7 levels. Smokers-55(10%), Nonsmokers-490; Prior surgery: smokers-24, nonsmokers-210. Work status preop: working- 195(work type: sedentary-102, medium-61, heavy-9, student-4, unknown-19), retired-276, disabled-73. Excluded: non-fusion surgery, age <18. Functional outcome scores are compared with the paired sign test.

Results: Follow-up averaged 5years(24-112months). There was no significant difference in complications smokers vs nonsmokers: non-union-23(4%), adjacent fracture-16(3%), infection-13(2%), whether primary or revision surgery. Clinically, significant improvement was noted in VAS, Oswestry (ODI), and pain medication records among smokers and nonsmokers for all diagnostic groups, whether primary or revision surgery. **SMOKERS:** Primary surgery (VASpreop-7.1, 2 year- 4.1, $p=0.0026$; ODI preop-51, 2 year-32, $p=0.0433$), Revision surgery (VASpreop-7.3, 2 year-3.7, $p=0.0034$; ODIpreop-56, 2 year-32, $p=0.0001$). **NONSMOKERS:** Primary surgery (VASpreop- 5.8, 2 year-2.8, $p<0.001$; ODI preop-44.9, 2 year-24.8, $p<0.001$), Revision surgery. (VASpreop-6.6, 2 year-4.0, $p<0.001$; ODIpreop-55, 2 year-36, $p<0.001$). Returned to work and remain working long-term: Smokers- 20/24(83%), Nonsmokers- 123/167(74%) ($p=0.45$), no difference in time to return. Smokers were more likely to file for disability after surgery: 4/24 smokers(17%), 5/167 nonsmokers(3%) ($p=0.016$). **Discussion:** Smokers and nonsmokers undergoing primary or revision spinal fusion for scoliosis, spondylolisthesis, and degenerative disease showed significant clinical improvement and a strong ability to return to work and remain working long-term in the largest series in the literature. Smokers had slightly more pain pre-op than nonsmokers, and were more likely to claim disability despite similar VAS and ODI improvement.

Conclusions: BMP appears to negate the influence of smoking on clinical, functional, and occupational outcomes after instrumented spinal fusion, regardless of fusion length, diagnosis, or revision surgery.

• *The FDA has not cleared this drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an “off label” use). See inside back cover for full information.*

Poster 19. Primary vs. Revision Fusion: How Well Do Patients Walk Long-term?

Dennis Crandall; Melissa Gebhardt, PA-C; Jan Revella, RN; Dustin Revella, BA; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: There is increasing interest and need for research regarding the value of spinal surgery. Outcomes measures such as Oswestry(ODI) are abstract to public understanding. We studied

walking ability (among other outcomes), an easily understood function common to all lower extremity surgery, to describe the impact of primary vs. revision fusion on long-term functional outcomes.

Methods: Prospectively collected outcomes on 551 consecutive adults undergoing instrumented fusion (374primary, 177revision). Diagnoses: degenerative disease(365, average 3 levels) or deformity(186, average 10 levels). Age averaged 61years(19-90); 60 were smokers. 267 underwent 1-2 level fusion (207primary,60 revision),102 underwent 3-4 level fusion (51 primary, 51revision), 182underwent 5 or more levels (116primary, 66revision). Outcomes: Visual analog pain score(VAS), ODI, and pain medication records pre-op, postop1 year and 2 years. Walk score(WS) from the ODI: 0- no limit. 1- walk one mile. 2- walk ½ mile. 3- walk ¼ mile. 4- cane or walker. 5- bedridden. (WS multiplied by 2)

Results: At 68 months followup(25-188months), both primary and revision patients significantly improved all clinical outcome measures($p<.01$). Patients undergoing revision surgeries had similar ODI($p=.875$) but worse WS($p=.001$), at 2 years than primary fusion patients. Primary WS:preop-4.6, 1year- 2.2, 2year-2.6. Revision WS:preop-5.6, 1year- 3.8, 2year- 4.0. Primary VAS: preop-6.0, 1year-2.6, 2year- 3.0. Revision VAS:preop 6.7, 1 year-4.0, 2 year- 4.1. Primary ODI:preop-45.2, 1year-22.9, 2year-26.2. Revision ODI:preop-56.2, 1year-38.8, 2year-38.0. Fusion length, gender, and age differences did not affect WS. Primary group complications:Nonunion-14(4%), adjacent fracture-6, infection-7, footdrop-5. Revision group complications:Nonunion-10(17%), adjacent fracture-7, infection-3, footdrop-3.

Discussion: Walk scores from the ODI provide a way to interpret an easily understood functional outcome that is useful apart from ODI. Both primary and revision fusions more than doubled patients walking distance, and maintained that improvement long-term, regardless of fusion length, age, or gender.

Conclusions: Differences in WS may reflect sensitivity to an outcome not captured by ODI. Two-year ODI was not different in primary vs revision fusion patients, but revision patients had significantly worse Walking Scores at 2 years.

Poster 20. Fixed vs. Expandable Cage In TLIF: A Radiographic Comparison

Dennis Crandall; Sigurd Berven, MD; Neel Anand, MD; Murali Kadaba, PhD; Eric Huish, BS; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: Posterior based interbody fixation is limited by a balance between graft size and safety of insertion. An expandable TLIF cage could improve structural fill of the interspace, disc height, and segmental lordosis while minimizing insertion size and risk to neural elements. This study compared change in disc height, segmental lordosis, and regional lordosis (L1-S1) with TLIF using a FDA approved expandable cage (EC) vs. a static, rectangular PEEK TLIF cage.

Methods: Matched cohort analysis comparing patients treated with the hydraulic expandable cage to a control group matched for surgical level, pre-op disc height and segmental lordosis. Standing AP and lateral radiographs taken pre-op and 3-6 weeks post-op were measured by an independent surgeon. Outcome variables included changes in disc height, and segmental and regional lordosis. Differences in disc heights and lordosis measures were compared using paired t-tests.

Results: The study cohort: 13 EC patients (15 discs) vs 15 control TLIF discs. EC and Control discs increased anterior, mid, and posterior height ($p<0.001$) from pre-op. Both groups increased segmental lordosis (EC $p<0.001$; control $p=0.019$). Regional lordosis was not affected in either group. EC group improved segmental lordosis, anterior and mid disc height more than control ($p=0.002/0.002/0.001$); EC posterior disc height also improved more than control but was not significant ($p=0.14$).

Anterior Disc Height (mm)	Expandable Cage	Control Cage
Pre Op	11.2 (4-15)	11.6 (8-15)
Post Op	16.3 (8.5-22)	13.8 (12-16)
Mid Disc Height (mm)		
Pre Op	8.5 (3-11.4)	8.5 (4-11)
Post Op	13.1 (7.5-16.6)	10.6 (9-12)
Posterior Disc Height (mm)		
Pre Op	5.6 (2-8.5)	5.1 (2-7)
Post Op	8 (3-11.5)	6.8 (5-9.5)
Segmental Lordosis (°)		
Pre Op	11.5 (3-19)	11.7 (6-18)
Post Op	16.5 (4-22)	13.4 (8-20)
Regional Lordosis (°)		
Pre Op	54.4 (41-65)	52.6 (31-68)
Post Op	54.2 (40-69)	52.8 (32-67)

Discussion: EC produces better anterior and middle disc height and segmental lordosis than static cage. Whether a smaller insertion size translates to less postop radiculopathy with EC remains to be studied.

Conclusions: The ability to expand a TLIF cage after insertion improves disc height and lordosis.

Poster 21. Meta-Analysis of Vertebroplasty Compared to Conservative Treatment

William L. Tontz, MD; Paul A. Anderson, MD; Alex Froysteter, BA

Coastal Orthopedics, Bradenton, FL

Introduction: Cement augmentation is a controversial treatment option for painful vertebral compression fractures (VCF). Our research questions for the meta-analysis were: is there a clinical and statistical difference in pain relief, functional improvement and quality of life between conservative care and cement augmentation for VCF. Are they maintained at longer time points?

Methods: A search of MEDLINE from January 1980 to July 2011 using PubMed, Cochrane Database of Systematic reviews and Controlled Trials, CINAHL and EMBASE. Searches were performed from Medical Subject Headings. Terms "vertebroplasty" and "compression fracture" were used. Paper's quality was graded by the PRISMA statement, Review Manager software and GRADE. Outcome variables pain, functional measures, health related quality of life and new fracture risk were analyzed

A random effects model was chosen. Continuous variables were calculated using the standardized mean difference and 95% confidence intervals comparing improvement from baseline of the experimental to control group. New vertebral fracture risk was calculated using log odds ratio. Test of significance utilized the Z statistic with a p value of 0.05.

Results: Six studies met the criteria. Pain, Visual Analogue Scale (VAS), was evaluated as the primary outcome in 4 papers, with Roland Morris Disability Questionnaire (RDQ), and Short-Form Health Survey 36 Questionnaire Physical Component Score (SF-36 PCS) in two papers. Pain VAS mean difference was 0.73 (CI 0.35, 1.10) for early (<12 weeks) and 0.58 (CI 0.19, 0.97) for late time points (6-12 months) favoring vertebroplasty ($p<0.001$). Functional outcome was measured by RDQ and Oswestry Disability Index (OSW). The standardized mean difference for early and late time points were statistically significant with 1.08 (CI 0.33, 1.82) and 1.16 (CI 0.14, 2.18). Health related quality of life (HRQOL) indices showed superior results of vertebroplasty compared with conservative care at early and late time points of 0.39 (CI 0.16, 0.62) and 0.33 (CI 0.16, 0.51). Adverse events as measured by secondary fractures were not

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

statistically different between the groups with a mean effect of 0.065 (CI -0.57, 0.70).

Discussion: This meta-analysis showed greater pain relief, functional recovery and health related quality of life with cement augmentation compared with controls. Cement augmentation results were significant in the early (<12 weeks) and the late time points (6-12 months). This meta-analysis provides strong evidence in favor of cement augmentation in the treatment of symptomatic VCF fractures.

Poster 22. Incidence And Morbidity Of Concomitant Spine Fractures In Combat Related Amputees

Adam Bevevino, MD; Ronald A. Lehman, MD; Daniel G. Kang, MD; Scott M. Tintle, MD; Theodora Dworak, BS; Benjamin K. Potter, MD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction. High-energy blasts are the most frequent cause of combat related amputations in Operations Iraqi and Enduring Freedom (OIF/OEF). The non-discriminating effects of this mechanism, often results in both appendicular and axial skeletal injuries. This study sought to determine the incidence and consequence of associated spine fractures on patients with traumatic lower extremity amputation sustained during OIF/OEF.

Methods. Data from 300 consecutive combat related lower extremity amputations was retrospectively reviewed and grouped. Group I consisted of amputees with associated spine fractures, and Group II consisted of amputees without spine fractures. The results of the two groups were compared with regard to initial presentation and final functional outcomes.

Results. A total of 226 patients sustained 300 lower extremity amputations. Twenty-nine of these patients had a spine fracture (13%). Group 1 had a higher Injury Severity Score (ISS) than Group 2 (30 vs. 19, $p < 0.001$). Group I patients were also more likely to be admitted to the ICU (86% vs 46%, $p < 0.001$). Furthermore, Group I patients had a significantly higher rate of heterotopic ossification in their residual limbs (82% vs 55%, $p < 0.005$).

Conclusion. The incidence of spine fractures in combat related amputees is 13%. The results suggest combat related amputees with spine fractures are more likely to sustain severe injuries to other body systems, as indicated by the significantly higher ISS scores and rates of ICU admission. This group also had a significantly higher rate of heterotopic ossification (HO) formation, which may be attributable to the greater local and/or systemic injuries sustained by these patients.

Poster 23. The Biomechanical Consequences Of Rod Reduction Following Facetectomy In The Lumbar Spine

Adam Bevevino, MD; Ronald A. Lehman, MD; Daniel G. Kang, MD; Melvin D. Helgeson, MD; Rachel Gaume, BS; Paul Happel, BS; Anton E. Dmitriev, PhD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction. Residual mismatch between pedicle screw-rod constructs is frequently encountered and corrected through rod reduction tools or by readjustment of the screw depth. This study sought to investigate the biomechanical effects of rod reduction and screw reinsertion on the lumbar spine following facetectomy.

Methods. Nine ($n=9$) three-segment, human lumbar spine specimens were tested following facetectomy. Pedicles were instrumented with 6.5mm screws and insertional torque (IT) was measured during

screw placement. On the left side, a rod with no residual rod-screw mismatch was placed. Then, on the right side an intentional 5mm rod-screw mismatch was contoured and reduced using a rod-reduction device. To simulate screw repositioning, one screw was backed out and reinserted while re-insertional torque was measured. Screws were pulled out "in line" with the screw axis to determine pullout strength (POS) in Newtons (N).

Results. Rod reduction significantly decreased pedicle screw POS compared to controls (961 ± 352 N versus 613 ± 563 N). Two of nine screws (22.2%) had outright failure during rod reduction. Screw reinsertion did not significantly decrease POS (943 ± 352 N versus 803 ± 422 N) despite having a significant decrease in IT compared to control IT ($9.56 \pm \text{in-lbs}$ versus $6.38 \pm 4.61 \text{in-lbs}$).

Conclusion. As in the thoracic spine, rod reduction decreases lumbar pedicle screw POS. Increasing the flexibility of the spine, through total facetectomy, does not negate the effects of rod reduction. Despite a significant decrease in IT, screw repositioning/reinsertion did not decrease POS, suggesting that a decreased IT does not affect biomechanical fixation strength. Surgeons should avoid rod reduction devices as they result in decreased screw fixation.

Poster 24. Do Ponte Osteotomies Affect The Biomechanical Consequences Of Rod Reduction In The Thoracic Spine?

Daniel G. Kang; Adam J. Bevevino, MD; Ronald A. Lehman, MD; Rachel E. Gaume, BS; Melvin D. Helgeson, MD; Anton E. Dmitriev, PhD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction: When a residual mismatch occurs between the rod and pedicle screw head, the use of a rod persuasion device has been found to have deleterious consequences on pedicle screw pull-out strength (POS) in the thoracic spine. However, posterior-only Ponte osteotomies are performed during many deformity surgeries to improve flexibility/correction of the spine, and may offset forces of the rod reduction maneuver. The objective of this study is to evaluate the biomechanical effect of the rod reduction technique on pedicle screw pull-out strength in the thoracic spine following Ponte osteotomies.

Methods: Fifteen ($n=15$) three-segment, fresh-frozen human cadaveric thoracic specimens were prepared. Specimens were instrumented with titanium pedicle screws, after Ponte's were performed, and the left side served as the control with perfect screw-rod alignment. The right side rod was intentionally contoured with a 5 mm residual gap between the ventral aspect of the rod and the inner bushing of the pedicle screw, followed by use of a rod reduction device. The pedicle screws were pulled out "in-line" with the screw axis, with peak POS measured in Newtons (N).

Results: After rod reduction, pedicle screws had significantly decreased POS compared to controls (419 ± 426 N versus 708 ± 462 N), with 40% lower mean POS. Eleven (73%) of the pedicle screws had visible pull-out/failure during the reduction attempt, and occurred irrespective of BMD. Although exhibiting a significant difference in insertional torque, there was no significant difference in POS between re-inserted screws compared to control screws (768 ± 375 N versus 819 ± 502 N).

Discussion and Conclusion: Despite Ponte osteotomies improving the flexibility of the spine, the rod reduction device significantly decreases overall pedicle screw POS; typically resulting in outright failure of the screw-bone interface. Therefore, the rod reduction technique should be performed with caution as it frequently results in failure of fixation of the pedicle screws.

Poster 25. The Ventral Lamina and Superior Facet Rule: A Morphometric Analysis for Ideal Thoracic Pedicle Screw Start Point

Ronald A. Lehman, MD; Daniel G. Kang; Lawrence G. Lenke, MD; Rachel Gaume, BS; Haines Paik, MD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction: With the increasing popularity of thoracic pedicle screws, the freehand technique has been espoused to be safe and effective. We set out to define the morphologic relationship of the ventral lamina (VL) to the pedicle in order to determine the optimal screw starting point in the thoracic spine.

Methods: 115 thoracic spine vertebral levels (n=229 pedicles) were evaluated. After the vertebral body was removed, K-wires were inserted retrograde along the four boundaries of the pedicle. Using digital calipers, we measured width of the superior articular facet (SAF) and pedicle at the isthmus, and from the borders of the SAF to the boundaries of the pedicle. We calculated the morphologic relationship of the VL and center of the pedicle (COP), to the SAF.

Results: The VL was identifiable in all specimens forming the roof of the spinal canal, and confluent with the medial pedicle wall (MPW). The mean distance from SAF midline to the MPW was 1.34 ± 1.25 mm medial. The MPW was lateral to SAF midline in 34 (14.85%) pedicles, with a mean distance of only 0.52 ± 0.51 mm lateral. The mean distance from SAF midline to COP was 2.22 ± 1.49 mm lateral. The COP was medial to SAF midline in only 11 (4.80%) pedicles.

Discussions and Conclusion: The ventral lamina is an anatomically reproducible structure, consistently located medial to the midline of the superior articular facet (85%). We also found the center of the pedicle consistently lateral to the SAF midline (95%). This study asserts that the optimal/safe starting point for thoracic pedicle screws should be 2-3 mm lateral to the SAF midline ("superior facet rule").

Poster 26. Biologic Augmentation of the Intervertebral Disc with a Growth Factor-Loaded Chitosan Hydrogel Administered Percutaneously: A Rabbit Nucleotomy Model

Casey Bachison, M.D.; Tristan Maerz, M.S.; Kevin Baker, Ph.D.; Harry Herkowitz, M.D.; Jeffrey Fischgrund, M.D.

William Beaumont Hospital, Dept of Orthopedic Surgery, Royal Oak, MI

Introduction. Considerable research is underway to devise a biologic strategy aimed at regenerating the intervertebral disc. Many of these strategies address the anabolic needs of disc regeneration with a single growth factor, and do not address the considerable inflammatory and degenerative environment with an injured or diseased disc. The aim of this study was to investigate the efficacy of a combination of anabolic growth factors (TGF-B3 and BMP-4) and a proteinase inhibitor (TIMP-2) to induce de novo disc tissue formation when delivered via a Chitosan hydrogel following acute nucleotomy.

Materials & Methods. Fifteen New Zealand White rabbits underwent a percutaneous nucleotomy of L4-L5 and L2-L3 under fluoroscopy using an 18G spinal needle. The nucleotomized levels were randomized to serve either as the defect-only control, or to receive an percutaneous injection of a Chitosan hydrogel containing either TGF-B3 + BMP-4, or TGF-B3 + BMP-4 + TIMP-2, or no growth factors into the disc space. Lumbar spines were harvested en bloc after six weeks and subjected to magnetic resonance imaging with a 3T clinical scanner. Safranin-O/Fast Green staining of decalcified histologic sections was used to compare proteoglycan content in discs. All discs were compared to endogenous controls of the "defect only" disc, as well as intact discs.

Results. No evidence of hydrogel leakage was observed at the time of explantation of the spines, nor did any animal display symptoms of neuritis that would be expected with hydrogel expulsion from the disc space. MRI analysis of the explanted spines shows obliteration of the disc space at the "defect only" level, with significant loss of disc height and bony changes. At the levels treated with Chitosan hydrogel, disc spaces maintained original height. Discs that received Chitosan loaded with TGF-B3, BMP-4 and TIMP-2 displayed signal intensities nearly identical to the intact, control discs, as shown in Figure 1.

Figure 1. T2-weighted MRI of excised rabbit lumbar spine demonstrating signal intensity in a nucleotomized disc (bottom), two normal discs and a nucleotomized disc that was treated with Chitosan containing TGF-B3, BMP-4 and TIMP-2

Discussion. In the acute setting, the percutaneous injection of Chitosan loaded with anabolic growth factors and a proteinase inhibitor into the disc space mitigates disc space obliteration and stimulates de novo disc tissue formation. Current studies are underway to examine the effects of this treatment in a model of degenerative disc disease.

Poster 27. In Vivo Delivery of E. Coli-Expressed rhBMP-2 by Biomimetic Calcium Phosphate Coatings in the Setting of Lumbar Spine Fusion: Effect of Incorporated Dose

Siddharth Badve, M.D.; Casey Bachison, M.D.; Kevin Baker, Ph.D.; Jeffrey Fischgrund, M.D.; Harry Herkowitz, M.D.

William Beaumont Hospital, Dept of Orthopedic Surgery, Royal Oak, MI

Introduction: Development of rhBMP-2 as an osteo-inductive substitute for use in spinal fusion has helped achieve excellent fusion rates. Physical adsorption of rhBMP-2 on a collagen sponge, while current best practice, results in poor protein-collagen sponge interaction, ultimately leading to burst release of rhBMP-2. Hence it necessary to use supraphysiologic doses of rhBMP-2, which may result in various adverse effects. Incorporation of the rhBMP-2 into a calcium phosphate coating deposited on a collagen sponge, slowly releases it at the intended site. Thus it may be possible to reduce the dose of

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

rhBMP-2 necessary to achieve spine fusion. Further, the utilization of E.Coli expressed rhBMP-2 to replace the mammalian variant may help reduce the cost.

Methods: The study involved bilateral postero-lateral spine fusion at L5-6 levels in a New Zealand White rabbit model. Escalating doses of E.Coli expressed rhBMP-2 (0,2.5,5 mcg/sponge bilaterally) were used in two groups. For Group I, BMP-2 was added to the collagen sponge immediately prior to the implantation, while in Group II the BMP-2 was incorporated in a calcium phosphate coating deposited on the collagen sponge. The animal grouping and the dosage of the BMP-2 used was randomized. Animals were sacrificed at 12 weeks and the spines were excised for manual, histological and radiographic including micro-CT evaluation. The fusion mass was graded and characterized based on these evaluation.

Results: 30 rabbits underwent bilateral postero-lateral spine fusion at L5-6 level. Analysis of the fusion mass demonstrated that in the lowest dosing sub-group (2.5mcg), the fusion mass of group II was about 2 grades higher than the fusion mass of group I, however the difference between mean volumes was not statistically significant. This advantage was not maintained at the higher dose(5mcg).

Figure 1. Bar diagram showing the grades of fusion mass in various subgroups.

Conclusions: Sustained release Ecoli expressed rhBMP-2 when used in lower doses is a promising method to achieve higher grades of postero-lateral spinal fusion mass in rabbits. Studies with large sample size will evaluate its efficacy. This method could be a safer and cost effective alternative to current used technique for mammalian rhBMP-2.

