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Oral Presentation Abstracts

Paper 1. Interspinous Fusion Device (IFD) Versus Laminectomy For Lumbar Spinal Stenosis: A Comparative Effectiveness Study

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Introduction: The aim of this study is two-fold: (1) to evaluate reoperation, complications, healthcare utilization, and costs for patients undergoing interspinous fusion device (IFD) placement, and (2) to assess potential outcome differences between IFD- and laminectomy-treated patients.

Methods: We reviewed the MarketScan database for adult patients with lumbar spinal stenosis (LSS) who underwent IFD placement as a primary inpatient procedure between 2007 and 2009. Reoperation, complications, healthcare utilization, and costs up to 18 months post-operation were analyzed. Each IFD patient was matched with a laminectomy patient on the basis of age, gender, comorbidities, and

insurance status using propensity score matching. Wilcoxon rank-sum and Chi-square tests were used to assess outcome differences between IFD and laminectomy patients.

Results: Among 498 inpatients that underwent IFD placement between 2007 and 2009, a subset of 182 patients was identified as having at least 18 months post-operative follow up; the average age was 73 years with 53.9% females. Most patients had no comorbidities (Charlson index 0; 75.8%) and had Medicare insurance (78.0%). The cumulative reoperation rates after IFD at 12 and 18 months were 21% and 23%, respectively. The average inpatient hospitalization lasted 1.6 days with an associated cost of \$17,432.

Two propensity-matched cohorts of 174 patients had undergone IFD vs. laminectomy with 18 months post-operative follow-up were analyzed. Longer length of stay was observed in the laminectomy cohort (2.5 days vs. 1.6 days, $p<.0001$), while IFD patients accrued higher costs at index hospitalization (\$17,674 vs. \$12,670, $p=.0001$). Index hospitalization (7.5% vs. 3.5%, $p=.09$), 30-day (9.2% vs. 3.5%, $p=.03$) and 90-day (9.2% vs. 3.5%, $p=.03$) complications were higher in the laminectomy cohort compared to the IFD cohort. IFD patients had significantly higher reoperation rates than laminectomy patients at 12 months follow-up (12.6% vs. 5.8%, $p=.03$). IFD patients incurred higher cumulative costs than laminectomy patients at 12 months follow-up (\$39,173 vs. \$32,324, $p=0.3$).

Conclusions: Patients that underwent laminectomy had longer in-hospital stays and were more likely to experience postoperative complications. However, 12 month reoperation rates and index hospitalization costs were significantly higher among patients who underwent IFD compared to laminectomy for LSS.

Table 4. Post-operative outcomes of matched patients with at least 18 months post-operative follow-up in an inpatient setting

Outcome	Laminectomy (n=174)	IFD (n=174)	p-value
12 month Reoperation [n (%)]			
All-type	10 (5.75)	22 (12.64)	0.0260*
Laminectomy	4 (2.30)	19 (10.92)	0.0012*
New interbody spinal fusion	6 (3.45)	4 (2.30)	0.521
Revision interbody spinal fusion	4 (2.30)	8 (4.60)	0.2399
IFD	0 (0.00)	1 (0.57)	1
18 month Reoperation [n (%)]			
All-type	17 (9.77)	26 (14.94)	0.1426
Laminectomy	7 (4.02)	23 (13.22)	0.0022
New interbody spinal fusion	10 (5.75)	4 (2.30)	0.1017
Revision interbody spinal fusion	6 (3.45)	12 (6.90)	0.1464
IFD	0 (0.00)	1 (0.57)	1
Complications [n (%)]			
Index hospitalization	13 (7.47)	6 (3.45)	0.0986
30-day complications	16 (9.20)	6 (3.45)	0.0276*
90-day complications	16 (9.20)	6 (3.45)	0.0276*
Index hospitalization			
Length of stay (LOS) in days	2.49 (2.77)	1.58 (1.41)	<.0001*
Cost in 2009 US\$	\$12,670 (\$9,883)	\$17,674 (\$19,959)	0.0001*
18 month hospital use, mean (SD)			
Cumulative LOS in days (excluding index hospitalization)	3.28 (11.20)	2.69 (6.84)	0.473
Cost in 2009 US\$ (cumulative, excluding index hospitalization)	\$12,331 (\$23,944)	\$13,559 (\$41,803)	0.499
18 month outpatient ED services			
Cumulative services (excluding index hospitalization)	2.14 (7.36)	1.84 (3.52)	0.0757
Cost in 2009 US\$ (cumulative, excluding index hospitalization)	\$272 (\$851)	\$322 (\$688)	0.0593
Overall costs in 2009 US\$			
12 month (including index hospitalization)	\$34,324 (\$33,209)	\$39,173 (\$45,608)	0.289
18 month (including index hospitalization)	\$44,834 (\$39,670)	\$51,255 (\$62,959)	0.6846

Paper 2. The Safety and Efficacy of a Novel Minimally Invasive Interspinous Spacer for the Treatment of Moderate Lumbar Stenosis: 18 Month Outcomes of a Prospective, Randomized, Controlled FDA IDE Clinical Trial

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Introduction: This study reports 18-month clinical outcomes in patients with moderate LSS treated with an investigational interspinous spacer (Superion®) compared to X-STOP®.

Methods: This prospective, randomized, controlled IDE trial (NCT00692276) enrolled 145 patients with radiographically confirmed moderate LSS unresponsive to at least 6 months conservative care. Patients were treated randomly with the Superion (n=75) or X-STOP (n=70) interspinous spacer and all were followed through 18 months post-treatment.

Results: ZCQ symptom severity and physical function scores improved 30% to 32% in both groups (all $p<0.001$). ZCQ patient satisfaction scores at 18 months were 1.7 ± 0.8 with Superion and 1.6 ± 0.7 with X-STOP. Axial pain decreased from 59 ± 25 mm at pre-treatment to 24 ± 27 mm at 18 months in the Superion group ($p<0.001$) and from 54 ± 24 mm to 26 ± 26 mm with X-STOP ($p<0.001$) ($p=0.28$ between groups). Extremity pain decreased from 66 ± 23 mm at pre-treatment to 20 ± 27 mm with Superion ($p<0.001$) and from 65 ± 23 mm to 25 ± 26 mm with X-STOP ($p<0.001$) ($p=0.71$ between groups). Back function similarly improved with Superion ($37\pm11\%$ to $21\pm15\%$; $p<0.001$) vs. X-STOP ($41\pm11\%$ to $21\pm14\%$; $p<0.001$) ($p=0.46$ between groups).

Discussion: The mid-term results of the Superion Interspinous

Abstracts of the 2013 Meeting of the Lumbar Spine Research Society

Spacer suggest that clinical improvements in axial and extremity pain and function remain durable 18 months after treatment.

Conclusions: The Superior Interspinous Spacer provides similar benefits as X-STOP in reducing pain and improving back function in appropriately selected patients with moderate LSS.

Paper 3. Characterization of Lumbar Spinous Processes for Applications in Minimally Invasive Spine Surgery

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Introduction: Detailed quantitative anatomy of lumbar spinous processes is essential for treatment of spinal stenosis using interspinous process distraction devices. The goal of the present study was to provide normative anatomic data pertinent to surgical patient selection, implant design and minimally invasive spine surgery.

Methods: This study utilized 2,955 cadaveric lumbar vertebrae from 591 human spines at the Hamann-Todd Human Osteological Collection, Cleveland, Ohio. Samples were evenly distributed between ages 20 to 79. Each vertebra was photographed and measured digitally. Direct measurements were made of the height, length, width, slope and curvature of the lumbar spinous process for each vertebra. Height, sex, race and age were recorded and analyzed.

Results: Of 591 subjects measured, 244 were female and 347 male. Females averaged 46.5 ± 15.34 years of age, while males averaged 50

± 17.39 . Spinous processes (SPs) varied in length by level, ranging from 24.76 ± 4.58 at L5 to 33.93 ± 3.90 mm at L3. Relative to other levels, L5 had smaller SP height at 18.2 ± 2.66 mm. The cranial aspect of the L5 SP was wider than others at 3.76 ± 1.38 mm, however, the caudal aspect of the L4 SP was widest at 11.09 ± 2.85 mm. L5 had a slope of 23.68 ± 10.51 degrees relative to the mechanical axis, which was steeper than other levels. At L2-L5, more SPs have convex morphology. Conversely, L1 exhibits convex morphology only 38.7% of the time (Table 1).