Poster 28. Hidden Blood Loss During Posterior Spinal Fusion

Yossi Smorgick, MD; Harry Herkowitz, MD; Kevin Baker; David Montgomery; Jeffrey S. Fischgrund, MD

William Beaumont Hospital, Dept of Orthopedic Surgery, Royal Oak, MI

Background Context: Posterior spine fusion is associated with significant intra- and postoperative blood loss. When referring to total blood loss during spine surgery the standard is to measure the intra-operative bleeding plus post-operative drainage. This ignores the 'hidden' blood loss due to extravasation of blood into the tissues during operation, blood hemolysis, and blood losses during the entire postoperative hospitalization which was found to be significant in other fields of surgery.

Purpose: The purpose of this study was to examine whether posterior spine fusion carries a substantial hidden blood loss.

Study Design/Setting: A prospective study.

Patient Sample: We prospectively studied 114 patients undergoing instrumented posterior spinal fusion at one center between January

2011 and April 2011.

Outcome Measures: Total blood loss, visible blood loss and hidden blood loss.

Methods: For each patient the hidden blood loss was calculated by deducting the observed perioperative blood loss from the calculated total blood loss based on hematocrit changes. We compared the percentage of hidden blood loss out of total blood loss for primary vs revision posterior spine fusion.

Results: Primary decompression and posterior fusion patients had a mean total true loss of 1439 ml. Their calculated hidden loss was 600 ml, which is 42% of the total loss. Following revision posterior spinal fusion surgery, the mean total blood loss was 1606 ml. The mean visible loss was 975 ml, and the mean hidden loss was 631 ml, 39% of the total loss. Thus, there was no statistically difference in hidden blood loss between primary and revision posterior spinal fusion surgery ($P>0.05$). We did not find a significant difference in the percentage of the hidden blood loss between patients who underwent one, two or three or more level surgery.

Conclusions: Total blood loss after posterior spine fusion is much larger than what we observed perioperatively, and a substantial portion of it is due to hidden blood loss.

Poster 29. 24 Month Functional Outcomes From The US IDE Trial Evaluating The Stabilimax®, A Lumbar Posterior Dynamic Stabilization (PDS) System With Interpedicular Travel (IPT)

Neel Anand, MD; Antonio Castellvi, MD; Ken Yonemura, MD; Scott Kitchel, MD; Boyle Cheng, PhD; Bruce Robie, PhD

Rachiotek, LLC Wellesley, MA

Introduction: Pedicle screw based PDS systems are intended to offer stability and are used in conjunction with decompression to treat patients with degenerative lumbar stenosis. These devices offer patients a potential alternative to traditional decompression and fusion. This study reports 24 month clinical outcomes from an IDE trial for one-level symptomatic stenosis patients treated with the Stabilimax, a PDS system that featured greater than one mm of IPT.

Methods: Patients with leg/back pain due to degenerative spinal stenosis were enrolled in a prospective, randomized clinical trial. Decompressive surgery was performed at a single level. The operative levels included L3 to S1. Patients were evaluated preoperatively and at six weeks, 3, 6, 12, 18 and 24 months postoperatively. Primary outcomes were ZCQ-SS (Symptom Severity), ZCQ-PF (Physical Function), VAS-R (Right Leg Pain), VAS-L (Left Leg Pain). Secondary outcomes included the ODI. Statistical evaluation compared preoperative outcomes to postoperative outcomes, using a paired t Test. Device failures and reoperations are also reported.

Results: 60 consecutive cases (35 females, 25 males) with mean age of 59.4 years were enrolled at 19 sites. Surgery was most often performed at the L4-L5 level. There was a highly significant improvement in all outcome measures in comparison to pre-op ($p<0.001$). See Table 1. There were six patients who had fractured grit-blasted screws and grit-blasting was found to be the root cause as it diminished the fatigue life of the titanium alloy screws. There was one reoperation for a potential disassembly which was found to be intact.

Outcome	Pre-Op (mean±sd)	Last F/u (mean±sd)	p Value
ZCQ-SS	3.68±0.64	2.09±0.95	$p<0.001$
ZCQ-PF	2.61±0.55	1.64±0.65	$p<0.001$
VAS-L (symptomatic side)	71±21	17±29	$p<0.001$
ODI	48.3±15.8	14.1±13.5	$p<0.001$

Table 1. Results

Conclusions: The data shows a significant improvement in patient based outcomes at 24 months following decompression and placement of the Stabilimax, a PDS device designed with greater than one mm of IPT. The screw failures identified in this trial forced a stop to the trial before significant numbers of control patients could be enrolled, thus preventing a comparison to an accepted control. The positive results found in this patient cohort support the underlying PDS technology. Further study of the Stabilimax is warranted with comparisons to a control population to prove the benefit of the technology.

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

Poster 30. The Impact Of Pain Reduction Following Lumbar Spine Surgery: The Relationship Between Pain And Depression

Richard L. Skolasky; Lee H. Riley, III, MD; Anica M. Maggard, BS; Stephen T. Wegener, PhD

Johns Hopkins University, Orthopedic Surgery, Baltimore, MD

Objective: A prospective cohort study to characterize the relationship between pain and depressive symptoms after lumbar spine surgery.

Background: Depressive symptoms are common among those living with back pain. There is limited data on the relationship between reduction in pain following surgery and changes in depressive symptoms.

Methods: 260 individuals undergoing lumbar spine surgery were assessed preoperatively and postoperatively (3 and 6 months) using pain intensity numeric rating scale and Patient Health Questionnaire depression scale. Change in pain was defined as two points or 30% reduction from pre-operative level. The relationship between change in pain and in depressive symptoms was examined using standard regression methods.

Results: Pre-operatively, mean pain intensity was 5.2 (SD 2.4) points and mean depressive symptom score was 5.0 (SD 2.4) points. At three and six months, mean pain intensity was 3.3 (SD 2.1) points and 3.0 (SD 1.9) points, respectively, and mean depressive symptom score was 2.0 (SD 1.9) points and 2.5 (SD 1.8) points, respectively.

Individuals that experienced a reduction in pain at three months (63%) were no more likely to experience a reduction in depressive symptoms (odds ratio (OR) 1.07, 95% confidence interval (CI) 0.58, 1.98) compared to those individuals that experienced no change from pre-operative pain (34%). However, at six months, individuals that experienced a reduction in pain (63%) were nearly twice as likely to experience a reduction in depressive symptoms (OR 1.93, 95% CI 1.15, 3.25) compared to those individuals that experienced no change or increase in pain (31%).

Conclusions: A majority of individuals experienced clinically important reductions in pain following surgery. Individuals that experienced a reduction in pain intensity at six months were more likely to experience a reduction in depressive symptoms.

Poster 31. Vascular Injury and Exposure in Anterior Lumbar Interbody Fusions

Daniel Lubelski; Vladimir Zahradnik, MD; Kalil G. Abdullah; Vikram Kashyap, MD; Thomas E. Mroz, MD

Cleveland Clinic Lerner College of Medicine, Dept of Neurosurgery, Cleveland OH

Background and Context: ALIF is a common spine surgery procedure used to treat degenerative disease, trauma, and infection.

The potential advantage of an anterior approach to the spine is more extensive access to the vertebral body and interbody space as well as improved fusion rates. There are, however, increased risks associated with the mobilization of the vessels needed to expose the disc space. Retrospective studies have shown injury to the vasculature as high as 24%.

Methods: Retrospective analysis was performed on all patients who underwent ALIF between 2004 and 2010 at the Cleveland Clinic. The exposure was done either by the spine surgeon performing the operation or by an assisting vascular surgeon.

Results: Two hundred and sixty nine ALIF procedures were identified (159 with vascular exposure, 110 without). The average age at operation was 50.1 years, there were 146 females (54.3%), and average BMI was 29.0 in both groups. Previous spine surgery was seen in 145 (53.9%). The vascular exposure group included 114 cases at the L5-S1 vertebral level and the group without vascular exposure had 50 cases at L5-S1 ($p=0.0003$). No statistical difference between the groups was recorded for number of operations at the L4-L5 level. Blood loss in both groups was significantly greater at the L5-S1 level (1507.2 ml) than at the L4-5 level (819.6 ml). The rate of vascular complications in the vascular exposure group was 13.2% (21/159) and 8.2% (9/110) in the non-vascular exposure group (NS). However, the non-vascular exposure group had greater average operative time (404 min versus 290 min; $p=0.002$), mean blood loss (500ml versus 250 ml; $p<.001$), and length of stay (6.5 versus 5 days; $p<.001$).

Conclusions: This review demonstrates that a vascular surgeon was involved in the exposure for almost 60% of all ALIF operations, the majority of which involved exposure of the higher risk vertebral levels of L5-S1. While there were more vascular complications in the cases in which the vascular surgeons were involved, the cases carried more inherent risk due to the level of exposure. When vascular surgeons performed the exposure, there was less intraoperative blood loss, shorter operative time, and decreased length of hospital stay. All the injuries that did not involve the vascular surgeon were considered major complications and resulted in significant blood loss.

Poster 32. A comparison of Open versus MIS TLIFs in a Worker's Compensation Patient Population

Kern Singh, M.D.; Miguel Pelton, B.S.; Frank M. Phillips, M.D.

Rush University Medical Center, Orthopedic Surgery, Chicago, IL

Introduction: Few studies have analyzed outcomes in a worker's compensation (WC) population of MIS (Minimally Invasive Surgery) TLIFs (Transforaminal Lumbar Interbody Fusions). The objective of this study was to analyze intraoperative, immediate post-operative and financial outcomes in worker's compensation and non-worker's compensation patients undergoing either an open or MIS TLIF.

Methods: 66 consecutive patients undergoing a single-level TLIF (open/MIS) were analyzed (33 open, 33 MIS). From this series, 24 total workers compensation patients were identified (11 MIS, 13 open). Patients in either cohort (MIS/Open) were matched according to insurance status (WC) and medical co-morbidities (Charleston disability index). Every patient in this study had a diagnosis of either degenerative disc disease or spondylolisthesis and stenosis. Operative time (minutes), Length of stay (LOS, days), estimated blood loss (EBL, cc), anesthesia time (minutes), and hospital cost/payment amount were assessed. Statistical analysis was conducted using SPSS Statistics version 17.0 (MIS/open and Work-Comp versus Non-Work Comp).

Results: There were no statistically significant differences between MIS WC and non-WC TLIFs with respect to surgical time, LOS, EBL, and Anesthesia time (Table 1). There were no statistically significant differences between Open WC and non-WC TLIF patients in all of the same above-mentioned parameters. There were significant differences between MIS WC and Open WC TLIFs with regards to surgical time, LOS, anesthesia time, and EBL (Table 1). There were statistically significant differences in total costs amounts between

Table 1

	Workers Compensation	Workers Compensation		Non Workers Compensation	Workers Compensation	
Parameter	MIS (n=11)	Open (n=13)	p-value	MIS (n=22)	MIS (n=11)	p-value
Operative time (minutes)	116	184	0.0001	110	116	0.6268
Length of stay (LOS, days)	2	3	0.0106	2	2	0.9999
Estimated blood loss (EBL, cc)	127	254	0.0007	124	127	0.9172
Anesthesia time	178	338	0.0246	176	178	0.8630
Hospital Costs	\$28,060	\$33,862	0.0311	\$29,429	\$28,060	0.6471

WC MIS TLIF and WC Open TLIF groups (\$28,060 vs \$33,862 respectively; p=0.0311).

Discussion: Contrary to popular belief immediate outcomes and hospitalizations between non-WC and WC populations did not differ regardless of surgical technique (MIS/open). The only differences appeared in improved outcomes with an MIS TLIF versus an Open TLIF even in a WC environment. MIS TLIF WC patient hospital costs were lower than their open TLIF counterparts.

Conclusion: Minimally invasive TLIFs appear to provide intra- and peri-operative improvements as compared to open procedures even in a worker's compensation population.

Poster 33. A Peri-operative Cost And Charge Analysis Following Single Level Minimally Invasive Versus Open Transforaminal Lumbar Interbody

Miguel Pelton, B.S.; Kern Singh, M.D.; Frank M. Phillips, M.D.

Rush University Medical Center, Orthopedic Surgery, Chicago, IL

Introduction: Emerging literature suggests superior clinical short term and long term outcomes of MIS (Minimally Invasive Surgery) TLIFs (Transforaminal Lumbar Interbody Fusion) versus open fusions. The purpose of this study was to determine the differences in peri-operative clinical outcomes and hospitalization costs for patients treated with primary single- level minimally invasive (MIS) versus open transforaminal lumbar interbody fusion (TLIF).

Methods: 66 consecutive patients undergoing a single-level TLIF (open/MIS) were analyzed (33 open, 33 MIS). Patients in either cohort were matched based on race, sex, age, smoking status, medical co-morbidities (Charlson disability index), payor and diagnosis. Every patient in the study had a diagnosis of either degenerative disc disease or spondylolisthesis and stenosis. Operative time (minutes), Length of stay (LOS, days), estimated blood loss (EBL, cc), anesthesia time (minutes), and hospital cost/payment amounts were assessed. Statistical analysis was conducted using SPSS Statistics version 16.0.

Results: Average surgical time was shorter for the MIS than the Open TLIF group (113.5 minutes versus 186 minutes respectively; p=0.001) (Table 1). Length of stay was also shorter for the MIS group (2.0 days versus 2.9 days respectively; p < 0.001). Average anesthesia time was lower for the MIS group (177.8 minutes versus 258.6 minutes respectively; p < 0.001). Estimated blood loss was lower for the MIS group (127.4 mL versus 380.3 mL respectively; p < 0.001). There were lower total hospital costs in the MIS group. Hospital payments were \$9,093 higher for open TLIF patients (p=0.132) (Table 1).

Discussion: MIS TLIF technique demonstrated significant reductions of operative time, LOS, anesthesia time, and EBL compared

Table 2. Patient Demographics

	MIS (n=33) N (%), Mean +/- SD	Open (n=33) N (%), Mean +/- SD	Significance
Race			
White	23 (69.7%)	20 (60.6%)	0.863
Black/African American	4 (12.1%)	5 (15.2%)	
Hispanic/Latino	5 (15.2%)	6 (18.2%)	
Other	1 (3.0%)	2 (6.1%)	
Gender			
Male	23 (69.7%)	21 (63.6%)	0.397
Female	10 (30.3%)	12 (36.4%)	
Age at admission (years)	56.7 +/- 12.19	49.8 +/- 10.72	0.796
CCI	1.09 +/- .95	1.30 +/- 1.13	
Payor			
Commercial	17 (51.5%)	16 (48.5%)	0.980
Worker's Comp	12 (36.4%)	13 (39.4%)	
Medicare	4 (12.1%)	4 (12.1%)	
Smoker			
No	24 (72.7%)	21 (63.6%)	0.431
Yes	9 (27.3%)	12 (36.4%)	
Diagnosis			
DDD	13 (39.4%)	14 (42.4%)	0.586
Spondylolisthesis	20 (60.6%)	19 (57.6%)	
Length of Stay	2.0 +/- 0.8	2.9 +/- 1.4	P = 0.001
Surgical Time (min)	113.5 +/- 28.6	186.0 +/- 31	P < 0.001
Anesthesia Time (min)	177.8 +/- 29.5	258.6 +/- 53	P < 0.001
Estimated Blood Loss (mL)	127.4 +/- 91.1	380.3 +/- 191.2	P < 0.001
Hospital Direct Costs +	\$10,224 +/- \$5,001	\$13,550 +/- \$3,501	P < 0.001
Direct Cost (imaging)	\$142 +/- \$26	\$180 +/- \$98	P = 0.023
Direct Cost (implant)*	\$13,714 +/- \$4,124	\$13,778 +/- \$3,180	P = 0.812
Direct Cost (Surgical Services)	\$3,606 +/- \$992	\$6,894 +/- \$1,535	P < 0.001
Total Cost (Direct-Indirect)	\$27,321 +/- \$7,154	\$33,312 +/- \$4,773	P < 0.001

+ Includes direct cost for blood, imaging, implant, lab, pharmacy, PT/OT, speech, room and board.
* not statistically significant

to the open technique. These reductions translated into lower total hospital costs.

Conclusion: Although hospital reimbursements appear higher in the open group over the MIS group, shorter surgical times and length of stay days in the MIS technique provide opportunities for hospitals to reduce utilization of resources and to increase surgical case volume.

Poster 34. Return To Golf After Spine Surgery

Dennis Crandall, MD; David Swanson, MD; Jan Revella, RN; Jason Datta, MD; Michael Chang, MD; Terrence Crowder, MD; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: With 9.6% of US population (29 million; 22% female) golfing on 17,000 golf courses in a \$60 billion industry, golf is important. Golfers want to return to the sport after surgery. There are no studies to provide a basis for expectations. This study evaluates the ability to return to golf, pain experienced and skill level achieved after various types of spine surgery.

Methods: We prospectively collected clinical, radiographic and golf data on 23 consecutive amateur golfers (13M, 10F) undergoing spine surgery for degenerative disease (17) or deformity (6). Age: 61yrs (21-75). Surgery types: Short fusion (SF) 1-3 levels-12pts, Long fusion (LF) 4-10 levels-9pts, multilevel laminectomy- 2pts. Excluded: patients requiring simple discectomy, tumor, level-Itrauma. Clinical (Visual Analog pain Scores (VAS), Oswestry, pain meds), radiographic, golf outcomes (effect of surgery on golf frequency, handicap, VAS before/during/after playing) collected preop, 1yr, 2 yrs.

Results: Followup averaged 50 months (24-108 mos). Complications: Infection-1, adjacent fracture-1, additional surgery (lami/fusion)-3. Clinical and golf related outcomes improved (P<0.01). Preop VAS-5.6 (SF-5.4, LF-5.8, Lami-5.5), VAS while golfing-5.9 (SF-5.8, LF-6.4, Lami-4.5), after golf-7.1 (SF-7.3, LF-6.9, Lami-7.0); At 2 YEARS VAS-2.8 (SF-2.3, LF-3.6, Lami-3.0), VAS while golfing-3.3 (SF-2.8, LF-4.0, Lami-3.5), after golf-4.5 (SF-4.0, LF-5.0, Lami-5.5). Oswestry: preop-39.9 (SF-37, LF-46, Lami-31), 1yr-16.4, 2yr-19.9. Frequency of golf play per year remained similar: pre-58.9, 2yrs-55.7. Handicaps

remained similar:pre-21.8(SF-22.3,LF-22.6,Lami-16), 2yrs-22.3(SF-23.5,LF-23.3,Lami-12). Transporting clubs during play by Golf Cart/Pull Cart/Carry Clubs:pre-17/4/2, 2yrs-19/1/1. Only 2/23 (SF-1/12, LF-1/9) did not return to golf postop, and 9/23 decreased frequency of golf postop. For those decreasing or quitting golf postop (N=11 total), reasons: pain-4, time-3, money-2, interest-1, other-1.

Discussion: Amateur golfers who undergo spinal surgery (multilevel laminectomy, short fusion, or long fusion for deformity) can reliably and successfully return to golf postop. Pain immediately after playing increased with time, but was still significantly better than preop. Frequency of play declined slightly after surgery, mostly for reasons unrelated to pain. Skill defined by handicaps remained similar.

Conclusions: Recreational golfers who require spinal surgery, even LF for deformity, should be encouraged to return to the sport if desired. Similar skill levels to preop can be expected.

Poster 35. The Effect Of Low Dose Bone Morphogenic Protein (rhbmp-2) On Posterolateral Fusion In Adult Spinal Deformity Surgery

Justin B. Hohl, MD; Michael D. Daubs, MD; Jayme R. Hiratzka, MD; Prokopis Annis, MD; Brandon D. Lawrence, MD; Darrel S. Brodke, MD

University of Utah, Salt Lake City, UT

Introduction. Bone morphogenic protein-2 (BMP) has been used in adult spinal deformity surgery to increase fusion rates, but the limitations of using BMP include high cost and increasing awareness of potential risks. The reported dosages range from 10 to 20mg per fusion level, but the minimum dosage needed for successful fusion is not known. The purpose of this study was to evaluate the efficacy of lower dose BMP in adult spinal deformity surgery.

Methods. A retrospective review was performed on 62 patients, mean age of 60.5 years (range: 21-81), 48 females and 14 males, with a minimum follow-up of 24 months (range: 24-56 months), who underwent a posterolateral fusion of at least 5 levels (mean 10, range 5-17), for adult deformity. BMP-2 soaked collagen sponges were placed posterolaterally along the length of the fusion. A mean of 1.78 mg of BMP-2 was used per level (range: 1.2-4.8 mg). Fresh-frozen cancellous allograft was used routinely along with local autograft when available. No iliac crest bone graft was harvested. Fusion success was graded using the Bridwell criteria utilizing standing PA and lateral 36 inch radiographs. ODI and VAS outcomes were recorded preoperatively and at last follow-up.

Results. The successful fusion rate by Bridwell criteria was 87% (54/62). Eight patients (13%) underwent revision for symptomatic nonunion. Patients with nonunion had less improvement in VAS back pain (p=.005) and a trend towards less improvement in ODI (p=.056). Patients with nonunion had less BMP per level but the result was not statistically significant (1.31 verse 1.85 mg) (p=.092). Nineteen patients (31%) had implant failure, defined as a broken rod, broken screw, or halo around screw. Patients who had implant failure had less BMP per level (1.28 versus 2.0 mg) (p=.003) and more levels fused (11.4 verse 9.4) (p=.038).

Conclusions. Low dose BMP-2 used for posterolateral fusion in adult spinal deformity surgery appears to be effective at 2 year follow-up with a fusion rate of 87%. Patients with nonunion had less improvement in VAS back pain scores, and a trend toward lower function.

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

Poster 36. A Retrospective Study of the Multiply Operated Back due to Lumbar Spinal Stenosis

Norifumi Suga

Hiroshima City Asa Hospital, Hiroshima, Japan

Introduction: Posterior decompression for lumbar spinal stenosis (LSS) has been developed into minimally invasive surgery (MIS) under microscopy or endoscopy. MIS without spinal fusion can provide successful outcomes, but the indication for multi-level stenosis and unstable spine has been controversial. The purpose of this study was to elucidate the limitation of decompression alone as a MIS based on the treatment for multiple operative LSS.

Methods: In this study 1194 patients who had undergone decompression alone under microscopy at the single level (249 patients at L3/4, 945 patients at L4/5 level) between 2001 and 2010 were included. Among them, 71 patients (5.9%) required second operation due to symptom recurrence. Despite the listhesis or instability, we performed decompression alone at the initial operation. The decompressed level, the radiological findings and the symptoms of these 71 patients were investigated retrospectively.

Results: The initial decompression level was L3/4 in 21 patients and L4/5 in 50 patients. The mean interval until the second operation was 3.3 years (3 months to 12 years). At the second operation, decompression alone was performed in all patients. In the 71 patients, 6 patients (8.5%) (L3/4: 3 patients, L4/5: 3 patients) required the same level decompression as the initial operation and the other 65 patients (91.5%) did other level decompression. The latter already had stenosis at the level which required the second surgery before the initial operation, but at that time, the required decompression level was not able to be correctly diagnosed from the neurological findings and efficacy of the selective nerve root block.

Conclusions: Limitation of decompression alone as a MIS has been pointed out, and it is a well-known fact that image findings such as multi-level stenosis and spinal instability do not correlate with the clinical symptoms. How to treat for multi-level LSS and LSS with the listhesis has therefore been controversial. We have performed decompression alone under microscopy for LSS despite the listhesis, which experience revealed that decompression alone preserving the facet joints could be effective for almost all types of LSS. As long as MIS preserving the facet joints is performed, ultimate surgical results are acceptable.

Poster 37. Biomechanical Assessment of Anterior Thoracolumbar Fixation: A Comparison of the Significance of Cross Connectors in a Calf Model

Martin Gehrchen, M.D., Ph.D.; Sajan K. Hegde, M.D.; Mark Moldavsky; Suresh Chinthukunta, M.S.; Manasa Gudipally, M.S.; Brandon Bucklen, Ph.D.; Saif Khalil, Ph.D.

Globus Medical Inc., Research and Development, Audubon, PA

Introduction: Dual rod anterior thoracolumbar plates (ATLP) are used clinically for stabilizing the spine after a corpectomy. Corpectomies are performed for tumor resection, burst fractures and sometimes deformities. Dual rod systems shows favorable clinical outcomes and can be supplemented with additional fixation.¹ The present study evaluates the effect of cross connectors on the Range of Motion (ROM) of thoracolumbar calf specimens.

Methods: Seven defrosted thoracolumbar calf specimens prepared from T12 to L3 were tested in a six degree of freedom machine. A load control protocol of 7.5 Nm at a rate of 1.5 o/sec was applied in flexion-extension, lateral bending, and axial rotation. A total vertebral body corpectomy was performed at L1 and the ATLP was placed from T13-L2. An expandable vertebral body replacement was positioned in-between the T13 and L2 vertebral bodies. Testing

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

was performed in the following sequence 1) Intact; 2) ATLP with 2 Cross Connectors (ATLP + 2 CC); 3) ATLP with 1 Cross Connectors (ATLP + 1 CC) and; 4) ATLP. ROM's were measured from T13 and L2. A repeated measures ANOVA followed by a Tukeys post hoc test ($p \leq 0.05$) was performed.

Results: ATLP + 2 CC and ATLP + 1 CC reduced ROM relative to intact, with significance, in flexion-extension and lateral bending. ATLP reduced ROM relative to intact in flexion-extension and lateral bending but with significance only in lateral bending. All three constructs increased ROM significantly relative to intact in axial rotation. The sequential addition of cross connectors reduced motion in all loading modes. (Figure 1).

Discussion: The addition of a cross connectors assist in stabilizing the junction and restoring ROM closer to intact. This could be of benefit in the case of a lumbar corpectomy where there is no support from the rib cage. Additional instrumentation may be used to further reduce motion. A limitation of the study is that calf vertebral bodies are larger than that of humans resulting in an increased ATLP distance.

Conclusion: Instrumentation after a corpectomy results in motion above intact in axial rotation and below intact in flexion extension and lateral bending. Addition of cross connectors reduces ROM in all loading modes.

Reference 1. Park JK, Kim KS: Follow-up Comparison of Two Different Types of Anterior Thoracolumbar Instrumentations in Trauma Cases : Z-plate vs. Kaneda Device. *J Korean Neurosurg Soc* 41:11-81, 2007

Poster 38. The Accuracy of Intraoperative 3D image guided Percutaneous Pedicle Screw Insertion

Edward Rainier G. Santos, MD; Jonathan N. Sembrano, MD; Charles Gerald T. Ledonio, MD; Sharon C. Yson, MD; A. Noelle Larson, MD; David W. Polly, Jr., MD

University of Minnesota, Orthopedics, Minneapolis, MN

Introduction. Minimally invasive techniques of pedicle screw instrumentation have been introduced that have the advantage of minimizing soft tissue injury, resulting in faster postoperative rehabilitation. However, the limited visualization of normal landmarks can give rise to higher malposition rates. The advent of image-guidance using fluoroscopy or preoperative CT scans has improved accuracy rates for pedicle screw placement both for open and percutaneous techniques. Intraoperative CT images acquire images in real-time, and can be

used in conjunction with computer navigation.

The objective of this study was to determine the accuracy and safety of intraoperative 3D-image guided percutaneous insertion of pedicle screws in the thoracic and lumbosacral spine in a consecutive series of patients.

Methods. Between April 2007 and September 2010, 166 pedicle screws were placed percutaneously using intraoperative 3D image guidance in 33 consecutive patients. Mean age was 53.5 years (13 to 87 years). There were 10 male and 23 female patients. Diagnosis included degenerative disc disease (24), lumbar stenosis (8), degenerative spondylolisthesis (4), isthmic spondylolisthesis (3), and degenerative scoliosis (2). Intraoperative 3D imaging was performed using the O-arm and the images were registered onto the computerized navigation system (Stealth). K-wires were placed using a navigated Jamshidi needle and K-wire position was then imaged. If the K-wire position was satisfactory, cannulated screws were placed. Imaging of the final screw position was then performed. The incidence of K-wire and screw revision based on intra-operative imaging was the primary outcome measure.

Results: A total of 166 pedicle screws were placed. Based on intraoperative imaging, a total of 9 (4.8%) K-wires were revised (8 redirected and 1 removed). No screws (0%) were revised, indicating a 100% screw placement accuracy rate. Reoperation rate was 0%. There were no major neurovascular complications.

Discussion: The technique of screw insertion described results in the accurate and safe placement of screws. Other advantages with this technique include relative preservation of the extensor musculature, less facet joint impingement, and optimization of the screw length, diameter and trajectory.

Conclusion: We report a 95.2% K-wire placement and 100% screw placement accuracy rate using intraoperative 3D image guidance for percutaneous pedicle screw insertion.

Poster 39. A Prospective Evaluation of Minimally Disruptive Lateral Interbody Fusion in the Treatment of Degenerative Spondylolisthesis: Mid-term Clinical and Radiographic Outcomes

Kaveh Khajavi; Alessandria Y. Shen, BA; Anthony L. Hutchison, MSN

Georgia Spine and Neurosurgery Center, Decatur, GA

Introduction: Modern minimally-disruptive lumbar interbody fusion (IBF) techniques minimize the morbidity of conventional surgical approaches. However, long-term outcomes are less well understood. This study's aim is to examine mid-term clinical outcomes following a minimally disruptive, 90° lateral, transpoas approach for IBF in degenerative spondylolisthesis patients.

Methods: 60 consecutive patients treated with extreme lateral interbody fusion (XLIF) for Grade I or II degenerative spondylolisthesis were followed in an IRB-approved, prospective registry (ProSTOS, PhDx) at a single institution in Atlanta, GA. Mean patient age was 65 years, 75% were female and 30% had undergone previous lumbar surgery. Supplemental posterior fixation was used in 57 (95%) cases and 26 (43%) patients underwent direct posterior decompression. Standard outcome and radiographic measurements were measured.

Results: Average follow-up was 13.5 months. Average ORT, EBL, and LOS were 206 minutes, 83cc, and 1.29 days, respectively. Complications occurred in three (5%) patients: one MI, one urinary retention, and one delayed mild dorsiflexion weakness which completely resolved by 3 months. Transient approach-related thigh/groin pain was observed in five (8%) cases, all resolved by 3 months. At one year, LBP and LP improved 73% (8.0 to 2.2) and 68% (7.7 to 2.5), respectively ($p < 0.001$), ODI decreased 52% from 42% to 20% ($p < 0.001$), SF-36 PCS and MCS improved 43% (31.2 to 44.6, $p < 0.001$) and 21% (43.2 to 52.1, $p = 0.003$), respectively. There were no cases of pseudoarthrosis. At last follow-up, disc height, foraminal

height, foraminal width, and foraminal volume increased 71%, 19.7%, 18.0%, and 39.6%, respectively. Segmental lordosis increased 27.8% from 25.9° to 33.1° at treated levels. Average preoperative slip was 8.1mm (20.3% of endplate), and improved 60.7% to 3.2mm (7.9% of endplate) with XLIF only, and further improved to 2.5mm (69.2% correction, 6.5% of endplate) after the placement of supplemental instrumentation in most patients.

Conclusions: MIS lateral IBF resulted in a hastened postoperative recovery with a low complication rate and high clinical efficacy on pain, disability and QOL measures, compared to conventional approaches. Radiographic measures were significantly improved following XLIF and maintained over mid-term follow-up. XLIF appears to be a safe and effective treatment option for patients with degenerative spondylolisthesis.

• The FDA has not cleared this drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an “off label” use). See inside back cover for full information.

Poster 40. Anterior Lumbar Interbody Fusion: The Use Of Ct In The Postoperative Patient And Guidelines On The Appropriate Time For Follow Up Imaging

Sima Banerjee, MD; Tharwat El-zahran, MD; John G. Heller, MD; Claude Pierre-Jerome, MD; Walt Carpenter, MD; Scott Boden, MD; Jian Kang; Michael R. Terk, MD; Ali Zahrai; Joe W. Chiles; Daniel Refai

Emory University, Atlanta, GA

Introduction: Debilitating lumbar disc degeneration and other diagnoses may be treated effectively with anterior interbody fusion (ALIF). ALIF allows effective access to the pathology while sparing the posterior muscles & ligaments. Previous studies have supported the effectiveness of stand-alone ALIF without posterior instrumentation, demonstrating equivalent fusion rates and patient satisfaction. Evaluating interbody fusions is problematic utilizing flexion/extension radiographs. Reformatted CT images of ALIF fusion status has become more widespread, but has not been extensively studied. The aim of this study is to develop criteria for determining bony fusion on CT scans after ALIF, to quantify the progression of fusion over time, and to suggest optimal time intervals for post operative CT imaging.

Methods: Twenty seven consecutive ALIF patients were identified; 18 males, 9 females; mean age, 46.3 years. Twenty-two patients were operated at a single level and five patients were operated at two levels. Among the 27 patients, seventeen were followed up with a CT spine examination between 1 and 6 months and greater than 6 months post surgery. The CT images were assessed separately for the presence of new bone formation in three zones. We used our criteria for bony fusion which are: there must be bony bridging in the centre of

the cage plus one of the two lateral zones. Complications such as endplate resorption, and cage migration were also assessed. All images were independently assessed by Bone Radiologists.

Results: Four patients out of 22 single-level ALIF patients demonstrated fusion before 6 months. At greater than 6 months, 11 of the 13 single-level ALIF patients showed fusion and all 4 of the two-level ALIF patients showed fusion. Using the Fischer exact method we found a statistically significant increase in interbody fusion between 1-6 months and >6 months to 1 year with p value = 0.003.

Conclusions:

This study describes reproducible CT criteria for assessing interbody fusion by CT after ALIF. There is a statistical significant difference in fusion seen on CT at less than 6 months and greater than 6 months to 1 year. Therefore, the most appropriate time to assess such a fusion would be between 6 and 12 months. CT imaging earlier than this would not be expected to demonstrate definitive fusion and could result in additional radiation dose to the patient.

Poster 41. Can Annular Reconstruction Reduce the Incidence of and Re-operations for Recurrent Herniated Nucleus Pulposus?

Jeffrey D. Coe; Jianghui Zhang, MD

Silicon Valley Spine Institute, Campbell, CA

Introduction: Annular reconstruction (AR) with the Xclose (and more recently the Versaclose system has been introduced for the repair of annular defects after lumbar microdiscectomy surgery (LMS) for lumbar disc herniation (LDH), ostensibly for the prevention of recurrent lumbar disc herniation (RLDH). Limited intermediate to long term data, however, has been available to establish efficacy of the primary goal of reducing RLDH as well as the safety of the

technique. The purpose of this study is to report the authors' experience with AR in LMS for LDH.

Methods: From in 2008 until January 2012, the senior author (JDC) performed AR in all LDH patients undergoing LMS in which AR was deemed to be technically feasible. All patients undergoing surgery for LDH during this period of time that had a minimum follow-up of 6 months were included in this study. A retrospective chart review was performed to analyze for RLDH and re-operation for RLDH in the AR group and the non-reconstruction (NR) groups. Complications associated with the use of AR were tabulated.

Results: A total of 88 patients underwent LMS during this period of time, of which 68 patients (77.3%) met the inclusion criteria for this study: 14 (20.6%) in the AR group and 54 (79.4%) in the NR group. Mean follow-up was 18.3 months (range 6-45 months). One of the 14 AR patients (7.1%) experienced RLDH and 7 of the 54 NR patients (12.9%) experienced RLDH. This difference was not statistically significant, however. Five of the 8 patients (62.5%) with RLDH underwent revision surgery, at a mean of 6.4 months after the index LMS. No complications were identified that were associated with the performance of AR.

Conclusions: AR appears to be an attractive option for the prevention of RLDH after LMS for LDH. The technique appears to be safe on the basis of this study, but its efficacy can not be established on the basis of this study. Moreover, only one-fifth of LDH patients undergoing LMS were felt to be candidates for AR. Larger studies with longer follow-up will likely be required to establish the efficacy of AR in LMS for the prevention of RLDH.

Median [IQR] length of hospitalization and time to return to work were both less for MIS vs. open TLIF: 3 [2-4] days vs. 4 [3-5] days, $p=0.006$ and 7 [4-11] weeks vs. 11 [9-16] weeks; $p=0.03$, respectively. MIS vs. open TLIF patients demonstrated similar 3-month and 2-year improvement in all PRO measures assessed, Figure 1A. MIS vs. open TLIF was associated with an \$8,474 reduction in mean indirect cost ($p=0.06$), but similar 2-year direct healthcare cost, Figure 1B. MIS vs. open TLIF was associated with a reduced total two-year societal cost: $\$38,563 \pm 10,594$ vs. $\$47,858 \pm 20,148$ ($p=0.03$) with a similar QALY-gained: 0.771 vs. 0.695 ($p=0.343$), Figure 1C.

Conclusions: MIS TLIF resulted in reduced operative blood loss, reduced hospital stay, accelerated return to work, and reduced two-year cost. Surgical morbidity, hospital re-admission, and short- and long-term clinical effectiveness were similar for MIS and open TLIF. Both MIS and open TLIF are effective treatments for degenerative spondylolisthesis. MIS TLIF may represent a valuable and cost saving advancement.

Paper Abstracts

Paper 1. Minimally Invasive versus Open Transforaminal Lumbar Interbody Fusion (TLIF) for Degenerative Spondylolisthesis: Comparative Effectiveness and Cost-utility Analysis

Scott L. Parker, M.D.; Stephen K. Mendenhall, B.S.; David N. Shau, B.S.; Scott L. Zuckerman, B.S.; Matthew J. McGirt, M.D.

Vanderbilt University Medical Center, Dept of Neurosurgery, Nashville, TN

Introduction: Minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) for spondylolisthesis allows for surgical treatment of back and leg pain while theoretically minimizing tissue injury and accelerating overall recovery. Although prior results have consistently shown shorter hospital stays and decreased intraoperative blood loss for MIS vs. open TLIF, short- and long-term outcomes have been similar. The effect of MIS vs. open TLIF on comprehensive healthcare cost is poorly understood. We performed a two-year prospective comparative effectiveness and cost-utility study for MIS vs. open TLIF.

Methods: 100 patients (50 MIS, 50 open) undergoing TLIF for degenerative lumbar spondylolisthesis-associated back and leg pain were entered into an institutional registry and prospectively followed. Baseline, 3-month, and 2-year patient-reported outcomes (PRO) were prospectively assessed via phone interviews. Total back-related medical resource utilization, missed work, and health-state values (quality adjusted life years (QALYs) were assessed by patient interview. Two-year resource use was multiplied by unit costs based on Medicare national allowable payment amounts and work-day losses were multiplied by the self-reported gross-of-tax wage rate (indirect cost). Difference in mean total cost per QALY gained for MIS- versus open-TLIF was assessed as incremental cost-effectiveness ratio (ICER: 2-year costMIS-2-year costOPEN/QALY gainedMIS-QALY gainedOPEN).

Results: MIS vs. open TLIF cohorts were similar at baseline.

Paper 2. Single Versus Multilevel Fusion, For Single Level Degenerative Spondylolisthesis And Multilevel Lumbar Stenosis. Four-Year Results of the Spine Patient Outcomes Research Trial

Yossi Smorgick, MD; Jeffrey S. Fischgrund, MD; Daniel Park, MD; Kevin Baker, PhD; Jon D. Lurie, MD, MS; Wenyan Zhao, PhD; Harry Herkowitz, MD; James N. Weinstein, DO, MS

William Beaumont Hospital, Dept of Orthopedic Surgery, Royal Oak, MI

Study design. A subanalysis study.

Objective. To compare surgical outcomes and complications of multi-level decompression and single level fusion to multi-level decompression and multi-level fusion for patients with multilevel lumbar stenosis and single level degenerative spondylolisthesis.

Summary of Background Data. In patients with degenerative spondylolisthesis who are treated surgically, decompression and fusion provides a better clinical outcome than decompression alone. Surgical treatment for multilevel lumbar stenosis and degenerative spondylolisthesis typically includes decompression and fusion of the spondylolisthesis segment and decompression with or without fusion for the other stenotic segments. To date, no study has compared the results of these two surgical options for single level degenerative spondylolisthesis with multilevel stenosis.

Methods. The results from a multicenter randomized and observational study, the Spine Patient Outcomes Research Trial (SPORT) comparing multilevel decompression and single level fusion and multi-level decompression and multi-level fusion for spinal stenosis with spondylolisthesis, were analyzed. The primary outcomes measures were the Bodily Pain and Physical Function scales of the Medical Outcomes Study 36-item Short-Form General Health Survey (SF-36) and the modified Oswestry Disability Index at 1,2,3

and 4 years postoperatively. Secondary analysis consisted of stenosis bothersomeness index, low back pain bothersomeness, leg pain, patient satisfaction, and self-rated progress.

Results. Overall 207 patients were enrolled to the study, 130 had multilevel decompression with one level fusion and 77 patients had multi-level decompression and multi-level fusion. For all primary and secondary outcome measures, there were no statistically significant differences in surgical outcomes between the two surgical techniques. However, operative time and intraoperative blood loss were significantly higher in the multilevel fusion group.

Conclusion. Decompression and single level fusion and decompression and multi-level fusion provide similar outcomes in patients with multilevel lumbar stenosis and single level degenerative spondylolisthesis.

Paper 3. Long-Term Re-operation Rates With Surgical Treatment of Lumbar Spondylolisthesis

Abdul Baker, MD; Beatrice Ugiliweneza, PhD,MSPH; Chirag Patil, MD,MS; Shivanand Lad, MD, PhD Lad, MD, PhD; Maxwell Boakye, MD,MPH

University of Louisville, Neurosurgery, Louisville, KY

Background: Surgery remains mainstay for management of lumbar degenerative spondylolisthesis and is considered superior to non-operative management. Procedures were categorized as decompression, decompression with instrumented fusion or decompression with non-instrumented fusion. The goal of the current study was to examine long-term re-operation rates for patients undergoing laminectomy with or without instrumented fusion for the treatment lumbar spondylolisthesis.

Methods: Reuter's MarketScan database was utilized to identify 16,556 patients with a primary diagnosis of lumbar degenerative spondylolisthesis who underwent surgical treatment between 2000-2009. Of these, a total of 6,507 had at least two years of pre-operative enrollment without a prior fusion surgery and two years post-operative continuous enrollment. Post-operative risk of re-operation and complications were analyzed with logistic regression and Cox-regression models for each of the surgeries. Hospital days, healthcare resources charges and utilization of outpatient services were also analyzed.

Results: The study cohort consisted of 738 (11%) patients who underwent laminectomy alone and 5,769 (89%) who underwent a fusion procedure (5,082 [88%] instrumented and 687 [12%] non-instrumented). Overall long-term reoperation rate at over 2 years were significantly lower for those who underwent initial fusion 11.84% compared to laminectomy alone 15.58% with a p value of 0.003. The complication rates among 16,556 patients during the initial procedure hospitalization (4.76%, 8.29%), 30 days post operatively (5.41%, 9.60) and at 90 days postoperatively (5.52%, 9.64%) were significantly higher in the fusion cohort compared to the laminectomy group. There were 1,136 patients with at least five years of follow-up, 164 (15%) underwent decompression and 972 (85%) underwent decompression with fusion. Among this group, over five year reoperation rate was 17.07% in the laminectomy group and 16.87% in the fusion group with no statistical significance and p value of 0.94. In the subgroup analysis of instrumented versus uninstrumented fusion, the 2 year cohort reoperation rate was 12.14% and 9.61% in instrumented and uninstrumented group respectively with a p value of 0.053. The five year sub group analysis revealed 17.85% and 11.19% reoperation rate among instrumented and uninstrumented fusion respectively with a p value of 0.04 which is statistically significant.

Conclusion: Patients with lumbar degenerative spondylolisthesis undergoing spinal fusions with or without instrumentation had significantly lower re-operation rates than laminectomy alone in patients with at least 2 years of follow up. Uninstrumented fusion appears to have lower reoperation rate than the instrumented lumbar fusion among 1,136 patients with at least five years of follow-up.

Paper 4. Complications Following Use Of rhBMP-2 In Anterior Lumbar Interbody Fusion

Daniel Lubelski; Kalil G. Abdullah; Amy S. Nowacki, PhD; Matthew D. Alvin; Michael P. Steinmetz, MD; Edward C. Benzel, MD; Thomas E. Mroz, MD

Cleveland Clinic Lerner College of Medicine, Dept of Neurosurgery, Cleveland OH

Background. rhBMP-2 has been used increasingly in spinal fusions. While initial studies extolled the product's improvement of patients' outcomes, recent investigations have revealed increased rates of urological complications, as well as wound infection, pseudoarthrosis, and reoperation, relative to the standard ALIF procedure.