Discussion: Past studies have examined the quantitative anatomy of the lumbar spine as it pertains to pedicle fixation for posterior spinal fusions. Little work, however, has been done to examine lumbar spinous processes and their variable morphology. Spinous process length, width, height and slope were consistently different at L5, relative to L1-L4.

Conclusion: This large cadaveric study provides valuable normative data. The detailed quantitative anatomy of lumbar spinous processes has broad implications for enhanced pre-operative planning, as well as improved implant design and performance.

Paper 4. Obese Class III Patients At Significantly Greater Risk Of Multiple Complications After Lumbar Surgery: An Analysis Of 10,484 Patients In The ACS-NSQIP Database

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Introduction: Prior studies on the impact of body mass index (BMI) on lumbar surgery outcomes have mostly come from single institutions with the exception of two large database studies which focused only on lumbar arthrodesis. National spine data from multiple institutions is amassing, allowing for large database comparisons. The purpose of our study is to characterize and compare with the literature the 30-day outcomes—while accounting for comorbidities—of patients with graded BMI from the American College of Surgeons National Surgical Quality Improvement Program database (ACS-NSQIP).

Methods: Patients undergoing lumbar anterior arthrodesis, posterior arthrodesis, TLIF/PLIF, discectomy, or decompression in the ACS-NSQIP, 2005-10 were categorized into 4 groups based on BMI: normal/overweight (18.5 - 29.9 kg/m²), obese I (30 - 34.9 kg/m²), obese II (35 - 39.9 kg/m²), obese III (> 40 kg/m²). Obese I-III patients were compared to patients in the normal/overweight category using χ^2 and ANOVA. Multivariate linear/logistic regression models were used to adjust for preoperative comorbidities. Significance was defined as $P < 0.05$.

Results: Data was available for 10,484 patients undergoing lumbar surgery. Of these, 4.6% underwent anterior arthrodesis, 17.9% posterior arthrodesis, 6.3% TLIF/PLIF, 40.5% discectomy, 30.5% decompression. Among all patients, 25.6% were obese I, 11.5% obese II, and 6.9% obese III. On multivariate analysis, obese I, III had a significantly increased risk of urinary complications and obese II, III patients had a significantly increased risk of wound complications and of longer operation times. Only obese III patients, however, had a statistically increased risk of having an extended length of stay, septic complications and of having > 1 complication.

Conclusions: Patients with high BMI appear to have higher complication rates after lumbar surgery than patients who are of a normal/overweight BMI. However, the complication rates seem to increase substantially for obese III patients. These patients have longer operation times, extended hospital stays and an increased risk for wound, urinary, and septic complications. Our results confirm the previous findings of large database research on lumbar surgery outcomes for obese patients. Surgeons should be aware of the increased risk of multiple complications for patients with BMI > 40 kg/m².