Materials and Methods. We retrospectively reviewed the medical records of all patients who underwent ALIF with and without rhBMP-2 between January 2002 and August 2010. Patient demographic, operative, and complication information was analyzed.

Results. Of the 267 included ALIF patients, there were 144 with rhBMP-2 and 123 without rhBMP-2 that served as the control cohort. The mean follow-up was 20.2 months for the rhBMP-2 group and 32.5 months for the control group. In a sub-analysis of male patients, no difference was found regarding the number of urological complications in the rhBMP-2 group versus the control group (10% versus 6%, respectively; $p=0.5$). Only one case of retrograde ejaculation was identified in the rhBMP-2 group; none were found in the control group. The rates of pseudoarthrosis, radiculitis, and reoperation were significantly higher in the rhBMP-2 group relative to the control (17% vs. 5%, 23% vs. 2%, and 22% vs. 5%, respectively).

Conclusions. The use of rhBMP-2 with ALIF surgery, in this study, was not associated with an increased incidence of urological complications and retrograde ejaculation. The higher rate of pseudoarthrosis, radiculitis, and reoperation confirm previous reports and should be considered by patients and surgeons before proceeding to operations with rhBMP-2.

Paper 5. Retrograde Ejaculation Following Single-Level Anterior Lumbar Surgery with or without rhBMP-2 in Five Randomized Controlled Trials

J. Kenneth Burkus, MD; Randall F. Dryer, MD; John H. Peloza, MD

The Hughston Clinic, Columbus, GA

Introduction: Risk factors for retrograde ejaculation (RE) in men treated for degenerative lumbar disc disease with anterior interbody implants with or without recombinant human bone morphogenetic protein-2 (rhBMP-2) are controversial.

Methods: Patients in 5 randomized multicenter studies were followed for a minimum of 2 years. Of 508 men with lumbar disc disease undergoing anterior interbody fusion at L4L5 or L5S1, 207 were treated with fusion cages and rhBMP-2. The control groups (n = 301) were treated with fusion cages and iliac crest autograft or a metal-on-metal disc arthroplasty device. Multivariate analyses of RE were performed to assess the influence of treatment (rhBMP-2), surgical approach, and treated level.

Results: RE occurred at the highest rates in the earliest clinical trial. Six (4.1%) of 146 men developed RE. In the other studies, the rates of RE ranged from 0% to 2.1 %. In the combined data from the 5 trials, RE was reported in 7 (3.4%) of 207 patients who received the rhBMP-2 treatment compared with 5 (1.7%) of 301 patients who received the control treatment ($P = 0.242$, Fisher's exact test). RE occurred in 7 (1.6%) of 445 patients with a retroperitoneal spinal exposure; RE occurred in 5 of 58 patients (8.6%) with a transperitoneal approach. This difference was significant ($P = 0.007$, Fisher's exact test). There was no difference in RE rates based on treated level ($P = 0.739$). Multivariate analyses were consistent with the conclu-

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

sions from Fisher's exact tests; after adjusting for effects of surgical approach and treated level, the difference in RE between the treatment groups (rhBMP-2 versus controls) was not significant; however, the difference between the surgical approaches was significant.

Conclusions: We sought to determine the role of rhBMP-2 in RE. Data were collected from surgeons who performed the procedures without practice cases. The first trial had the highest rate, but subsequent trials showed reduced rates. This trend may, in part, be related to experience with the approach. RhBMP-2 was associated with a higher incidence of RE but did not reach statistical significance. Based upon surgical approach, the difference in RE rates was statistically significant.

Paper 6. Anterior Lumbar Interbody Fusion With Recombinant Human Bone Morphogenetic Protein-2 And Retrograde Ejaculation: Results From A Non-industry Sponsored, Single Surgical Team

Alexander Ghanayem, MD; John Santaniello, MD

Loyola University, Orthopaedic Surgery, Maywood, IL

Introduction. Retrograde ejaculation is a known complication of anterior surgery in the lumbar spine. Concerns have been raised over the variable risk of retrograde ejaculation with respect to the use of recombinant human bone morphogenetic protein-2 (rhBMP-2), in studies with and without a financial relationship with the manufacturer of this product. The aim of this study is to evaluate the rate of retrograde ejaculation in a cohort of patients undergoing anterior lumbar interbody fusion with rhBMP-2 performed by a single surgical team, without financial relationship with the manufacturer of this product. Special attention will also be placed on technical issues in our surgical technique.

Methods. All male patients who underwent an anterior lumbar interbody fusion, using a retroperitoneal exposure, by the two authors from May 2004 to June 2011 were identified after IRB approval. Patients were excluded if rhBMP-2 was not used, or if the surgical level did not include L4-5 or L5-S1. The risk of retrograde ejaculation was reviewed preoperatively in with all patients and incidence recorded postoperatively, along with disposition of this complication at final follow-up.

Results. One hundred and fifty two patients were identified. Three patients were excluded because the surgical level was isolated to L3-4, and one excluded because rhBMP-2 was not used. Of the remaining 148 patients, 4 had preoperative erectile dysfunction that mitigated the issue of retrograde ejaculation with their dysfunction unaffected by our intervention. Two remaining patients, ages 67 and 78, had no interest in discussing the retrograde ejaculation preoperatively and out of respect to their wishes, was not discussed post-surgery. One patient was excluded because the retroperitoneal exposure was abandoned. Of the remaining 141 patients, there were 2 cases of retrograde ejaculation of which 1 did not recover giving an incidence of 0.7%.

Conclusion. These findings indicate that the use of rhBMP-2 in the anterior lumbar interbody region can be used safely with respect to the incidence retrograde ejaculation with a rate that does not exceed that found in patients undergoing similar surgery without rhBMP-2. Given that the authors have no financial relationship with the manufacturer of rhBMP-2, the variability of retrograde ejaculation in studies utilizing rhBMP-2 may be related to technical considerations rather than just the presence or absence of industry relationships.

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

Paper 7. Recurrent Stenosis Following Transforaminal Interbody Fusion (TLIF) Using Bioresorbable Cages and Bone Morphogenic Protein

Jeffrey D. Coe, MD; Michael W. Cluck, MD, PhD; Jianghui Zhang, MD

Silicon Valley Spine Institute, Campbell, CA

Introduction: Transforaminal lumbar interbody fusion (TLIF) is a common technique for decompression and stabilization of the lumbar spine, performed with a variety of structural grafts and non-structural graft materials. The purpose of this study is to compare the reoperation rate in patients undergoing open TLIF procedures using bioresorbable cages and either iliac crest bone graft (ICBG) or allograft bone with demineralized bone matrix (DBM) and rhBMP-2 bone morphogenic protein (BMP).

Methods: Between December 2001 and December 2003, thirty-one patients underwent an instrumented TLIF procedure using bioresorbable interbody implants (PLDLA) with ICBG and 47 patients underwent an instrumented TLIF procedure using PLDLA implants, allograft bone, DBM and BMP; all performed by a single surgeon (JDC) between December 2001 and December 2003. Only patients with a minimum follow-up of 2 years were analyzed. Data analyzed included fusion and reoperation rate and reoperations associated with BMP usage.

Results: Twenty-three ICBG patients and 36 BMP patients met the follow-up criteria. The mean follow-up for the ICBG group was 79.3 months (range 24-119 months) and for the BMP group was 68.8 months (range 24-110 months). All patients in both groups were judged to be solidly fused at final follow up. In the BMP group, 8 patients (22.9%) underwent additional lumbar surgery. One was operated for adjacent segment disease (ASD), however 7 patients (19.4%) underwent decompression for foraminal stenosis resulting from bone overgrowth which encased the exiting nerve root at the operative level(s). In the ICBG group, 2 out of 23 (8.7%) (NS) patients underwent additional lumbar surgery; however none of these patients required reoperation for recurrent stenosis at a previously operated level ($p < 0.05$).

Conclusion: BMP is commonly used as an iliac crest bone graft substitute in TLIF procedures. While some studies show there are no symptoms related to heterotopic bone growth, we found that 19.4% of TLIF patients using BMP required reoperation for heterotopic bone growth and nerve root compression, whereas none of the TLIF patients using ICBG required reoperation for heterotopic bone growth.

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

Paper 8. The Presence and Distribution of Leg Pain After Spine Surgery: Laminectomy vs. TLIF with BMP

Dennis Crandall, MD; Jan Revella, RN; Dustin Revella, BA; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: Laminectomy, TLIF, and off label use of rhBMP-2 (in TLIF) have each been associated with post-op radiculopathy. This is the first study to analyze occurrence, distribution, and natural history of all types of leg pain after laminectomy compared to TLIF using interbody BMP.

Methods: Retrospective review of prospective clinical and radiograph outcomes on 495 consecutive adults with spinal stenosis, age 61 years (19-91 years). Patients were divided into 2 groups: laminectomy vs. laminectomy and TLIF+BMP. Excluded: simple disc herniations, anterior surgery. Pain distribution (buttock, thigh, past knee) ana-

lyzed pre-op, 6week/3month/6month/1year/2year. Fusion indications: degenerative, spondylolisthesis, or deformity. Laminectomy group: 74 patients(59primary, 15revision) lami at 3.0 levels(1-5). TLIF+BMP group:421 patients(255primary,166revision) had laminectomy 2.6 levels(1-6), TLIF 1.7 levels(1-4), and posterior instrumented fusion 4.3 levels(2-17).

Results: Follow-up 65 months(24-117months). Lami group: VAS improved 5.7pre-op to 2.8(p=0.026)6week, 2.6(3months)(p=0.042) and remained stable. ODI improved 49 pre-op, 24(6week)(p<0.001), 28(3 month)(p=0.049) and remained stable. TLIF group: VAS improved from 6.2(pre-op), 3.9(6weeks), 3.5(3months), 3.1(6months), 2.9(1year), 3.1(2year); ODI improved from 49(pre-op), 32(6weeks), 34(3months), 28(6months), 26(1year), 28(2year)(p<0.001). Leg pain past the knee in 416 TLIF group was still present in 19%(6weeks), 13%(3months,8% for primary TLIF), and remained stable. Lami group leg pain past the knee in 10% at 6 weeks, 11%(3months), and remained stable(7% for primary lami). Both groups achieved similar long-term VAS(p=0.152); slightly more revision surgery in TLIF group(38%vs.32%).Transient increase in buttock or thigh pain at 6 weeks was seen in revision laminectomy(26%), revision TLIF(12%), and primary TLIF(1%), each returning to baseline by 3 months.

Discussion: Revision surgery was associated with more residual leg pain short and long-term in both groups. Post-op buttock/thigh pain showed transient increase in both groups. Lami group clinical outcomes were stable after 6-12 weeks, with TLIF group stabilizing after 6 months.

Conclusions: Comparing laminectomy vs. TLIF+BMP in patients with leg pain, TLIF had a small transient increase in leg pain at 6 weeks, with both groups similar at 3 months.

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

Paper 9. Cost-utility And Comparative Effectiveness Analyses Of Transforaminal Lumbar Interbody Fusion (tlif) Versus Comprehensive Medical Management For Lumbar Spondylolisthesis

Scott L. Parker, M.D.; Scott Zuckerman, B.S.; David N. Shau, B.S.; Stephen K. Mendenhall, B.S.; Matthew J. McGirt, M.D.

Vanderbilt University Medical Center, Dept of Neurosurgery, Nashville, TN

Introduction: SPORT suggested that lumbar fusion was efficacious but NOT cost-effective for the treatment of lumbar spondylolisthesis. Such trials inherently control and standardize medical resource utilization and cost. Mid-trial crossover of medicine non-responders inflates the utility of medical management, further biasing cost-utility analysis (CUA). We performed a comparative effectiveness and CUA of TLIF vs. medical management for lumbar spondylolisthesis utilizing a prospective spine center registry in a real-world practice setting.

Methods: 80 patients with lumbar spondylolisthesis managed at a single institution were entered into a prospective registry. A patient had to have: MRI evidence of grade I degenerative lumbar spondylolisthesis, mechanical low-back pain and radicular symptoms, and an age of 18-70 years. A surgical candidate had to have failed at least 6 weeks of non-operative therapy. Surgical management consisted of TLIF, while comprehensive medical management included spinal steroid injections, physical therapy, oral medications, and various other therapies. 2-year patient-reported outcomes (PRO), back-related medical resource utilization, and work-day losses were prospectively assessed via phone interview and used to calculate Medicare fee-based direct cost and indirect costs from occupation loss. Primary endpoint for the cost-utility analysis is the incremental cost-effective-

ness ratio (ICER).

Results: 80 patients were enrolled (45 surgery cohort, 35 comprehensive medical management cohort). Patients in each cohort were similar at baseline. TLIF resulted in a significant two-year improvement (p<0.01) in all outcome measures. On the other hand, comprehensive medical management failed to provide significant improvement for any of the outcome measures assessed: BP-VAS (p=0.13), LP-VAS (p=0.28), ODI (p=0.08), SF-12 PCS (p=0.64), SF-12 MCS (p=0.74), and Zung depression (p=0.45), Figure 1A. 2-year gain in QALY was significantly greater after TLIF (0.43 QALY) versus medical management (0.06 QALY), Figure 1B. Total 2-year cost was significantly greater for TLIF (\$36,836) versus medical management (\$8,762), Figure 1C. Cost per QALY gained for surgery vs. medical management (ICER) was \$75,876, Figure 1D.

Conclusions: In this prospective registry, TLIF versus medical management was shown to be cost-effective and provide greater 2-year improvement in outcomes. The findings from this real-world practice setting may more accurately reflect the true value and effectiveness of surgical versus medical care for degenerative spondylolisthesis.

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

Paper 10. Translational Correction of High Grade Spondylolisthesis: What Distal Anchorage is Best?

Dennis Crandall, MD; Kenneth Schmidt, MD; Jan Revella, RN

Sonoran Spine Center, Mesa, AZ

Introduction: High grade spondylolisthesis can present with significant pain along with neurologic deficits and spinal deformity. Most advocate surgical reduction along with decompression and correct and stabilize the sagittal plane. We compared the clinical outcomes and complications of two types of distal fixation in gradual translational correction of high grade spondylolisthesis.

Methods: The charts of 26 consecutive patients who underwent surgical treatment of high grade spondylolisthesis were reviewed retrospectively. All patients underwent posterior only approach, full decompression, sacral dome osteotomy in Grades 4 and 5, slow incremental correction of lumbosacral kyphosis and listhesis, and instrumented posterolateral arthrodesis. Grade 3 patients had distal fixation of S1 bicortical screws alone. Grades 4 and 5 had one of two supplemental fixation strategies: bilateral S1 and S2 sacral alar screws vs. bilateral S1 pedicle screws supported by bilateral iliac screws. Distal fixation at S1 alone was used in 5 patients (all Grade 3), 9 patients had iliac screw fixation (all grade 4 or 5). Of the 12 patients

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

treated with S2 fixation, 11 had Grade 4 or 5 spondylolisthesis.

Results: The average age was 31.3 years. Slip grade were: Grade 3- 13, Grade 4- 2, Grade 5- 10. Follow up 2-10 years. Screw loosening or hardware failure was noted in 4/12 patients with S2 distal fixation, and 0/ 9 patients with iliac screws. Complications included 2 foot drop, 1 temporary quadriceps weakness and 3 infections. The 5 patients that presented with cauda equina syndrome improved. Clinical outcomes: VAS averaged 6.2 pre-op, improved to 2.0 at 2 years. Oswestry averaged 35 pre-op improved to 17.2 at 2 years.

Discussion: High Grade spondylolisthesis is associated with significant ligament and bony obstacles to reduction, resulting in a flexion moment and kyphosis at the lumbosacral junction. After surgical decompression, stable distal fixation is required to maintain stability and allow for correction. Bilateral iliac screws provide superior fixation and resist failure at the bone-screw interface compared to S2 alar screws.

Conclusions: Instrumented reduction of high grade spondylolisthesis and restoration of lumbosacral anatomy is better achieved using bilateral iliac screws for distal fixation.

Paper 11. Relationship Of The Lumbar Lordosis Angle To The Abdominal Aortic Bifurcation And Inferior Vena Cava Confluence Levels

Charbel D. Moussallem, M.D., FEBOT; Ibrahim Abou Hamad, PhD; Christine EL-Yahchouchi, M.D.; Maroun D. Moussallem, PhD; Damien Arnalsteen, M.D.; Patrice Mertil, M.D., PhD; Heric Havet, M.D., PhD

Mayo Clinic, Orthopedic Surgery, Rochester, MN

Background: The objective is to determine the relationship of the variations of the lumbar lordosis angle to the aortic bifurcation level and inferior vena cava confluence level using CT angiography (figure 1)

Methods: A retrospective study was conducted using the data available on abdomino-pelvic CT angiography scans (Figure 1). The lumbar lordosis angle, the level and angle of bifurcation of the aorta, the level and angle of confluence of the inferior vena cava were identified using multiplanar and 3D reconstruction. Linear regression models were fitted to the data.

Results: The study consisted of 181 individuals: 100 (55.25%) males and 81 (44.75%) females having a mean age of 55.64 years (18-89y). The mean lumbar lordosis angle (LLA) was 34.65° (13°-77°). The aortic bifurcation level (ABL) was found at the L4-L5

disc in 63 cases (34.8%) and the inferior vena cava confluence level (IVCCL) was found at the upper of L5 in 53 cases (29.3%). The aortic bifurcation reached proximally the lower level of L3 in only one case and distally the level of L5-S1 disc in 8 cases (4.41%). Whereas the IVCCL reached proximally the L3-L4 disc space in only 2 cases and distally the upper level of S1 in 9 cases (4.97%). The mean aortic bifurcation angle (ABA) was 47.43° (17°-100°) and the mean IVC confluence angle (IVCCA) was 71.86° (30°-120°). Linear correlation analysis showed a negative correlation ($r=-0.240$; $p=0.0012$) between the LLA and the ABL as well as a negative correlation ($r=-0.325$; $p=0.0001$) with the IVCCL. The correlation between the ABL and the IVCCL was ($r=+0.809$; $p=0.0001$). The age showed a correlation of ($r=+0.305$; $p=0.0001$) with the ABL but a correlation of ($r=+0.19$; $p=0.0098$) with the IVCCL. The ABA and IVCCA also had a positive correlation ($r=+0.240$; $p=0.0012$). No correlation whatsoever was found between the age and the

Conclusions: This study showed the ABL and IVCCL tend to be proximally situated in an increased LLA and more distally in an decreased LLA. This will help for better planning of anterior approaches of the lumbar spine and will offer better understanding of the anatomy for spine surgeons.

Paper 12. Change in Functional Activity One Year Following Lumbar Decompression with or without Fusion

Rosanna L. Wustrack, MD; Guillermo Ramirez, BS; Shane Burch, MD

University of California San Francisco, Orthopedics, San Francisco, CA

Purpose: Several studies have shown a significant improvement in patient-reported outcomes following surgery compared to non-operative treatment for degenerative lumbar conditions. However, change in physical activity was not measured. The goal of this study was to determine, using objective measures, whether improvement in activity occurred one year following lumbar decompression with or without fusion. This study also evaluated the correlation between objective and subjective measures of activity in this population.

Materials and Methods: 46 patients over the age of 18 undergoing lumbar decompression with or without fusion were followed prospectively for one year. Patient activity levels and duration was assessed pre-operatively and at 6 weeks and 52 weeks post-operatively using the Actigraph 3GTx accelerometer over 3-5 consecutive days. Average minutes per day spent in moderate to vigorous activity (MVPA; >1950 activity counts per minute) were determined from the accelerometers. Patients also completed the EQ-5D, SF-36 and ODI questionnaires at each time point. Change in activity and HRQL scores were analyzed using the paired t-test; correlation between the change in activity and HRQL scores were analyzed using the Spearman Rank Correlation Coefficient.

Results: The study group included 25 women and 21 men, average age was 63.2. At baseline the group spent an average of 8.8 minutes per day in MVPA. This improved to 14 minutes per day at one year; the average change per individual was 5.3 minutes per day (95% CI 0.85-9.7; $p<0.05$). There was a significant improvement in all three HRQL scores; the ODI decreased by 22 points (-15 - -28.7, $p<0.001$), the EQ-5D improved by 0.20 points (0.1- 0.29; $p<0.001$) and the SF-36 PCS improved by 12.5 points (7.1- 17.9; $p<0.001$). There was no correlation between the change in HRQL scores and the change in MVPA ($\rho=0.05$).

Conclusions: Following decompression with or without fusion for degenerative lumbar conditions, there is a significant improvement in both HRQL scores and average minutes per day of MVPA. However, this study group continued to participate in much lower amounts of MVPA compared to the CDC recommendation of 30 minutes per day needed to reduce morbidity and mortality from heart disease.

Paper 13. Pitfalls of Calculating Hospital Readmission Rates Based Solely on Nonvalidated Administrative Datasets

Beejal Amin, MD; Urvij Modhia; Steven Takemoto, PhD; Dean Chou, MD; Vedat Deviren; Christopher Ames; Sigurd Berven, MD; Praveen Mummaneni

University of California, San Francisco, Neurological Surgery, San Francisco, CA

Introduction: Administrative databases are increasingly being used to establish benchmarks for quality of care and to compare performance across peer hospitals. As proposals for Accountable Care Organizations are being developed, readmission rates will be increasingly scrutinized. The purpose of this study is to assess the accuracy of the University Health-System Consortium (UHC) dataset for our hospital and identify independent predictors of readmission.

Methods: Data for 5780 consecutive patient encounters managed by 10 spine surgeons at UCSF from October 2007 - June 2011 was abstracted from the UHC dataset using the Clinical Database/Resource Manager. Of these admissions, 281 cases were re-hospitalized within 30 days of the previous discharge date. We performed an independent chart review to determine reasons for readmission and extracted hospital administrative data to calculate total and direct costs. Logistic regression analysis was used to test the odds of readmission on categorical variables. The two-sample t-test was used to test the difference of total and direct cost between readmission and non-readmission.

Results: The main reasons for readmission were infection, planned staged surgery, and nonoperative management. The UHC database overestimated the "true" readmission rate from the surgeon's point of view. Based on our manual chart review, 69 cases (25% of the 281 total readmissions) should not be included in the readmission rate calculation since 39 cases were planned as staged procedures; 14 surgical cases were cancelled or rescheduled at index admission; and 16 cases were unrelated to spine surgery. When these 69 cases are excluded, the total cost of readmission is reduced by 29% ($p=0.005$). The cost variance is in excess of one million dollars.

Of the remaining 212 readmissions, 125 were readmitted for surgery related to infection, 42 were readmitted for nonoperative management, 17 were readmitted for repair of CSF leak, and 14 were readmitted to fix hardware related issues.

Predictors of readmission were urgent/emergent admission status ($p<0.0001$), length of stay >5 days ($p=0.0001$), risk of mortality ($p<0.0001$), and age >65 ($p=0.021$).

Conclusions: Our findings uncover the potential pitfalls of calculating hospital readmission rates based solely on nonvalidated administrative datasets. Benchmarking algorithms for defining hospitals' readmission rates must take into account planned, staged surgery and eliminate unrelated reasons for readmission. Current tools overestimate the true readmission rate and cost.

Paper 14. Cost effective Analysis Utilizing a Markov Model: Total Hip Arthroplasty and Total Knee Arthroplasty for Osteoarthritis vs. Posterior Spinal Fusion for Degenerative Lumbar Spondylolisthesis

Brian Cunningham, MD; Dennis Crandall, MD; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: Economics have become increasingly important in determining the value of a surgical intervention. The primary metric used to compare different treatments outcomes has been Quality Adjusted Life Years. Arthroplasty has long been considered the gold standard while spine surgery has been criticized based on anecdotal evidence. The purpose of this study was to compare the

cost effectiveness of total hip arthroplasty (THA) and total knee arthroplasty (TKA) to posterior spinal fusion (PSF) for the treatment of degenerative spondylolisthesis.

Methods: A Markov model was constructed for three cohorts of 1000 patients (3000 total), age 55. The three cohorts: 1) THA, 2) TKA, 3) PSF. Pre-operative and post-operative HRQoL scores were utilized to model disease states. The PSF scores were collected from a single surgeon's prospective database, converted from ODI; THA and TKA scores were collected from the literature. Cost was estimated utilizing average Medicare DRG re-imbursement for the index procedure in 2011 dollars. Revision was assumed to be a sink state for all groups and the cost of revision surgery was not incorporated into this model.

Results: Hip and knee had replacement had reported cost of \$13,000/case. Spine fusion had reported cost of \$20,900/case. Over a 10-year model projection, our Markov THA cohort amassed 496 QALY across 1000 patients while our Markov TKA cohort amassed 229 QALY. Our PSF cohort amassed 613 QALY over the same time frame. The THA group had a cost of \$27,450 per change in QALY, the PSF group had a cost of \$34,110 per change in QALY, and the TKA group had a cost of \$59,165 per change in QALY.

Discussion: The more expensive index procedure for spinal fusion was offset by the significant clinical improvement as expressed in quality of life years. PSF actually fell between THA and TKA in terms of cost effectiveness.

Conclusions: PSF for the treatment of degenerative spondylolisthesis is as cost effective as THA and TKA.

Paper 15. Intradiscal Injection Of Simvastatin Results In Radiologic, Histologic, And Genetic Evidence Of Disc Regeneration In A Rat Model Of Degenerative Disc Disease

Khoi D. Than; Shayan U. Rahman, M.D.; Lin Wang, M.D.; Kwaku A. Kyere, B.A.; Tracey T. Than; Adam Khan, B.A.; Frank La Marca, M.D.; Paul Park, M.D.; Huina Zhang, M.D., Ph.D.; Chia-Ying Lin, Ph.D.

University of Michigan, Neurosurgery, Ann Arbor, MI

Introduction: Back pain is a common medical problem, and a large percentage can be attributed to degeneration of the intervertebral disc (IVD). Bone morphogenetic protein-2 (BMP-2) is known to play an important role in the chondrogenesis of the IVD. The drug simvastatin is known to up-regulate the expression of BMP-2. Thus, we hypothesized that intradiscal injection of simvastatin in a rat model of degenerative disc disease (DDD) would result in retardation of DDD.

Methods: Disc injury was induced in 272 rats via 21-gauge needle puncture. After six weeks, injured discs were treated with simvastatin in saline or a hydrogel carrier. Rats were sacrificed at predetermined time points. Outcomes measures assessed were radiologic, histologic, and genetic. Radiologically, the MRI index (calculated by the number of pixels multiplied by the corresponding image densities) was determined and then normalized by comparing with non-injured discs. Histologically, disc spaces were read by three blinded scorers based on a previously used grading scale. Genetically, nuclei pulposus were harvested and polymerase chain reaction was run to determine relative levels of aggrecan and collagen type II gene expression.

Results: Radiologically, discs treated with 5 mg/ml simvastatin in hydrogel or saline demonstrated MRI indices that were normal through 8 weeks post-treatment, although this was perhaps more sustained when delivered in hydrogel. Doses >10 mg/ml appeared toxic to the disc. Histologically, discs treated with 5 mg/ml simvastatin in hydrogel demonstrated improved grades in comparison with discs treated with 15 mg/ml in hydrogel or saline, confirming the toxicity of higher dosing. Genetically, discs treated with 5 mg/ml of simvastatin in hydrogel demonstrated higher gene expression of aggrecan and collagen type II than control.

Discussion: In interpreting data for all three outcomes measures, degenerate discs treated with 5 mg/ml simvastatin in a hydrogel carrier demonstrated radiographic and histologic features resembling normal, non-injured IVDs. In addition, gene expression of aggrecan and collagen type II (important constituents of the IVD extracellular matrix) was up-regulated in treated discs.

Conclusion: Injection of simvastatin into degenerate IVDs may result in retardation of disc degeneration and represents a promising investigational therapy for the conservative treatment of DDD.

Paper 16. Notochordal Cells Protect Nucleus Pulposus Cells From Degradation And Apoptosis: Implications For The Mechanisms Of Intervertebral Disc Degeneration

William M. Erwin, DC, PhD; Diana Islam, MSc; Robert D. Inman, MD, FRCP(C); Michael G. Fehlings, MD, PhD, FRCS(C); Florence WL Tsui, PhD

Toronto Western Hospital/University of Toronto, Toronto, CANADA

Introduction: Non-chondrodystrophic (NCD) canines resist developing degenerative disc disease (DDD) possibly due to factors secreted by notochordal cells within their intervertebral disc (IVD) nucleus pulposus (NP). DDD is known to be mediated by interleukin-1 beta (IL-1 β) and/or Fas-Ligand (Fas-L). Therefore we evaluated the ability of notochordal cell conditioned medium (NCCM) to protect NP cells from IL-1 β and IL-1 β +FasL-mediated cell death and degeneration.

Methods: We cultured bovine NP cells with IL-1 β or IL-1 β +FasL under hypoxic serum-free conditions (3.5% O₂) and treated the cells with either serum-free NCCM or basal medium (Advanced DMEM/F-12). We used flow cytometry to evaluate cell death and real-time (RT)-PCR to determine the gene expression of aggrecan, collagen 2, and link protein, mediators of matrix degradation ADAMTS-4 and MMP3, the matrix protection molecule TIMP1, the cluster of differentiation (CD)44 receptor, the inflammatory cytokine IL-6 and Ank. We then determined the expression of specific apoptotic pathways in bovine NP cells by characterizing the expression of activated caspases-3, -8 and -9 in the presence of IL-1 β +FasL when cultured with NCCM, conditioned medium obtained using bovine NP cells (BCCM), and basal medium all supplemented with 2% FBS.

Results: NCCM inhibits bovine NP cell death and apoptosis via suppression of activated caspase-9 and caspase-3/7. Furthermore, NCCM protects NP cells from the degradative effects of IL-1 β and IL-1 β +Fas-L by up-regulating the expression of anabolic/matrix protective genes (aggrecan, collagen type 2, CD44, link protein and TIMP-1) and down-regulating matrix degrading genes such as MMP-3. Expression of ADAMTS-4, which encodes a protein for aggrecan remodeling, is increased. NCCM also protects against IL-1 β +FasL-mediated down-regulation of Ank expression. Furthermore, NP cells treated with NCCM in the presence of IL-1 β +Fas-L down-regulate the expression of IL-6 by almost 50%. BCCM does not mediate cell death/apoptosis in target bovine NP cells.

Conclusions: Notochordal cell-secreted factors suppress NP cell death by inhibition of activated caspase-9 and -3/7 activity and by up-regulating genes contributing anabolic activity and matrix protection of the IVD NP. Harnessing the restorative powers of the notochordal cell could lead to novel cellular and molecular strategies in the treatment of DDD.

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

Paper 17. The Variability Of Commercially Available Scaffolds In Promoting Osteogenesis In Vitro

Jason Ghodasra; Michael Nickoli, MD; Samuel I. Stupp, PhD; Wellington K. Hsu, MD; Erin L. Hsu, PhD

Northwestern University, Orthopaedic Surgery, Chicago, IL

Introduction: Due to vastly differing compositions, clinically available synthetic scaffolds to elicit bone regeneration vary widely in their efficacy. In this study, cell adhesion, proliferation/survival, growth factor sequestration, and gene expression changes were quantitated in pre-osteoblasts to compare scaffold performance in the promotion of osteogenic differentiation.

Methods: Commercially available scaffolds included Absorbable Collagen Sponge (ACS), Mastergraft®, Chronos®, Allograft, and Mozaik®. Still in the developmental stage, a nanofiber-based hydrogel scaffold [S(P)], which contains phosphoserine residues that promote hydroxyapatite mineralization, was also used in this study. A standard ratio of # MG-63 human pre-osteoblasts:volume scaffold was used. Adhesion rate and proliferation/survival were quantitated via Pico Green assays. BMP-2 sequestration/release assays were performed by preloading scaffolds with 50 ng BMP-2, followed by quantitation of growth factor at increasing time points via ELISA. Gene expression analyses were performed using QPCR.

Results: Induced MG-63 cells adhered most efficiently to S(P) gel, whereas Mastergraft® and Chronos® performed the worst. Growth/survival was greatest in the S(P) gel and ACS groups, with minimal growth seen on Chronos® and Mozaik® scaffolds (Fig 1A). In comparing scaffolds for their capacity to sequester and release growth factor, Mastergraft®, and Chronos®, Allograft, and Mozaik® inefficiently sequestered BMP-2 after initial inoculation. ACS displayed a burst release of BMP-2 from days 3-6 that was not replicated by other scaffolds (Fig 1B). S(P) gel exhibited the best balance between sequestration and release. QPCR analyses showed significant differences in CXCL12, CXCR4, and RANKL expression when grown on the various scaffolds.

Discussion: Several factors that influence a scaffold's capacity

to promote osteoinductivity were examined here. Although scaffold performance varied widely across each parameter, a nanofiber-based hydrogel may provide an ideal balance between growth factor sequestration and release, osteoblastic gene expression, cell adhesion, and survival/proliferation.

Conclusion: Surgeons are saddled with numerous options for bone grafting, yet few in vitro studies have directly compared these products. This study provides insight into the cellular response to various scaffolds, and together with follow-up studies, could explain the clinical performance of such scaffolds and provide physicians with information on which may most effectively promote osteogenic differentiation.

Paper 18. Characterization Of Calcified Fibrocartilage within the Lumbar Vertebrae Before and After Standard Cortical Endplate Preparation

Sarina Sinclair; Michael Daubs; Brandon Lawrence; Darrel Brodke; Alpesh Patel

University of Utah, Salt Lake City, UT

Introduction: Calcified fibrocartilage (CFC) is a hypermineralized tissue layer found at the junctions between hard and soft tissues. Previous work suggests that CFC at the interface between the cartilaginous and cortical endplates may influence the outcome of spinal fusion. It is believed that CFC inhibits bone bridging between vertebrae if not properly removed from the cortical endplate during preparation of the spinal fusion surface. There is limited information on this distinct tissue layer of the spine and a lack of research into its clinical relevance.

Methods: Human lumbar spine segments were purchased from an accredited tissue bank, (n=4). Two levels of each spine segment were randomly assigned to one of two treatment groups: Group 1 underwent histological analysis of the CFC layer within the native spine, Group 2 specimens underwent cortical endplate preparation for spinal arthrodesis prior to analysis. Specimens were embedded in polymethylmethacrylate, cut into 2mm sections and imaged with a scanning electron microscope and backscattered electron technology. Images were taken within six zones along the cortical endplate from anterior to posterior (Fig 1). CFC depth was quantified from 100x magnification images taken within each zone. For Group 2 specimens, the percent of CFC removed within each zone was determined as the percent of individual data points where no CFC was present.

Figure 1: Contact microradiograph of 2 mm thick section illustrating the six areas that were examined along the surface of each vertebra.

Results: The most anterior and posterior areas of the vertebrae (Zones 1 and 6) had the largest amount of CFC at each level within Group 1 specimens. Zone 1 had the highest overall average value. These two zones had the lowest percent of CFC removed by endplate surgical preparation within Group 2. In contrast, Zone 3 had the highest average percentage of CFC removed.

Discussion: This study is the first to determine that CFC is thickest at the most anterior and posterior areas of the native lumbar vertebrae and is not fully removed during endplate preparation using current techniques. This remnant CFC may limit the potential for successful fusion.

Conclusion: While current endplate preparation techniques are able to decrease the amount of CFC, it appears it is not efficiently removed with standard techniques.

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

Paper 19. The Reliability Of The Thoracolumbar Injury Classification And Severity Score Among Orthopedic Surgeons At Different Levels Of Training

Adam J. Bevevino, MD; Ronald A. Lehman, MD; Daniel G. Kang, MD; John P. Cody, MD; Robert W. Tracey, MD; Robert W. Tracey, MD; Husain Bharmal, MD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction. Despite the increased use of Thoracolumbar Injury Classification and Severity Score (TLICS), it has not yet gained universal acceptance. In the Emergency Department, the least experienced orthopedic surgeon (Intern/Junior Resident) often performs the initial evaluation of a patient with thoracolumbar spine trauma. They must then relay reliable information to Staff spine surgeons for efficient care and initial treatment decision-making. Our objective was to examine the reliability of TLICS between orthopedic physicians from intern to staff level surgeons.

Methods. Ten cases of thoracolumbar spine fractures were reviewed and scored using TLICS by eight evaluators: intern (n=2), junior level orthopedic resident (n=3), senior level resident (n=2), spine surgeon (n=1). Each participant evaluated the same cases on three different occasions. Statistical analysis with Intraclass Correlation Coefficient (ICC) was calculated assessing the inter- and intra-observer reliability of the TLICS classification.

Results. Interobserver reliability yielded moderate to excellent agreement between evaluators in all three rounds of testing. Neurologic injury produced the highest ICC values, ranging from 0.820 to 0.902. Fracture morphology demonstrated the lowest interobserver ICC scores with moderate agreement of 0.449 and 0.423.

Intraobserver ICC scores improved with increasing levels of training. The intern evaluators recorded the lowest intraobserver ICC values, while the staff surgeon scored the highest. Staff surgeon ICC values all ranked above 0.800 for excellent intraobserver agreement. Fracture morphology produced the lowest intraobserver ICC values, ranging 0.586 to 0.683. The total severity score yielded the highest intraobserver ICC values of 0.768 to 0.920 for interns through senior residents.

Conclusions. The use of Thoracolumbar Injury Classification and Severity Score (TLICS) demonstrated moderate to excellent intra- and inter-observer reliability among all training levels. Senior Residents and Staff demonstrated improved ICC scores in higher training levels, however interns and Junior Residents were able to reliably classify spinal trauma injuries. This suggests that the TLICS scheme is a reliable way to successfully communicate thoracolumbar injury information.

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

Paper 20. The Impact of Nonoperative Treatment, Vertebroplasty, and Kyphoplasty on Survival and Morbidity after a Vertebral Compression Fracture in the Medicare Population

Andrew T. Chen; David B. Cohen, MD; Richard L. Skolasky

Johns Hopkins University, Orthopaedic Surgery, Baltimore, MD

Background. Treating vertebral compression fractures (VCFs) with vertebral augmentation procedures is associated with acute pain relief and improved mobility, but direct comparisons are limited. Our goal was to compare the survival, complications, length of stay, charges, discharge location, readmissions, and repeat procedures of Medicare patients whose new VCFs were acutely treated with vertebroplasty, kyphoplasty, or nonoperative modalities.

Methods. The 2006 Medicare Provider Analysis and Review file was used to identify 69,377 patients diagnosed with a new VCF. Patients were stratified into nonoperative (55.7%), vertebroplasty (11.2%), and kyphoplasty (33.1%) cohorts. Survival was compared using Kaplan-Meier analysis and Cox regression. Secondary parameters of interest were analyzed using the Chi-square (categorical variables) and one way ANOVA (continuous variables) tests (significance [α], 0.05).

Results. Estimated 2-year survival rates were 60.7%, 66.9%, and 75.3% for nonoperative, vertebroplasty, and kyphoplasty patients, respectively. The adjusted risk of death for kyphoplasty was 20.5% lower than that for vertebroplasty (hazard ratio = 0.80, 95% confidence interval [CI], 0.76 to 0.83). Patients with kyphoplasty had the shortest length of stay and highest hospital charges; they were also the least likely to have pneumonia and decubitus ulcers during the index hospitalization and at 6 months. However, kyphoplasty was more likely to result in a subsequent augmentation procedure than vertebroplasty (9.63% vs. 8.10%, $P < 0.001$).

Conclusions. Vertebral augmentation procedures appear to improve the survival of patients compared with nonoperative management. Kyphoplasty tends to have a more significant impact than vertebroplasty, but it is costly and may have a higher rate of subsequent VCF.

Paper 21. Racial Differences In Lumbar Spinous Process Anatomy Relevant To Interspinous Process Spacer Surgery

Jeremy D. Shaw, BA; Daniel R. Cooperman, MD; Jason D. Eubanks, MD; Daniel L. Shaw; Ling Li, MSPH; David H. Kim, MD

Case Western Reserve University, Dept of Orthopedics, Cleveland Heights, OH

Introduction: The popularity of interspinous process devices in spinal surgery has been diminished by inconsistent early results and increasing failure rates with longer-term follow-up. Development of first generation implants was likely hampered by a relative paucity of high quality population-based anatomic data regarding the human lumbar spinous process.

Methods: This study utilized 2,955 cadaveric lumbar vertebrae from 591 human lumbar spines at the Hamann-Todd Human Osteological Collection, Cleveland, Ohio. Samples were evenly distributed between ages 20 to 79 years. Each vertebra was photographed and measured digitally. Direct measurements were made with respect to positioning an interspinous process device between adjacent spinous processes and included effective spinous process length, angulation, and spinous process morphology. Height, sex, race and age were also recorded and analyzed.

Results: There was significant anatomic variance between African American and Caucasian populations. Average spinous process slope was smaller in the Caucasian population (e.g. L4 14.85 ± 9.03 vs. 21.10 ± 7.93 degrees $p < 0.0001$), and average spinous process effective length was greater (e.g. L4 20.62 ± 3.41 vs. 19.15 ± 3.93 millimeters

$p < 0.0001$). Differences in spinous process morphology were also noted at the L4 and L5 levels. African-American specimens were more likely to have convex as opposed to straight or concave morphology (87% vs. 74% L4 $p = 0.0002$, 74% vs. 61% L5 $p = 0.0009$).

Discussion: This data demonstrates significant racial differences in lumbar spinous process dimensions and morphology that may be directly relevant for interspinous process implant design and performance. Different designs may be better suited to different racial populations.

Conclusion: Regarding first generation implants, Caucasian patients may have decreased rates of implant migration and more effective interspinous distraction compared with the African American population due to shallower spinous process slope, larger spinous process length and relatively less convex spinous process morphology.

Paper 22. Adverse clinical outcomes following rhBMP-2 Use in a Minimally Invasive Transforaminal Lumbar Interbody Fusion

Miguel Pelton, B.S.; Thomas D. Cha, M.D.; Safdar N. Khan, M.D.; Kern Singh, M.D.

Rush University Medical Center, Orthopedic Surgery, Chicago, IL

Introduction: Recent reports of post-operative radiculitis, bone osteolysis, and symptomatic ectopic bone formation after rhBMP-2 use in transforaminal lumbar interbody fusions (TLIF) are a cause for concern.

Methods: After IRB approval, a retrospective review of all patients undergoing an MIS TLIF (single surgeon) at our institution was performed. All patients underwent a minimally invasive laminectomy with bilateral facetectomy, single transforaminal lumbar interbody fusion cage, unilateral pedicle screw fixation and 12 mg (Large kit) or 4.2 mg (small kit) of rhBMP-2. The BMP-2 collagen-soaked sponge was placed anteriorly in the disc space, followed by local bone graft, and then the cage filled only with local bone and no BMP-2. Patients were evaluated at 6 months and 1 year with CT scan. CT scans demonstrating neuroforaminal bone growth, osteolysis or cage migration were reviewed and cost data including direct cost/procedure for both index and revision surgeries were collected.

Results: A total of 573 patients were identified that underwent MIS TLIF with rhBMP-2 (2007-2010) with at least 1 year of post-operative follow-up and CT imaging. The mean age was 48.7 (Range 27-82). Of the 573 patients, 10 (1.7%) required an additional 15 procedures based upon recalcitrant radiculopathy and CT evidence of neuroforaminal bone growth, vertebral body osteolysis, and/or cage migration. A total of 39 patients (6.8%) required re-operation for clinically symptomatic pseudarthrosis (Figure 1). Bone overgrowth was associated with nerve impingement and radiculopathy in all 10 patients (small kit, $n = 9$; large kit, $n = 1$). Osteolysis and cage migration occurred in 2 (18%) of these same 11 patients. Average total costs were calculated per procedure (\$19,224), and additional costs equaled \$14,785 per encounter. There were no cases of asymptomatic neuroforaminal bone growth or osteolysis.

Discussion: Symptomatic ectopic bone formation, vertebral osteolysis and pseudarthrosis are recognized complications with the use of rhBMP-2 in minimally invasive transforaminal interbody fusions. Potential causes include improper dosage and a closed space that prevents the egress of the post-operative BMP-2 fluid collection.

Conclusion: Management and surgical treatment of these complications has a substantial cost for the patient and surgeon and needs to be considered with the off-label use of rhBMP-2.

Paper 23. Long-term Effects Of Bone Morphogenetic Protein In Lumbar Fusion

Beatrice Ugiliweneza, PhD, MSPH; Chirag G. Patil, MD, MS; Shivanand P. Lad, MD, PhD; Abdul A. Baker, MD; Maxwell Boaky, MD, MPH

University of Louisville, Neurosurgery, Louisville, KY

Objective: Our aim was to define and compare the two-year re-operation rates, complication rates and healthcare resource utilization of patients who underwent spinal lumbar fusion for degenerative conditions with and without bone morphogenetic protein (BMP).