Table 1: Spinous Process Morphology

Dimensions	Female	Male	AB
	Mean $\pm$ STD (mm)	Mean $\pm$ STD (mm)	Mean $\pm$ STD (mm)
L1 Spinous Process Length	26.95 $\pm$ 2.77	29.73 $\pm$ 3.07	28.58 $\pm$ 3.25
L2 Spinous Process Length	30.19 $\pm$ 3.08	33.88 $\pm$ 3.23	32.36 $\pm$ 3.66
L3 Spinous Process Length	31.68 $\pm$ 3.30	35.51 $\pm$ 3.50	33.93 $\pm$ 3.90
L4 Spinous Process Length	29.79 $\pm$ 3.89	32.86 $\pm$ 4.23	31.59 $\pm$ 4.36
L5 Spinous Process Length	23.73 $\pm$ 4.36	25.48 $\pm$ 4.60	24.76 $\pm$ 4.58
L1 Spinous Process Effective Length	18.46 $\pm$ 2.21	20.08 $\pm$ 2.57	19.47 $\pm$ 2.57
L2 Spinous Process Effective Length	20.86 $\pm$ 2.47	23.35 $\pm$ 2.71	22.52 $\pm$ 2.89
L3 Spinous Process Effective Length	22.85 $\pm$ 2.64	25.7 $\pm$ 2.88	24.52 $\pm$ 3.12
L4 Spinous Process Effective Length	23.32 $\pm$ 2.96	25.49 $\pm$ 3.24	24.59 $\pm$ 3.30
L5 Spinous Process Effective Length	21.65 $\pm$ 3.68	23.47 $\pm$ 3.34	22.72 $\pm$ 3.33
L1 Spinous Process Height	19.88 $\pm$ 2.32	20.97 $\pm$ 2.24	20.29 $\pm$ 2.30
L2 Spinous Process Height	19.87 $\pm$ 2.27	20.67 $\pm$ 2.34	20.34 $\pm$ 2.34
L3 Spinous Process Height	20.51 $\pm$ 2.61	21.07 $\pm$ 2.52	20.83 $\pm$ 2.57
L4 Spinous Process Height	20.39 $\pm$ 2.32	20.61 $\pm$ 2.73	20.52 $\pm$ 2.73
L5 Spinous Process Height	17.8 $\pm$ 2.61	18.48 $\pm$ 2.66	18.2 $\pm$ 2.66
L1 Spinous Process Width (Cranial)	2.88 $\pm$ 0.86	2.86 $\pm$ 0.87	2.87 $\pm$ 0.86
L2 Spinous Process Width (Cranial)	2.72 $\pm$ 0.77	2.76 $\pm$ 0.83	2.74 $\pm$ 0.80
L3 Spinous Process Width (Cranial)	3.01 $\pm$ 0.97	3.13 $\pm$ 1.01	3.08 $\pm$ 1.00
L4 Spinous Process Width (Cranial)	3.27 $\pm$ 1.06	3.44 $\pm$ 1.23	3.37 $\pm$ 1.20
L5 Spinous Process Width (Cranial)	3.87 $\pm$ 1.29	3.9 $\pm$ 1.43	3.76 $\pm$ 1.38
L1 Spinous Process Width (Caudal)	9.03 $\pm$ 1.33	9.19 $\pm$ 1.72	9.12 $\pm$ 1.33
L2 Spinous Process Width (Caudal)	9.18 $\pm$ 1.82	9.61 $\pm$ 1.85	9.43 $\pm$ 1.89
L3 Spinous Process Width (Caudal)	10.45 $\pm$ 2.19	10.81 $\pm$ 2.17	10.66 $\pm$ 2.19
L4 Spinous Process Width (Caudal)	10.97 $\pm$ 2.85	11.08 $\pm$ 2.84	11.09 $\pm$ 2.85
L5 Spinous Process Width (Caudal)	9.41 $\pm$ 2.67	9.88 $\pm$ 2.73	9.69 $\pm$ 2.71
L1 Spinous Process Radius	22.45 $\pm$ 19.88	21.09 $\pm$ 19.35	21.45 $\pm$ 19.55
L2 Spinous Process Radius	23.98 $\pm$ 26.55	23.17 $\pm$ 26.72	23.51 $\pm$ 25.29
L3 Spinous Process Radius	27.51 $\pm$ 27.48	30.52 $\pm$ 29.68	29.28 $\pm$ 28.93
L4 Spinous Process Radius	24.21 $\pm$ 21.9	25.65 $\pm$ 23.03	24.79 $\pm$ 22.55
L5 Spinous Process Radius	24.99 $\pm$ 25.59	26.44 $\pm$ 21.94	25.84 $\pm$ 23.51
Slope	Female	Male	AB
	Mean $\pm$ STD (°)	Mean $\pm$ STD (°)	Mean $\pm$ STD (°)
L1 Spinous Process Slope	15.53 $\pm$ 18.64	13.36 $\pm$ 13.68	14.25 $\pm$ 15.94
L2 Spinous Process Slope	14.89 $\pm$ 7.8	13.26 $\pm$ 7.63	13.95 $\pm$ 7.74
L3 Spinous Process Slope	16.11 $\pm$ 7.61	15.00 $\pm$ 7.57	15.46 $\pm$ 7.60
L4 Spinous Process Slope	18.18 $\pm$ 9.45	17.66 $\pm$ 8.79	17.88 $\pm$ 9.06
L5 Spinous Process Slope	24.11 $\pm$ 10.13	23.37 $\pm$ 10.79	23.68 $\pm$ 10.51
Morphology	Female	Male	AB
L1 Concave	67.6%	56.9%	61.3%
L1 Convex	32.4%	43.7%	38.7%
L2 Concave	38.1%	33.4%	36.5%
L2 Convex	61.9%	66.6%	63.5%
L3 Concave	25.8%	23.6%	25.7%
L3 Convex	74.2%	76.4%	74.3%
L4 Concave	20.5%	18.4%	19.3%
L4 Convex	79.5%	81.6%	80.7%
L5 Concave	32.4%	32.6%	32.5%
L5 Convex	67.6%	67.4%	67.5%