Methods: Reuter's MarketScan database was utilized to identify 35,400 patients who underwent spinal fusion for degenerative lumbar disease between 2002 and 2009 with at least two years of postoperative follow-up. Propensity score matching techniques were used to match 4310 patients who underwent spinal fusion with BMP to those who underwent spinal fusion without BMP. Post-operative risk of re-operation and complications were analyzed with logistic regression and Cox-regression models. Hospital days and healthcare resources charges were analyzed with the use of general linear models on logarithmic transformed variables. Utilization of outpatient services was analyzed with Poisson regression.

Results: The study cohort comprised a matched set of 8620 patients. The average age in both groups was 52 years old and patients were followed for an average of 39 months after surgery. One year after the initial spinal fusion, BMP was found to be associated with a reduced risk of re-operation (3.39% versus 4.80%, adjusted OR: 0.696, 95% CI: 0.560 - 0.864, p-value: 0.0010). Two years after the initial spinal fusion, patients in the BMP group still had a lower re-operation rate (7.22% versus 8.72%, adjusted OR: 0.814, 95 % CI: 0.696 - 0.952, p-value 0.0101). Analysis of hospital costs showed the charges for the index hospitalization were significantly higher for patients who underwent the initial procedure with the use of BMP (p-value < 0.0001). Over two years, patients in the BMP group had fewer hospital days (p-value: 0.0109) and lower charges (p-value: 0.0206). Accumulated outpatient charges over two years were significantly lower in the BMP group (p-value: 0.01). After both one and two years, the BMP group had significantly lower combined hospital and outpatient charges (p-value: 0.04 for one year totals and p-value: 0.02 for two years totals).

Conclusion: One year and two years after the spinal lumbar fusion, BMP was associated with lower re-operation rates, lower hospital days, inpatient charges and outpatient charges.

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

Paper 24. Adverse Events With The Use Of RhBMP-2 In Thoracolumbar And Lumbar Spine Fusions: A Nine Year Institutional Analysis

Daniel Lubelski; Kalil G. Abdullah; Michael P. Steinmetz, MD; Matthew D. Alvin; Amy S. Nowacki, PhD; Edward C. Benzel, MD; Thomas E. Mroz, MD

Cleveland Clinic Lerner College of Medicine, Dept of Neurosurgery, Cleveland OH

Background. rhBMP-2 has been increasingly used in spinal fusions over the past decade. Early studies reported that the use of rhBMP-2 is associated with decreased operative time, blood loss, and pain scores, as well as improved fusion rates. Recent investigations have shown rhBMP-2 to be associated with various complications occurring at incidences ranging from 0 to 100%.

Materials and Methods. We retrospectively reviewed all patients between January 2002 and September 2010 that underwent thoracolumbar and lumbar spine fusion. Patient demographic, operative, and outcome/complication information was collected.

Results. 547 patient charts were reviewed with a mean follow-up time of 17 months. Mean age was 58 years. Forty-five percent of patients had undergone previous spine surgery. Thirty-nine percent had PLIF/TLIF operations, 20% ALIF, 29% PLF, and 8% combined anterior/posterior procedures. No relevant differences in the patient characteristics and complications were identified between the various surgical approaches. Adverse outcomes included 6% urological complications, 9% wound-related infections, 10% pseudoarthrosis, 19% radiculitis, 15% reoperation, and 1% death. Having undergone a previous spine surgery was associated with increased incidence of radiculitis, reoperation, and pseudoarthrosis (p=0.005, p=0.0008, p=0.05, respectively). Being a current smoker at the time of operation was associated with increased rate of radiculitis (p=0.03).

Conclusions. The use of rhBMP-2, in this study, had an incidence of radiculitis, pseudoarthrosis, and reoperation that was similar to the rates in historical controls without rhBMP-2. Complications do not differ by surgical approach, but are more likely in current smokers and those undergoing revision surgery. A prospective study is warranted to further delineate the adverse event profile of rhBMP-2 and the variables that are likely to affect it (i.e. type of surgery, carrier, and dose).

Paper 25. The Real Life Use of Bone Morphogenetic Protein in the United States

Jason W. Savage, MD; Paul A. Anderson, MD

University of Wisconsin, Orthopedics & Rehabilitation, Madison, WI

Introduction: Randomized controlled studies determine efficacy while effectiveness is determined by widespread clinical use. Of particular concern recently is potential for harm from BMP-2 that may be suggested from RCTs but appears more frequent in clinical studies. Using a large institutional database, our purpose is to compare complication rates of large numbers of patients undergoing spinal fusion with and without BMP-2.

Methods: The PearlDiver database was accessed, which includes approximately 15% of US Healthcare interactions. From 2005 to 2009, cases having lumbar fusion and bone graft or BMP-2 exposure were identified. The two cohorts (BMP-2 and bone graft) were analyzed for complications using ICD9 codes of the 13 most common adverse events. The incidence of complications was compared between groups for each year using Chi-square analysis.

Results: From 2005 to 2009, a total of 582,135 spinal fusions were performed using BMP-2 (Group 1). This represents a 60% increase over a 5-year period (85,833 procedures in 2005 versus 137,856 in 2009). The overall complication rate for the BMP-2 cohort was 11.2%. The complication rate was lowest in 2009 (8.2%), despite

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

an increase in total number of cases using BMP-2. During the same time interval 619,106 spinal fusions were performed without BMP-2 (Group 2). The overall complication rate for these patients was 12.7%. There was no statistically significant difference between the two groups regarding overall complication rates. Patients under the age of 65 had a markedly lower complication rate in the BMP group compared to controls. In patients older than 65, there was no difference between Group 1 (5.5% versus 20.9%) and Group 2 (9.8% versus 19.6%). The most common adverse event reported was associated with a mechanical complication of the implant or graft (4.5% in Group 1 and 8.6% in Group 2).

Discussion: The use of BMP has significantly increased in the United States. The overall complication rate of spinal fusions using BMP-2 is approximately 11.2%. This rate has remained stable despite the increased use of BMP over the past 5 years. Furthermore, there is no difference in overall complication rate in patients undergoing spinal fusion with or without BMP-2. Patients younger than 65-years-old had lower complication rates with the use of BMP. The highest risk of having an adverse event is seen in patients older than age sixty-five.

Conclusion: There is no difference in the overall complication rate in patients undergoing spinal fusion with or without BMP-2.

Paper 26. Early Failures Following Surgical Treatment For Spinal Stenosis With Lumbar Deformity

Darrel S. Brodke, MD; Prokopis Annis, MD; Brandon D. Lawrence, MD; Justin B. Hohl, MD; Jayme R. Hiratzka, MD; Michael D. Daubs, MD

University of Utah, Salt Lake City, UT

Introduction: As our population ages, we are seeing an increasing number of patients with symptomatic lumbar spinal stenosis associated with lumbar deformity, such as degenerative spondylolisthesis or degenerative scoliosis. The surgical treatment options have traditionally been limited to laminectomy alone or laminectomy and fusion. Interspinous Process Spacers (ISPs), developed to treat straightforward spinal stenosis, have been increasingly utilized in this group of patients in hopes of limiting surgical morbidity and complications. To our knowledge there have been no published studies comparing these surgical treatments in patients with stenosis and deformity. The purpose of our study was to evaluate and compare early treatment failures of these three procedures used to treat patients with symptomatic lumbar spinal stenosis and mild degenerative spondylolisthesis (grade I) or scoliosis ($<30^\circ$).

Methods: We reviewed 61 consecutive patients (25 male and 36 female), mean age 70 years, treated at a single institution with minimum 2 year follow-up (mean 48.4 months) for symptomatic spinal stenosis associated with lumbar deformity. The patients were treated with either ISP device placement, laminectomy alone, or laminectomy and short-segment fusion. Early failure was defined as return to the operating room for revision of the index level or adjacent segment within 2 years.

Results: Early failure was noted in 14 of 61 patients (23%) within 2 years. There was a significantly higher rate of same level recurrence leading to early failure in the ISP group (43%), as compared with the laminectomy and lami/fusion groups ($p<0.0001$). Early failure due to adjacent segment degeneration (ASD) was more common in the lami/fusion group (17%). Kaplan Meyer analysis revealed significantly lower survival for the ISP devices and highest survival in the laminectomy alone group ($p=0.01$).

Conclusion: Early failure with recurrent stenosis requiring revision surgery was significantly more common in patients treated with an ISP device for spinal stenosis and lumbar deformity, while ASD was more common in patients treated with laminectomy and fusion. Laminectomy alone had the highest rate of survival. These results

should be considered along side surgical morbidity when treating patients with spinal stenosis and associated lumbar deformity.

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

Paper 27. Perioperative Complications of Pedicle Subtraction Osteotomy

Michael D. Daubs, MD; Prokopis Annis, MD; Brandon D. Lawrence, MD; Darrel S. Brodke, MD

University of California San Francisco, Orthopedics, San Francisco, CA

Introduction: Pedicle subtraction osteotomies (PSO) are now commonly performed to correct significant sagittal imbalance. The complications and outcomes of this complex procedure have been reported largely from the few major centers instrumental in perfecting and teaching the technique. The purpose of our study was to describe the perioperative complications (0-90 days) associated with PSO's performed at a tertiary spine center that has more recently adopted the technique.

Methods: We reviewed all 65 patients (47 females and 18 males, mean age of 60 years (range(r) 24-80)) that underwent a PSO at our institution. Descriptive data and analysis of complications were limited to the perioperative time - within 90 days of surgery. Therefore, no patients were excluded for lack of long-term follow up. Data analyzed included: OR time, length of stay (LOS), EBL, blood products, comorbidities, neurologic complications, and medical complications. Complications were analyzed as major and minor. Radiographic data were also analyzed.

Results: The PSO was performed at L1(2), L2(18), L3(34), L4(9), and L5(2). The mean sagittal C7 plumb line improved from 118mm to 53mm. The mean OR time was 438 minutes (r 256-768), mean EBL 2371 cc (r 450-9000), mean LOS 7.6 days (r 3-24), mean ICU stay 1 day (r 0-5), and mean patient comorbidities 1.78(r 0-5). Ten patients (15.4%) had a major complication, and 15 (23%) had a minor complication. There were 3 perioperative deaths. The most common major complication was neurologic deficit 6.2% (4/65), 3 with a permanent foot drop, and one with paraplegia secondary to postoperative hematoma. There seemed to be no differences between patients with and without a major complication in regard to age, gender, comorbidities, OR time, number of levels fused, and EBL ($p>0.05$). Patients with a major complication had a longer ICU stay ($p=0.04$). There was no difference in the rate of major complications between the initial and later cases performed.

Conclusion: The pedicle subtraction osteotomy major complication rate was 15% and the minor complication rate was 23%. The most common major complication was neurologic deficit 6.2%. The complication rate did not change with increased surgeon experience.

Paper 28. The Schwab-SRS Adult Spinal Deformity Classification: Assessment and Clinical Correlations Based On A Prospective Operative and Non-Operative Cohort

Frank Schwab, MD; Virginie Lafage, MD; Christopher Shaffrey, MD; Justin Smith, MD, PhD; Benjamin Blondel, MD; Christopher Ames, MD; Kai-Ming Fu, MD, PhD; Praveen Mummaneni, MD; Douglas Burton, MD; Munish Gupta, MD; Vedat Deviren, MD; Gregory Mundis, MD; Robert Hart, MD; Shay Bess, MD; International Spine Study Group

International Spine Study Group, ISSGF, Brighton, CO

Introduction: The Schwab-SRS Classification of Adult Spinal Deformity (ASD) is a validated system that provides a common language for the complex pathology of ASD. Classification reliability has been reported; however, correlation with treatment has not been

assessed. Purpose: assess association between disability, classification type/modifier and ASD treatment.

Methods: Prospective analysis of consecutive ASD patients. Inclusion criteria: age ≥ 18 yrs and scoliosis $\geq 20^\circ$, sagittal vertical axis (SVA) ≥ 5 cm, pelvic tilt (PT) $\geq 25^\circ$ or thoracic kyphosis (TK) $> 60^\circ$. All patients had 36" standing x-rays. Differences in demographics, health related quality of life (HRQOL; ODI, SRS, SF36), and classification curve type/modifier distribution between operative (OP) and nonoperative (NONOP) treatment were evaluated.

Results: 757 patients (mean age 53 yrs, range 18-85) met inclusion criteria. OP (n=311) were older (mean age 56 vs 51 yrs), had greater BMI (27.7 vs 25.7), more previous surgery (45% vs 19%), and greater Charlson comorbidity index (1.1 vs 0.85) than NONOP (n=446), respectively (p<0.05). OP had worse HRQOL scores on all surveys than NONOP (p<0.05). OP and NONOP had similar coronal alignment (p<0.05). OP had worse sagittal spinopelvic alignment for all measures than NONOP except cervical lordosis, TK and pelvic incidence (PI). OP had greater percentage of pure sagittal classification (type S; OP=23%, NON=14%; p<0.05). OP had worse grades for all modifier categories: PT (26% vs 16%), PI-lumbar lordosis mismatch (37% vs 21%) and global sagittal alignment (29% vs 9%), OP vs NONOP, respectively (p<0.05).

Conclusions: Prospective analysis of OP vs NONOP treated ASD patients demonstrated OP patients were older, had more co-morbidities, greater disability and worse sagittal spinopelvic alignment as defined by the Schwab-SRS Classification subtype and sagittal modifiers. This classification is descriptive, correlates with HRQOL scores, and corresponds to treatment preference for ASD.

Paper 29. Degenerative Lumbar Scoliosis vs. Adult Idiopathic Scoliosis: Long-term Outcomes and Complications Following Surgical Correction

Robert Waldrop, MD; Dennis Crandall, MD; Jan Revella, RN; Michael Chang, MD; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: The value of spine surgery is increasingly being scrutinized, both for Medicare and pre-Medicare patients. Most series of adult scoliosis outcomes focus on younger patients and do not distinguish de novo degenerative lumbar scoliosis (DLS) from adult idiopathic scoliosis (IS). A direct comparison of DLS vs. IS outcomes has not been done, to identify clinical and functional outcome differences over time.

Methods: Prospectively collected data was analyzed on 121 consecutive adults age 62 years (19-90 years) who underwent primary posterior spinal fusion for DLS (68 patients, age 68) or IS (53 patients with T/TL/L/Double curves, age 54). Fusion length:

DLS- 7.7 levels(4-9), IS-10.9 levels(7-17). Anterior fusion: DLS-17, IS-23. Excluded: revision surgery, congenital and neuromuscular scoliosis. Radiograph measurements: curve, coronal/sagittal balance, sagittal:T5-T12, T10-L2, T12-S1, pelvic incidence. Complication rates were evaluated using Fisher's exact test. The effect of diagnosis as well as number of levels fused on VAS and Oswestry(ODI) outcomes were evaluated with a linear regression model.

Results: Follow-up averaged 67 months(25-110 months). DLS had more complications than IS though not statistically significant: Infection: DLS-4, IS-0; Nonunion: DLS-7, IS-3; Adjacent fracture: DLS-3, IS-1; Revision fusion: DLS-15, IS-11. Both groups improved clinically. VAS: DLS-preop-6.1, 1year-2.5, 2year-3.4, 5year-4.2; IS-preop-5.1, 1year-2.2, 2year-2.2, 5year-2.7. ODI:DLS-preop-50.8, 1year-25.2, 2year-31.8, 5year-33.7; IS-preop-37.2, 1year-19, 2year-22.0, 5year-23.2. Curve correction also improved in both groups: DLS-preop-31, 2year-11(63%); IS-57, 2year-19(67%). Lordosis: DLS-preop-39, 2year-45. Both groups show significant ($\alpha < 0.05$) improvement in VAS and ODI between 0 and 2 years.

Discussion: Both DLS and IS adults improved clinically and maintained improvement longterm, despite DLS patients being older and having more preop pain. DLS patients showed gradual degradation of initial postop outcomes over until plateau at 3-4 years. Complications are somewhat more common in the older DLS group (more osteoporosis, arthritis, fusions to sacrum) though need for revision surgery was similar in both groups.

Conclusions: Surgery for DLS results in a different natural history postop compared to surgery for IS. Beneficial outcomes are achieved in both groups, and maintained longterm.

Paper 30. The Accuracy of Pedicle Screw Insertion Using Intraoperative Three-dimensional Image Guidance

Edward Rainier G. Santos; Jonathan N. Sembrano, MD; Charles Gerald T. Ledonio, MD; A. Noelle Larson, MD; Sharon C. Yson, MD; David W. Polly, Jr., MD

University of Minnesota, Orthopedics, Minneapolis, MN

Introduction. Image-guided navigation has led to increased accuracy rates for pedicle screw placement. We present the largest study demonstrating the accuracy and safety of pedicle screw insertion using intraoperative 3D image-guided navigation. The objective of the study was to determine the accuracy and safety of intraoperatively acquired three-dimensional (3D) image-guided insertion of pedicle screws using screw revision rates, reoperation rates and incidence of neurovascular injuries as outcome measures.

Methods. Between April 2007 and September 2010, 227 patients underwent pedicle screw instrumentation using intraoperatively acquired 3D image-guidance. Another intraoperative 3D scan was performed after insertion of the screws to assess pedicle screw position and to permit intra-operative revision as necessary. The accuracy of pedicle screw placement was then determined based on the screw revision rates, reoperation rates for a malpositioned screw, and occurrence of neurovascular complications.

Results. A total of 2,495 screws were placed. Sixty-three screws were revised intraoperatively for a 2.5 % revision rate. There were no patients that required a return to the operating room for a malpositioned screw. There were no major neurologic, vascular or visceral injuries.

Discussion. The overall accuracy of open intraoperative CT image-guided pedicle screw insertion was 97.5%. More importantly, there was a 0% reoperation rate and no major neurologic or vascular injuries using this technique. In addition to the accurate placement of screws within the pedicles, this technique also has several other advantages. Based on the navigation system and the 3D images of the pedicles, it was possible to perform intraoperative measurement of pedicle dimensions, allowing for the determination of the ideal screw diameter and length along the exact trajectory of the screw, which is

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

something that is not always possible with preoperative scans. This permitted individualized selection of the appropriate size and length of screw within the pedicles. Filling the pedicle with the screw of appropriate length results in increased pull-out strength and likely a stronger biomechanical construct.

Conclusions. Intraoperatively acquired three-dimensional (3D) image-guided insertion of pedicle screws is safe and accurate.

Paper 31. Trans-cranial Motor Evoked Potential Neuro-monitoring During Trans-psoas Lumbar Interbody Fusion

Kshitij Chaudhary, MD; Katharine Speights, BS, CNIM; Kevin McGuire, MD; Andrew P. White, MD

Beth Israel Deaconess Medical Center, Orthopaedics, Brookline, MA

Background. Despite normal intraoperative electromyography (EMG), unfavorable neurological symptoms are frequently observed following lumbar trans-psoas interbody fusion, particularly when operating at L4/L5. Postoperative weakness has been reported to be as high as 24% with numbness seen in up to 42% of cases. Currently, there is limited information regarding the sensitivity of EMG and there is no published experience with tcMEP (trans-cranial motor evoked potential) monitoring during trans-psoas surgery.

Methods. This series evaluated intra-operative tcMEP and EMG to predict post-operative unfavorable neurological symptoms. Six patients underwent single level L4/L5 trans-psoas interbody fusion. Propofol and remifentanyl were used without neuromuscular blockade. Subdermal needle electrodes accommodated sEMG, tEMG, and tcMEP monitoring. Triggered EMG was used during trans-psoas retractor placement. tcMEP was obtained pre-incision, before retractor placement, and every few minutes after retractor placement.

Results. Among six consecutive patients who underwent trans-psoas surgery with tcMEP monitoring, three had tcMEP alerts. These occurred 27, 17 and 47 minutes after retractor placement. No change in EMG was noted during these procedures in any patient. In response to each tcMEP alert, the retractor was removed (12, 9 and 4 minutes following the alert, respectively). In one case, tcMEP signals returned to normal 7 minutes after removing the retractor. This patient had normal strength postoperatively. In two cases, however, intra-operative tcMEP did not return to normal, and both exhibited ($< 3/5$) ipsilateral knee extensor weakness. No evidence of psoas hematoma, implant malposition or stenosis was found on postoperative MRI. Strength recovered within the first week in each case. In this series, no patient had a neurological deficit in the setting of normal tcMEP.

Conclusions. It is our hypothesis that prolonged retractor placement frequently causes clinically significant lumbar plexus compression between the retractor and the transverse processes. EMG alone has been inadequate in detecting clinically significant intra-operative nerve injury. In our series, tcMEP provided either true positive or true negative information, while EMG provided false negative data in 50% of cases. We propose that tcMEP monitoring provides an opportunity for the surgeon to intervene upon impending or progressive neurological injuries, which may improve the safety of this procedure.

Paper 32. Radiation Exposure To The Spine Surgeon In Lumbar And Thoracolumbar Fusions With The Use Of An Intraoperative Computed Tomography 3-dimensional Imaging System

Daniel Lubelski; Frank S. Bishop, MD; Kalil G. Abdullah; Michael P. Steinmetz, MD; Edward C. Benz, MD; Thomas E. Mroz, MD

Cleveland Clinic Lerner College of Medicine, Dept of Neurosurgery, Cleveland OH

Background. Intraoperative radiation exposure to the spinal surgeon has been assessed during 2-dimensional fluoroscopy, but has

not been investigated during intraoperative 3-dimensional imaging.

Methods. 10 patients undergoing lumbar or thoracolumbar fusion were enrolled in a prospective trial to determine the radiation exposure to a spine surgeon standing in the sub-sterile room with the use of the O-ARM imaging system. A thermoluminescent digital dosimeter was worn at chest level without a lead apron. Dosimeter readings and distance from the spine surgeon were recorded.

Results. Average surgeon exposure was $44.22 \pm 17.4 \mu\text{Rems}$ (range $17.71 \mu\text{Rem} - 70.76 \mu\text{Rem}$). The mean distance from the O-ARMTM was $4.56 \pm .32$ meters, and the surgeon was exposed an average of 19.6 ± 5.7 seconds (range: 8.05 seconds to 28.7 seconds). The annual number of necessary procedures (NNP) required to surpass the exposure limit, according to the data presented here, would be 113,071 operations using O-ARMTM.

Discussion. The NNP for O-ARM use is predicted to be 1,130,710 annual procedures to reach the OEL limits for extremity, skin, and all other organs, and 339,213 procedures to reach the limits for the lens of eye. This indicates that the radiation exposure experienced by a spine surgeon with the use of O-ARM imaging is minimal over the course of one year given maintenance of appropriate distance from the O-ARM machine.

Conclusions. Radiation exposure is minimal to the surgical team during routine use of the O-ARM imaging system. The number of procedures required to surpass occupational exposure limits is high if utilizing appropriate distance from the O-ARM.

Paper 33. Implant Footprint and Vertebral Augmentation Improve Resistance to XLIF Interbody Cage Subsidence in Osteoporotic Patients

Benjamin Y. Chen, MD; Wayne K. Cheng, MD; Alexander W. L. Turner, PhD; Bryan Cornwall, PhD; Mark Peterson, MD

Silicon Valley Spine Institute, Campbell, CA

Introduction: Interbody cage subsidence into the vertebral body (VB) is a concern in osteoporotic spinal fusion patients. Methods to minimize subsidence include larger footprint interbody device, PMMA reinforcement and supplemental fixation. In the current study, 18 mm, 22 mm and 26 mm anterior-posterior width XLIF interbody cages were considered to study the influence of cage size and PMMA endplate reinforcement on subsidence resistance in individual VBs with osteoporotic bone.

Methods: Lumbar spines were dissected into individual VBs (L1 to L5) and assigned to six test groups based on BMD and anterior-posterior VB size. Five groups consisted of BMD-matched osteoporotic bone and a sixth group had non-osteoporotic bone. The test groups were: (1) osteoporotic bone + 18 mm cage, (2) osteoporotic bone + 22 mm cage, (3) osteoporotic bone + 26 mm cage, (4)

osteoporotic bone + 18 mm cage + endplate reinforced with PMMA (injected using a lateral approach), (5) osteoporotic bone + 22 mm cage + PMMA, and (6) non-osteoporotic bone + 18 mm cage. Cage lateral width was selected to span the the apophyseal ring per the XLIF surgical technique. The VBs were mounted on a materials test frame with the interbody device positioned over the middle of the endplate and pushed into the vertebral body at a rate of 0.2 mm/sec to a total of 6 mm. The force and displacement data were acquired and the maximum load to failure was determined and normalized to condition (6).

Results: The results indicate that the maximum failure load was substantially reduced in the osteoporotic groups with 18 mm and 22 mm cages, compared to the non-osteoporotic group (see Figure). The 18 mm implant in osteoporotic vertebrae produced the least resistance to subsidence (46%), as compared to the 22 mm implant (59%), and the 26 mm implant (89%). PMMA reinforcing increased the 18 mm implant to 85%, and the 22 mm to 102% (the only condition to exceed the 18 mm cage in non-osteoporotic bone).

Conclusions: In osteoporotic bone, the subsidence resistance of the 22 mm cage with PMMA reinforcing was closest to the 18 mm cage in non-osteoporotic bone, followed by the 26 mm cage without augmentation. The results thus provide a biomechanical rationale for using larger footprint interbody devices (reduces endplate stress) and/or PMMA reinforcement (strengthens bone), especially in osteoporotic patients.

Paper 34. Pedicle Screw “Hubbing” in the Adult and Immature Thoracic Spine: A Biomechanical and Micro-Computed Tomography Evaluation

Daniel G. Kang; Ronald A. Lehman, MD; Adam Bevevino, MD; Anton E. Dmitriev, PhD; Rachel E. Gaume, BS; Haines Paik, MD; Lawrence G. Lenke, MD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction: Pedicle screw “hubbing” involves seating the screw head into the dorsal lamina. This technique is postulated to provide 1) a load-sharing effect thereby improving pullout resistance, and 2) a reduction in the moment arm thereby decreasing cephalo-caudad toggling and implant loosening. The purpose of our study was to evaluate pull-out strength (POS) of fixed-head pedicle screws after hubbing versus standard insertion in the adult and immature thoracic spine.

Methods: Twenty-six (26) fresh-frozen human cadaveric and 22 fresh-frozen immature calf thoracic vertebrae were prepared. Osteoporotic BMD (n=16), normal BMD (n=6), and immature (n=12) specimens were instrumented with pedicle screws in Group I (non-hubbed, control) and Group II (hubbed) in the opposite pedicle. Cyclic, fatigue loading in a cephalocaudal direction was applied for 2000 cycles at a rate of 1 Hertz (Hz). Pull-out testing was performed in-line with the midline of the vertebra at 0.25 mm/sec and peak POS measured in Newtons (N). Micro-computed tomography (uCT) was used to evaluate trabecular architecture and incidence of iatrogenic microfractures in both adult (n=4) and immature (n=10) specimens.

Results: Hubbed screws resulted in significantly lower POS (p<0.05) in all specimens (452±274N versus 656±285N), adult specimens (291±142N versus 512±243N), and immature specimens (747±197N versus 922±112N). With the hubbing technique, 50% of all adult specimens, and 83% of non-osteoporotic adult specimens had visible fractures of the dorsal cortex. For immature specimens, the dorsal cortex demonstrated plastic deformation and conformed to the screw head in 88% of cases. No visible fractures occurred in the control group. uCT demonstrated microfractures of the dorsal cortex in 4/4 adult and 10/10 immature hubbed specimens, and no fractures in 0/4 adult and 1/10 immature control specimens.

Discussion and Conclusion: This is the largest cadaveric study ever

performed to evaluate this topic. Hubbed pedicle screws have significantly lower pull-out strength in adult and immature thoracic vertebrae, and frequently cause iatrogenic fractures of the dorsal cortex (micro or visible). This study provides the surgeon with vital information to avoid this common misconception with screw insertion.

• *The FDA has not cleared this drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an “off label” use). See inside back cover for full information.*

Paper 35. Dynamic Biomechanical Examination of the Lumbar Spine with Implanted Total Disc Replacement (TDR) Utilizing a Pendulum Testing System

Alan H. Daniels, MD; David J. Paller; Sarath Koruprolu; Matthew McDonnell, MD; Mark A. Palumbo, MD; Joseph J. Crisco, PhD

Warren Alpert Medical School of Brown University, Dept of Orthopedics, Providence, RI

Introduction: The pendulum testing system is capable of applying both physiologic compressive loads and a variety of dynamic bending moments without constraining motion of functional spinal units (FSUs). The number of cycles to equilibrium observed under pendulum testing is a marker of the energy absorbed by the FSU. Energy absorption of motion preserving spinal implants under simulated physiologic motion and loading conditions has not previously been described. In this study, we hypothesized that the lumbar spine with implanted Total Disc Replacement (TDR) would exhibit lower dynamic stiffness and absorb less energy than native lumbar FSUs under simulated physiologic motion when tested with the pendulum system.

Methods: Five unembalmed, frozen human lumbar FSUs were tested on the pendulum system with axial compressive loads of 181N, 282N, 385N, and 488N before and after Total Disc Replacement implantation. Testing in flexion, extension, and lateral bending began by rotating the pendulum to 5°; resulting in unconstrained oscillatory motion. The number of rotations to equilibrium was recorded and bending stiffness (N-m/°) was calculated and compared for each testing mode.

Results: The number of cycles to equilibrium increased with increasing load for flexion/extension and lateral bending for both the intact FSU and TDR constructs. In flexion/extension, the average number of cycles to equilibrium for the intact FSUs increased from 9.6 to 15.4 with increasing loading with 181N to 488N, while under the same loading conditions with the disc, the average number of cycles to equilibrium increased from 7.1 to 11.5 (p<0.05 for loads of 282N, 385N, 488N). In lateral bending, the average number of cycles to equilibrium for the intact FSUs increased from 10.9 to 22.0, while the disc specimens' cycles increased from 8.4 to 11.4 (p<0.05 for loads of 385N and 488N). Bending stiffness in flexion, extension, and lateral bending increased with increasing load for both the intact FSU and TDR samples. At each compressive load, the intact FSU was significantly more stiff than the TDR in flexion/extension and lateral bending (p<0.05).

Conclusions: This study examined the dynamic biomechanical properties of cadaver FSUs with and without implanted TDR utilizing a pendulum testing apparatus and large compressive loads. The disc had significantly fewer cycles to equilibrium, indicating more energy absorption than the intact FSU. Additionally, the TDR was significantly less stiff in flexion/extension and lateral bending compared to the intact FSU.

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

Paper 36. Clinical Outcomes following Silicate -Substituted Calcium Phosphate use in a Minimally Invasive Transforaminal Lumbar Interbody Fusion

Miguel Pelton, B.S.; Kern Singh, M.D.

Rush University Medical Center, Orthopedic Surgery, Chicago, IL

Introduction: Pre-clinical animal studies suggest that silicate-substituted calcium phosphate (Actifuse®) bone graft substitute offers equivalent or increased fusion rates over other graft enhancers and extenders. The objective of this study was to compare the rates of arthrodesis in patients undergoing a primary single-level minimally invasive (MIS) transforaminal lumbar interbody fusion (TLIF) with either Actifuse or bone morphogenetic-2 (BMP-2).

Methods: 52 consecutive patients undergoing a single-level unilateral MIS TLIF with either 5cc Actifuse (with 5 cc of marrow aspirate from the pedicle) or a small kit of BMP-2 (4.2mg) were analyzed. Twenty-six patients in each cohort were matched (Charlson Comorbidity Index) based on race, sex, age, smoking status, and diagnosis (spinal stenosis and spondylolisthesis). CT scan analysis was performed at 6 months and 1 year post-operatively. Fusion determination was performed by two separate blinded orthopedic surgeons and a board certified radiologist. SPSS Statistics Version 17.0 was used for statistical analysis.

Results: Pseudarthrosis rates at 6 months via CT scans were determined to be 35.0 % (9/26) and 7.7% (2/26) for the Actifuse and rhBMP-2 groups respectively (p=0.039, Odds ratio= 6.35, CI=1.22-33.19) (Table 1). These patients presented with intractable radiculopathy and axial pain and significantly higher 6 months post operative Numerical Rating Scale (0 least to 10 most) low back pain scores (Actifuse=6.4 ± 2.3, rhBMP-2= 5.0 ± 2) than patients with arthrodesis. A higher re-operation rate was noted in the Actifuse group as compared to the BMP-2 cohort (30.8 % (8/26) versus 7.7 % (2/26); p=0.075). In the BMP-2 group, one patient had neuroforaminal bone growth (n=1, 3.8%) requiring re-operation.

Discussion: Silicate substituted calcium phosphate was associated with a significantly lower rate of arthrodesis as compared to BMP-2

in the setting of a MIS TLIF. However, rhBMP-2 also has an added complication of neuroforaminal bone growth. NRS scores seem to correlate well with CT evidence of arthrodesis and subsequent re-operation.

Conclusion: Early results in an MIS TLIF suggest that more analysis should be performed before using Actifuse as the primary graft extender and enhancer in MIS TLIFs.

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

Paper 37. The Impact of Diabetes on Spinal Arthrodesis: Analysis of Complications and Outcomes

Robert Waldrop, MD; Dennis Crandall, MD; Jan Revella, RN; Michael Chang, MD; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: Diabetes(DM) increases the risk of postop wound infection in orthopedic and spine procedures. However, the full impact of DM on clinical outcomes and complications after spine fusion has not been studied. How DM compares to Non-DM patients for primary vs. revision surgery or fusion length also remain unknown. We studied the long-term clinical outcomes and complications of diabetics vs. non-diabetics after instrumented spinal arthrodesis.

Methods: 380 consecutive adults(DM- 47, Non-DM- 333) age 63 years(19-90) underwent posterior fusion for Deformity(129, 12DM) or Degenerative disease(251, 35DM); Fusion length: Deformity- 8 levels(4-15), Degen-3 levels(1-3). Prior surgery-256(67%; 47 Deformity, 209 Degen). Clinical and radiographic data was obtained preop, 1 year, 2 years, and latest followup. Infection rates were evaluated with Fisher's Exact test, while VAS and ODI results were evaluated by the Mann-Whitney test.

Results: Follow-up averaged 5years(24-188months). DM patients had more complications. Infection: DM-3(6.4%, 2 Degen, 1 Deformity), NonDM- 11(3.3%, 7 revision Deformity). Nonunions: DM-4(8.5%, 3 Deformity), NonDM-15(4.5%, 12 Deformity). Clinically, both groups improved, but DM patients improved less than nonDM at 2 years. VAS preop: DM-6.2, NonDM-6.2; 2years:DM-4.2 (p=0.0023), NonDM-3.45 (p=0.0005), p=0.1709 comparison. ODI preop: DM-52, NonDM-49.4; 2years:DM-37(p<0.001), NonDM-31.2(p<0.001), p=0.1794 comparison.

Discussion: DM carries double the risk of infection and pseudoarthrosis in spinal fusions done for deformity or degenerative disease in this patient sample. DM patients undergoing revision surgery have the highest risk. While DM and NonDM patients improved clinically, DM had more pain and lower function at 2 years than NonDM patients.

Conclusions: Diabetic patients have inferior clinical outcomes as well as double the infections and nonunions as nondiabetics after spinal fusion for degenerative disease or deformity in this sample population. Power calculations were performed from this sample and indicate a further study with at least 240 patients in the diabetic arm and 1160 in the non-diabetic arm will be necessary to detect a significant difference in outcomes.

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

Table 1. Demographic Characteristics

Variable	Actifuse® (n=26)	rhBMP-2 (n=26)	P-Value
Gender			
Male	13	13	1.000
Female	13	13	
Age	51.1 (26-79)	56.3 (26-80)	0.202
Race			
White	18	15	0.529
African American	5	5	
Latino	3	6	
Smoker			
Yes	8	7	0.760
No	18	19	
Payer			
Commercial	11	14	0.641
Worker's Comp	10	7	
Medicare	5	5	
Charlson Co-morbidity Index Score	0.78 +/- 0.93	0.59 +/- 0.69	0.412
Surgical Time (minutes)	140 +/- 44.6	141 +/- 32.2	0.932
Estimated Blood Loss (cc)	101 +/- 68.0	91 +/- 58.1	0.571
Arthrodesis (6 months)			
Yes	17	24	
No	9	2	0.039
Pseudarthrosis (6 months)			
Yes	9	2	
No	17	24	0.039
Other graft complications (Neuroforaminal bone growth, Adjacent segment disease)	0	1	1.000
Average time to Reoperation (months)	9.1 months (277 days)	13.0 months (395 days)	0.215
Baseline NRS low back pain Scores	6.8 ± 1.8	7.7 ± 1.7	0.070

Paper 38. Long-term Outcome Of Minimally Invasive Transforaminal Lumbar Interbody Fusion; 5 Years Post-op And Beyond

Kevin T. Foley, M.D.; Hamid Shah, M.D.

University of Tennessee, Memphis, Neurosurgery, Germantown, TN

Introduction: Several reports have described the efficacy of minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF), but none have documented the long-term outcomes of patients undergoing this procedure. The purpose of this study was to quantify patient-derived outcomes for MIS-TLIF patients who were 5 years or more post-operative.

Methods: A chart review was performed after obtaining IRB approval. All patients who had undergone a single-level MIS-TLIF 5 or more years prior for lumbar spondylolisthesis or spondylosis and for whom preoperative Oswestry Disability Index (ODI) and visual analog pain scale (VAS) data had been collected were included. These patients were contacted by phone and mail. After informed consent, they filled out ODI and VAS forms and returned them to the investigators. The current outcome data were compared to the preoperatively derived measures.

Results: 55 patients had undergone MIS-TLIF within the specified time frame [mean 72.6 months (60-90)] and had preoperative baseline ODI and VAS scores. Of these, 39 (19 male/20 female) patients were successfully contacted and returned current ODI and VAS scores. The mean cohort age was 63 years (37-80). The mean baseline ODI was 53 (30-100) and mean baseline VAS back and VAS leg were 50 (0-99) and 56 (0-98), respectively. The mean scores at the time of inquiry for ODI, VAS back, and VAS leg were 17(0-60), 12 (0-62), and 16 (0-77), respectively. These scores represent a decrease of 36, 38, and 40 points from baseline.

Conclusions: Although multiple reports have documented patient-derived outcome data following MIS-TLIF, none have done so for patients who were 5 or more years beyond their index procedure. The significant improvements in disability, back pain, and leg pain seen in the present study imply that MIS-TLIF is capable of producing sustained relief of symptoms and improvement in patient function. This has positive implications for the cost-effectiveness of this procedure.

Paper 39. Intervertebral Disc-derived Stem Cells: Implications For Regenerative Medicine And Neural Repair

William M. Erwin, DC, PhD; Diana Islam, MSc; Eftekhari Eftekarpour, PhD; Robert Davies Inman, MD FRCP; Michael George Fehlings, MD, PhD, FRCS(C)

Toronto Western Hospital/University of Toronto, Toronto, CANADA

Introduction: Degenerative disc disease (DDD) is the most common form of spinal stenosis, a leading cause of spinal neurological disability in those over 60 yrs of age. Cervical spondylotic myelopathy is most commonly caused by advanced DDD and may to tetraparesis or even death. It is known that the nucleus pulposus (NP) of human intervertebral discs (IVDs) contain multipotent progenitor cells that have been shown to have mesenchymal-like differentiation capacity in vitro. We elected to test the hypothesis that nucleus pulposus progenitor cells (NPPCs) would within the neural niche, differentiate into neural precursor cells for use in neural repair.

Methods: We obtained NP cells from non-chondrodystrophic (mongrel) canine IVDs, following enzymatic digestion and generated populations of self-renewing cell colonies and evaluated them for the expression of stemness genes, their ability to differentiate along chondrogenic, adipogenic, osteogenic and neurogenic lineages in vitro. We then GFP-transfected them and determined their ability to differentiate in vivo into neural precursor cells within the compact myelin deficient shiverer mouse brain.

Results: NPPCs express genes associated with 'stemness' including Sox2, Oct4, Nanog, CD133, Nestin and NCAM. NPPCs are capable of differentiation into chondrogenic, adipogenic and neural lineages in vitro however they do not differentiate into osteogenic precursor cells. Following injection into the shiverer mouse brain NPPCs differentiate into the major classes of neural precursor cells such as neuron and astro-glial cells. Most significantly we detected GFP expressing cells that demonstrated immunoreactivity to CNPase a marker of oligodendrocyte precursor cells (Figure 1; white arrows depict GFP-transfected NPPCs that differentiate into CNPase positive cells), as well as GFP positive cells that were immunopositive for myelin basic protein.

Discussion: Progenitor cells obtained from the intervertebral disc have the capacity to be used not only for cartilage and IVD repair, but also for neural repair strategies and most importantly and of profound potential significance, offer the possibility of use in the case of the injured spinal cord.

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

Paper 40. Evaluation of a Novel Bioactive Nanofiber Scaffold to Elicit Spine Fusion in a Rodent Arthrodesis Model

Michael S. Nickoli, M.D.; Jason H. Ghodasra, B.S.; Marco Mendoza, M.D.; Jacob Babu; Mahesh Polavarapu; David Nelson; Kaveesh Maharaj; Samuel I. Stupp, Ph.D.; Jeff S. McKee, Ph.D.; Shawn F. Bairstow, Ph.D.; Erin L. Hsu, Ph.D.; Wellington K. Hsu, M.D.

Northwestern University, Orthopaedic Surgery, Chicago, IL

Introduction. The use of recombinant bone morphogenetic protein-2 (rhBMP-2) has led to high fusion rates in the lumbar spine, eliminating the need for autogenous iliac crest bone graft. However, complications have been reported including radiculopathy, seroma formation, and bone resorption. Improvements in carrier technology may allow surgeons to minimize undesired complications of rhBMP-2 by decreasing the exogenous dose needed to achieve fusion. The aim of this study was to investigate the capability of a biodegradable nanofiber matrix containing a BMP-2-binding epitope to elicit spine fusion. This technology could decrease the reported complications associated with rhBMP-2 use.

Methods. Posterolateral lumbar intertransverse spinal fusions were performed on Sprague-Dawley rats assigned to groups treated with

one of two scaffolds: absorbable collagen sponge (ACS) or BMP-2-binding nanogel (BMP-2PA). Each group was further divided into sub-groups, where scaffolds were preloaded with 0, 0.1, or 1.0 µg rhBMP-2 (per animal). Ten µg rhBMP-2/ACS served as a positive control. Fusion was assessed via AP radiographs and manual palpation. Spines were scored by three blinded observers using a previously-established scoring system: 0=no bridging bone; 1=unilateral bridging; 2=bilateral bridging; 3=bilateral bridging with abundant bone. Spines which scored an average of ≥ 1.0 were considered fused.

Results. When preloaded with 0, 0.1, or 1.0 µg rhBMP-2, the BMP-2PA elicited significantly higher fusion scores relative to ACS, with fusion rates of approximately 42%, 33%, and 100% for BMP-2PA compared to 0%, 0%, and 67%, respectively, for ACS (Figure 1). Notably, BMP-2PA preloaded with 1.0 µg rhBMP-2 had equivalent fusion scores and rates to the positive control (10 µg rhBMP-2/ACS).

Discussion. Animals implanted with the BMP-2PA nanogel demonstrated superior spine fusion rates and scores relative to those treated with ACS, decreasing the required rhBMP-2 dose by ten-fold. Furthermore, use of nanogel alone (0 µg rhBMP-2) resulted in a spine fusion rate of 42% compared to 0% for ACS.

Conclusion. Use of a BMP-2-binding nanogel may lead to a stand-alone bone graft substitute by maintaining higher levels of endogenous BMP-2 at the fusion bed site. Further studies will evaluate the potential of this technology to replace exogenous growth factors for successful spine fusion in humans.

Paper 41. A Novel Therapeutic Agent for Rescuing the Adverse Effects of Advanced Glycation End-products in the Intervertebral Disc

Alok Sharan; Lee Morse, MD; Simon Tang

Montefiore Medical Center, Orthopedics, New York, NY

Introduction: Long-lived structural proteins, such as collagen in the intervertebral disc (IVD), are susceptible to the accumulation of Advanced Glycation End-products (AGEs). The increase in AGEs have been implicated in the degeneration of the IVD. We aim to

investigate the relationship between AGEs and the IVD tissue material behavior. We hypothesize that it may be possible to rescue the deleterious effects of AGEs using a novel AGE breaker and restore the tissue mechanical function.

Materials and Methods: 11 fresh frozen lumbar spines were collected (mean age 82.5 ± 10.2). Grade 1 ("Control") and grade 5 ("Degenerate") discs were used for this study ($n=27$). The discs were separated into annulus fibrosus (AF) and nucleus pulposus (NP) tissues. The Control discs were tested mechanically and then divided to undergo 0, 2, 4, 8, and 10 days of ribosylation. The treated Control discs, along with the degenerate discs were then tested mechanically. The resulting force-deformation curves were used to compute elastic modulus and $\tan \delta$.

Following mechanical measurements, the Control and degenerated NP tissues were incubated in a thiazolium salt known to cleave AGEs products for 4 days. All tissues were mechanically assessed again, and AGE content was measured.

Results: The in vitro ribosylation of the Control AF and NP tissues resulted in a significant increase in the AGEs with changes in the elastic ($p < 0.001$; ANOVA) and viscoelastic ($p < 0.001$; ANOVA) behavior of the tissues (Fig 1). Treatment by thiazolium salts resulted in significant reductions in AGEs in the Grade 1, Grade 1 + Ribosylation, and Grade 5 NP disc tissues (Fig 2) with changes in both the indentation modulus and $\tan \delta$ of the thiazolium-treated tissues.

Conclusion: We show here that modulating the levels of the AGEs can produce specific changes in elastic and viscoelastic properties differentially in the AF and NP tissues that are similar to that of degeneration. Furthermore, reduction in AGEs restores the tissue functional mechanical behavior comparable to a healthy disc. The results here suggest that modulating the levels of AGEs may be a feasible strategy towards restoring tissue mechanical function of the IVD.

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

Paper 42. Biomechanical Comparison of Spino-pelvic Fixation Constructs in the setting of Total Sacrectomy

Stefan Mindea, MD; Suresh R. Chinthakunta; Mark Moldavsky, MS; Manasa Gudipally, MS; Saif Khalil, PhD

Globus Medical Inc., Research and Development, Audubon, PA

Introduction: Total sacrectomy is indicated when a malignant or aggressive benign lesion involves the first sacral vertebra. Instrumentation and reconstruction of the lumbar spine and pelvis is required after total sacrectomy and can be achieved by various reconstruction methods. Techniques have been developed based on the use of two longitudinal supporting rods with pedicle screw fixation from L3-L5. Currently, the preferred method of lumbopelvic fixation in the setting of total sacrectomy is controversial. The goal of the present study is to determine the biomechanical stability of three different spino-pelvic reconstruction methods following total sacrectomy.

Methods: Seven human cadaveric (L1- Pelvis) specimens were evaluated in flexion-extension, lateral bending, and axial rotation in a total sacrectomy model. Following intact testing, specimens were instrumented from L3-L5 with pedicle screw fixation and tested in one of the three methods of lumbopelvic fixation after total sacrectomy (Figure 1): A) Double-rod, double iliac bolt (DDB); B) Double iliac screw fixation (DIF); and C) Modified Galveston technique (MGT). A load control protocol with 7.0 Nm moments applied at a rate of 1.5°/sec was used to establish range of motion (ROM) values for each tested construct. Data was analyzed and normalized to intact values.

Results: All instrumented constructs offered significant stability compared to the intact condition. Mean ROM of the three reconstruction techniques trended as follows: DDB>DIF> MGT. Overall, the DDB construct provided 43%, and 60% additional stability, compared to DIF, and MGT, respectively. This was significant in flexion-extension compared to MGT. In lateral bending, no significant differences among the instrumented constructs were found. In axial rotation, DDB significantly reduced mean ROM compared to MGT.

Conclusions: In the setting of total sacrectomy, the double-rod double iliac bolt fixation method provided the most rigid fixation, followed by the double iliac screw fixation, and the modified Galveston technique. In cases precluding a double-rod double iliac bolt, double iliac screw fixation may provide sufficient stability while eliminating rod contouring.

Paper 43. Caudal Pedicle Screw Compression Optimizes Thoracic Kyphosis Correction: A MicroCT And Biomechanical Analysis Of Pedicle Morphology And Screw Failure

Adam J. Bevevino, MD; Ronald A. Lehman, MD; Daniel G. Kang, MD; Haines Paik, MD; Melvin D. Helgeson, MD; Rachel Gaume, BS; Anton E. Dmitriev, PhD; Lawrence G. Lenke, MD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction. As surgeons perform cantilever correction maneuvers in the spine, it is common to have pedicle screws pullout or loosen. Currently, during kyphosis correction, surgeons either compress against the cephalad aspect of the pedicle, or vice versa. The purpose of this study was to evaluate the bone density/trabecular width of the thoracic pedicle to determine which aspect of the pedicle provides the most resistance to cantilever bending.

Methods. Fourteen fresh-frozen cadaveric vertebrae (n=14) were examined by MicroCT to determine bone volume / total volume ratio (%BV/TV) within the cephalad and caudad aspects of the pedicle. Specimens were sectioned in the sagittal plane. Pedicles were instrumented using the straightforward trajectory on both sides. Specimens were then mounted and loading to failure was performed perpendicular to the screw axis (either the cephalad or the caudad aspect of the pedicle).

Results. Mean failure when loading against the caudad aspect of the pedicle was statistically, significantly greater (454.5 + 241.3 N versus 334.79 1+158.435 N) than for the cephalad pedicle (p<0.001). In concordance with the failure data more bone was observed within the caudal half of the pedicle (87.6% + 3.5% versus 84.3% + 6.0%) compared to the cephalad half (p<.001).

Conclusion. Our results suggest that the caudal aspect of the pedicle is denser and stronger compared to the cephalad cortex. This research provides strong evidence that kyphosis correction should be performed against the caudad aspect of the pedicle (i.e. progressing from caudal to cephalad during compressive maneuvers).

Paper 44. Tapping Insertional Torque Predicts Better Pedicle Screw Fixation and Optimal Screw Size Selection

Melvin D. Helgeson, MD; Daniel G. Kang; Ronald A. Lehman, MD; Anton E. Dmitriev, PhD; Scott J. Luhmann, MD

Walter Reed National Military Medical Center, Dept of Orthopedics, Bethesda, DC

Introduction: Previous studies have evaluated screw insertional torque (IT) and its direct correlation with pullout strength. We set out to investigate the effects of tapping IT on pedicle screw fixation strength.

Methods: Five specimens were instrumented using optimal tap size (1 mm less than pedicle width), and the optimal tapping IT was found to be 2.5 in-lbs, with 1.5 in-lbs was used as a paired comparison. Next, 15 specimens (n=30 pedicles) were probed and tapped with increasing tap size until threshold torque was reached (Group 1: 1.5 in-lbs; Group 2: 2.5 in-lbs). Screw size was determined by adding 1 mm to the tap size that crossed the threshold torque value.

Results: The pedicle screw pullout strength was significantly increased (23%) in Group 2 (877.9 235.2 N) compared to Group 1 (712.3 223.1 N) (p=0.017). The mean pedicle screw diameter was significantly increased in Group 2 (5.70 1.05 mm) compared to Group 1 (5.00 0.80 mm). There was also an increased rate of optimal pedicle screw size selection in Group 2 with 9 of 15 (60%) pedicle screws compared to Group 1 with 4 of 15 (26.7%) pedicle screws within 1 mm of the measured pedicle width. There was a moderate correlation for tapping IT with both screw IT (r=0.54) and pedicle screw POS (r=0.55).

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

Discussion and Conclusion: Our findings suggest tapping IT directly correlates with pedicle screw IT, pedicle screw pullout strength and optimal pedicle screw size. We recommend incrementally increasing tap size until a tapping insertional torque threshold of 2.5 in-lbs is reached, which may maximize fixation strength and obtain optimal pedicle 'fit and fill' with the largest screw possible.

Paper 45. An Evaluation Of The Safety And Complications Of Pharmacologic VTE Prophylaxis After Spine Surgery

David J. Lunardini, MD; Nicholas T. Spina, MD; Omar Ayyash, BS; Antonia F. Chen, MD/MBA; Joon Y. Lee, MD

University of Pittsburgh, Dept of Orthopedics, Pittsburgh, PA

Introduction: Guidelines for pharmacologic venous thromboembolic (VTE) prophylaxis are well established in joint arthroplasty and orthopaedic trauma, however the risk of epidural hematoma has precluded widespread acceptance in the setting of spine surgery. Recent data has demonstrated that more extensive lumbar spine surgery may carry a VTE rate as high as 2.3%, which could shift the risk:benefit ratio in favor of anticoagulation if a reasonably safe regimen can be established.

Methods: This study is an ongoing, prospective pilot study to evaluate for any major complications of a pharmacologic VTE prophylaxis regimen consisting of 2.5 mg Arixtra starting post-operative day two, and transitioning to 325 mg Aspirin for 4 weeks upon discharge from the hospital. This regimen has been used by the senior author (JYL) since August 2009 for all patients undergoing primary lumbar fusion of ≥ 2 levels, any revision lumbar fusion, or those with a personal history of DVT or PE. Trauma, tumor, and infection patients were excluded.

Primary outcomes aimed to demonstrate safety include rate of epidural hematoma, and major and minor wound complications. Minor complications were defined as persistent drainage, antibiotics prescribed for the wound, or the use of an incisional VAC. Major complications include wound dehiscence, documented culture positive deep infection, or a return to the operating room.

Results: There were 199 control patients and 108 patients in the study group, of which 48 control patients and 51 study patients would have or did qualify to receive Arixtra.

There were no epidural hematomas in any patient who received Arixtra. There were no statistical differences in wound complications between the two groups. Minor wound complications occurred in 17/199 (8.54%) of controls versus 12/108 (11.3%) in the study group ($p=0.46$). Major wound complications occurred in 4/199 (2.0%) of controls and 6/108 (5.7%) of study group participants ($p=0.19$).

There were no statistical differences in rates of PE, DVT, blood transfusion, or H&H at discharge between those who received Arixtra and their control group counterparts.

Conclusions: Preliminary results with admittedly small numbers show no major complications from the implementation of a novel VTE prophylaxis regimen for complicated lumbar spinal surgery.

Paper 46. Outcome and Treatment of Post-operative Spine Surgical Site Infections: Predictors of Treatment Success and Failure

Keishi Maruo, MD; Sigurd Berven, MD; Serena Hu, MD; Shane Burch, MD; Vedat Deviren; Bobby Tay, MD; Amir Abdul-Jabbar, BA; Ames Christopher, MD; Praveen Mummaneni, MD; Dean Chou, MD; Steven Takemoto, PhD

University of California San Francisco, Orthopedics, San Francisco, CA

Introduction: Surgical site infection (SSI) is an important complication after spine surgery. The management of SSI is characterized

by significant variability and there is little guidance regarding an evidence-based approach. The purpose of this paper is to report the treatment and outcome of 225 SSIs, and to identify risk factors associated with treatment failure.

Methods: Retrospective study of consecutive spine surgeries between July 2005 and July 2010 were studied. Treatment success was defined as resolution within 90 days with at least one year with no further surgeries. Treatment failure included delayed resolution (>90 days treatment), persistence (implant removal/reimplantation), or death.

Fisher's exact or X2 test and logistic regression were used to identify significant associations.

Results: 225 surgical site infections were identified. Microbial distribution of 222 cultured cases: 44% *Staphylococcus aureus* (28% MSSA, 16% MRSA), 35% polymicrobial, 27% *Staphylococcus epidermidis*, 16% *Enterococcus*, 10% *E coli*, 7% *P acnes*, 5% *Pseudomonas*, 5% *Enterobacter*, 3% Fungi, and 3% culture negative. Early resolution was achieved in 92% of 50 non-instrumented cases and 73% of 147 instrumented cases. A total of 43 cases had treatment failure including patients with ongoing infection after 90 days of treatment (23 cases), the need to remove and/or implants (15 cases), and death due to sepsis (5 cases). Risk factors for treatment failure included late infection (first detected more than 90 days after, 38%), fusion with fixation to ilium (67%), poly microbial (68%), > 6 spine levels (67%), instrumented (73%) and *P acnes* (43%). Multivariate regression revealed late infection ($P = 0.011$) was the most significant independent risk factor associated with treatment failure.

Conclusions: Post-operative spine infections were treated with aggressive surgical debridement and antibiotic therapy. Superficial infection, short fusion and MSSA were predictors of early resolution.

High rates of treatment failure occurred in cases with late infection, long instrumented fusions, poly microbial infections, and *P acnes*. Removal of implants and direct or staged reimplantation may be a useful strategy in cases with high risk of treatment failure.

Paper 47. Low-grade Isthmic vs. Degenerative Spondylolisthesis: Complications and Outcomes Following Decompression, Reduction, And Arthrodesis

Dennis Crandall, MD; Melissa Gebhardt, PA-C; Jan Revella, RN; Dustin Revella, BA; Ryan McLemore, PhD

Sonoran Spine Center, Mesa, AZ

Introduction: Isthmic (IS) and degenerative (DS) spondylolisthesis cause pain through different pathologies. Slip reduction provides indirect foraminal decompression, improved sagittal balance, and more room for interbody cage. Disc distraction alone usually improves the slip for DS but not IS. This is the largest series of long-term outcomes comparing surgical treatment of IS and DS after single and multilevel arthrodesis.

Methods: A retrospective review of prospectively collected data on 249 consecutive adults with low-grade spondylolisthesis (DS-199, IS-50) undergoing laminectomy and fusion. Instrumented reduction was performed on grade 2 slips only. Excluded: high-grade slips, patients with scoliosis. Age: DS 65.4 years (34-85 years); IS 50.5 years (14-82 years). VAS, Oswestry (ODI), pain medication records, and radiographs were reviewed pre-op, 1 and 2 years.

Results: Follow-up averaged 57 months (12-114 months). Complications were similar: infection (2% for IS, DS), nonunion (1 each), and painful hardware. DS had more degeneration related complications: adjacent level degeneration (DS-43%, IS-2%), herniated disc (DS-6%, IS-0%). Footdrop was more common in DS (3 vs. 0), as was additional surgery (DS-9%, IS-2%). These differences were not statistically significant. Both single (DS-72, IS-28) and multi-level (DS-127, IS-22) fusions improved clinically. Single-level: VAS for IS: 6.01 pre-op, 2.4 at 2 years ($p=0.001$); DS: 6.1 pre-op to 2.4 at 2 years ($p=0.001$). ODI for IS: 46.8 pre-op to 26 at 2 years ($p=0.057$);

DS ODI improved from 47.3 pre-op to 22 at 2 years($p=0.002$). Multi-level: VAS for IS: 5.7 pre-op to 2.4 at 2 years($p<0.001$); DS: 6.0 pre-op, 2.8 at 2 years($p=0.038$). ODI for IS: 45 pre-op, 29 at 2 years($p=0.008$); DS ODI improved from 46 pre-op to 26($p<0.001$) at 2 years.

Discussion: Surgical treatment of low-grade DS and IS produced similar long-term clinical outcomes for single and multi-level constructs. The differences in complications appear related to degenerative disease. DS patients were 15 years older on average, had more adjacent level disease, and underwent more revision surgery over nearly 5 years follow-up than did patients treated for IS.

Conclusions: Long-term clinical outcomes for single and multi-level arthrodesis in low grade DS and IS are similar. DS had more degenerative related complications.

Paper 48. Serum 25-OH Vitamin D Levels in a Population of 51,314 Patients

Jeffrey M. Bair, M.D.; Susan Bukata, M.D.; Stephen L. Kates, M.D.; Ellen Coyne, M.S.; John T. Wright, M.S.; Glenn R. Rechtine, M.D.

University of Rochester, Rochester, NY

Introduction: Associations exist between low vitamin D levels and skeletal health, muscle weakness, and an increased rate of falls.

Vitamin D repletion reduces fragility fracture incidence, while 25-OH vitamin D (25OHVD) levels above accepted norms may reduce risks associated with chronic disease and mortality.

The purpose of this study was to analyze the demographic and laboratory data of a large population undergoing 25OHVD testing to identify patient groups at risk for hypovitaminosis D, determine the incidence of hypervitaminosis D, and assess the potential safety of a universal vitamin D supplementation program.

Methods: All patients tested for 25OHVD concentrations between December, 2004 and November, 2009 were identified, with lab and demographic data extracted from the medical record. Definitions of vitamin D status were based on published literature: $<20\text{ng/mL}$ = Deficiency; $<32\text{ng/mL}$ = Insufficiency; $\geq 32\text{ng/mL}$ = Sufficiency; $50\text{--}69\text{ng/mL}$ = Optimal.

Results: A population of 51,314 subjects (range 0 days->90 yrs old) yielded 90,232 25OHVD results. The mean 25OHVD level was 29.7ng/mL . Vitamin D Insufficiency was present in 61.6%, Deficiency in 22.0%, Sufficiency in 38.4%, Optimal in 4.2%. Teenagers and Adults demonstrated the highest percentage of insufficiency. Blacks

demonstrated severe deficiency in 17.4%. Hypercalcemia and hypervitaminosis D were present in 4/52,188 calcium-25OHVD pairings (0.007%).

Discussion: High rates of hypovitaminosis D were identified in this large population, reinforcing that all age groups are at risk. Attention to the vitamin D status of younger populations may be advisable in order to optimize skeletal and extraskeletal benefits. Populations with increased skin pigmentation demonstrated more significant 25OHVD deficits. The incidence of hypervitaminosis D with hypercalcemia is low, identified in only four subjects.

Conclusions: Treatment of hypovitaminosis D reduces fragility fracture risk and could improve functional outcomes after elective surgery. Universal vitamin D3 supplementation (2000 IU/day) upon discharge may aid in achieving these goals in hospitalized patients, while preoperative supplementation may benefit patients undergoing elective procedures. The occurrence of vitamin D toxicity and hypercalcemia is rare in patients with normal calcium metabolism. Defining optimum 25OHVD levels and implementing supplementation programs to achieve them may be systemically beneficial.

Paper 49. Likelihood of Reaching Minimal Clinically Important Difference (MCID) in Health Related Quality of Life (HRQOL) Measures: Prospective Analysis of Operative and Non-operative Treatment of Adult Spinal Deformity (ASD)

Virginie Lafage, PhD; Justin Smith, MD, PhD; Frank Schwab, MD; Christopher Shaffrey, MD; Eric Klineberg, MD; Christopher Ames; Richard Hostin, MD; Kai-Ming Fu, MD, PhD; Praveen Mummaneni, MD; Khaled Kebaish, MD; Vedat Deviren, MD; Oheneba Boachie-Adjei, MD; Robert Hart, MD; Shay Bess, MD; International Spine Study Group

International Spine Study Group, ISSGF, Brighton, CO

Introduction: Few reports have examined threshold improvements of HRQOL by MCID for treatment of ASD. Our hypothesis was that operative (OP) treatment would be more likely to achieve MCID threshold improvement compared with nonoperative (NONOP) care.

Methods: Multicenter, prospective, consecutive case series. Inclusion criteria: ASD, age>18 years, baseline and min 1 yr HRQOL measures (Oswestry Disability Index [ODI], SRS-22 and SF-36). Percentages of patients achieving established MCID thresholds were compared between OP and NONOP groups.

Results: The 391 patients included 189 OP and 202 NONOP patients. Demographic differences were noted, with OP patients having a higher rate of prior surgery (40% vs 19%, $p<0.001$), greater BMI (27.7 vs 25.7 , $p<0.001$) and greater baseline disability across all HRQOL measures ($p<0.001$). There were no significant age or gender differences. NONOP patients had only minimal improvement in one HRQOL measure (SRS-22 activity), while OP patients had improvement across all measures ($p<0.001$). Regarding MCID for ODI, NONOP patients had threshold improvement in 26% and threshold deterioration in 22% of cases. OP patients had threshold improvement in 51% and threshold deterioration in 5% of cases. Regarding MCID for SRS-22 activity, NONOP patients had threshold improvement in 46% and threshold deterioration in 28% of cases. OP patients had threshold improvement in 72% and threshold deterioration in 8% of cases. Regarding MCID for SRS-22 pain, NONOP patients had threshold improvement in 35% and threshold deterioration 27% of cases. OP patients had threshold improvement in 76% and threshold deterioration in 4% of cases. All differences between OP and NONOP groups in terms of reaching MCID thresholds were significant ($p<0.05$).

Conclusions: While OP treatment offered significantly greater HRQOL improvement and likelihood of reaching threshold MCID than NONOP treatment, there was a subset of patients that had significant benefit from NONOP care.

Abstracts of the 2012 Meeting of the Lumbar Spine Research Society

Paper 50. Pre-Operative Activity Levels do not Correlate to Self-Reported Scores in Patients with Lumbar Spine Disorders: Results of 81 Patients

Rosanna L. Wustrack; Guillermo Ramirez; Shane Burch, MD

University of California San Francisco, Orthopedics, San Francisco, CA

Introduction: Degenerative conditions of the lumbar spine (DL) are very common in the adult population and have a negative impact on quality of life. Activity monitors have not been used as a tool to assess the burden of lumbar disease despite having been validated in other fields. The hypotheses of this study were 1) Patients with lumbar spine disorders have a low level of activity and 2) Activity levels and patient-reported HRQoL outcome scores correlate in this population.

Methods: Patients with DL prior to surgical treatment comprised the study group. They wore an accelerometer for 3 consecutive days, 12 hours per day and completed the Oswestry Disability Index, the SF-36 and the EuroQual-5D questionnaires. The average minutes per day spent in sedentary activity (SA), light activity (LA) and moderate-to-vigorous physical activity (MVPA) was determined for each patient and was correlated to each questionnaire. Correlation was determined using the Spearman Rank Correlation coefficient, significance level was set a $\rho > 0.3$, $p < 0.05$.

Results: 81 patients, 45 females and 36 males with an average age of 61.5 and BMI of 28.8 participated in the study, which included 60 patients with LSS and 21 with degenerative spondylolisthesis or scoliosis. The study patients spent 8.6 minutes per day in MVPA and 136.9 minutes in LA. The average ODI score was 45.7, SF-36 PCS was 28.6 and EQ-5D was 0.504. The correlation between the ODI and MVPA was -0.275 , $p=0.019$, while the correlation between the EQ-5D and MVPA was 0.283 , $p=0.024$.

Conclusion: Patients with degenerative lumbar spine disorders have limited moderate-level and total activity, however, there appears to be no correlation between patient-reported outcome scores and activity levels as measured by accelerometry. Larger numbers are needed to better assess the relationship between activity and general health and disease-specific questionnaires.

Disclaimer: The *Journal of Neurosurgery* acknowledges that the preceding abstracts and poster sessions are published verbatim as submitted and did not go through either the Journal's peer-review or editing process.