Paper 5. Comparative Survivorship on role of Primary Closure versus Complex Muscle Flap Closure procedure after irrigation and debridement for deep spinal surgical site infection

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Background: It is unknown whether the failure rate of a irrigation and debridement (I & D) procedure after a deep surgical site infection (SSI) varies according to the type of wound closure performed. The purpose of this study was to compare the survivorship of a commonly used wound closure technique by primary intention, compared with newer muscle flap reconstruction procedures.

Methods: We performed a retrospective review of a series of 235 consecutive patients who underwent an I & D procedure for a deep surgical site infection between January 1, 2006 and December 31, 2009. A total of 162 patients received a primary closure while 73 patients received a muscle flap closure after I & D of the wound respectively. A total of 49 cases(PC-36; MFC-13) required a 2nd repeat I& D procedure to cure the deep SSI while 21 cases(PC-13; MFC-8) required 2nd repeat I& D procedure with removal of instrumentation along with the repeat I & D. Overall failure rate was calculated with Kaplan-Meier analysis .The log rank test used to distinguish the effect of the two wound closure techniques based on overall survival. Cox proportional hazards regression models were used to determine cause specific failure for different patient and surgical characteristics.

Results: Compared to a primary closure after an I & D, muscle flap closure did not provide a significant survival benefit.(p=0.24). Primary closure after a cervical I & D had a higher likelihood of failure compared to a muscle flap closure (Figure 1)(p=0.038). Based on our hazards model, compared to degenerative spine conditions, a 2nd repeat I & D was significantly more common in deformity (Hazard Ratio [HR] 3.9 95% Confidence Interval [CI] 1.23-12.7) and malignant spinal conditions (HR 4.13 95% CI 1.19-14.3). A wound abscess

during the initial I & D resulted in a significantly higher risk of a 2nd repeat I & D procedure (HR 2.35 95% CI 1.23-4.5). Placement of a V.A.C apparatus lowered the risk of a 2nd repeat I & D(HR 0.39 95% CI 0.14-1.12).

Conclusion: Multi-level spinal surgery, a diagnosis of deformity or a malignancy is highly likely to require a future I & D after discharge. Multiple irrigation and debridement procedures with a V.A.C apparatus decrease the risk of recurrence. MFP did confer any significant survival advantage to prevent resurgence of infection.

Paper 6. Complications Of Flat Bedrest Following Incidental Dural Repair

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Introduction: Flat bed rest after incidental durotomy is commonly used to reduce the risk of CSF leakage and associated complications. We examined the incidence of medical complications after flat bed rest using modern dural repair methods and determine whether bedrest is a risk factor for specific medical complications.

Methods: Retrospective case series of consecutive patients with incidental durotomy following lumbar laminectomy between 2005 and 2009 with an incidental durotomy were identified. The patients all underwent lumbar laminectomy for lumbar stenosis for symptomatic neurogenic claudication or lumbar radiculopathy. Medical records were reviewed for duration of bed rest and complications (pulmonary, wound, neurological, gastrointestinal, CSF and urinary) in the chart notes, repair methods, subfascial drain placement, consultant notes, imaging reports, and discharge summaries. Patients were compared with duration of bedrest > 24 hr versus duration of bedrest ≤ 24 hr. The incidence of complications was compared between groups using Fisher's exact test.

Results: There were total 42 patients. There were 18 patients in the bedrest ≤ 24 hr group and 24 patients in the bedrest > 24 hr group. Comparing the bedrest ≤ 24 hr to bedrest> 24 hr patients, there was no statistically significant difference in the percentage of patients with complications related to the durotomy(headache, blood patch) (≤24 hours 39% vs> 24 hours 21%, p=0.12) or wound complications (22% vs 33%, p=0.21). There was no statistically significant difference in the incidence of revision surgery including for pseudomeningocele (11% vs 0%, p=0.18) or infection (0% vs 4%, p=0.57). There was a statistically significant decrease in the incidence of total medical complications in the ≤ 24 hour group (0% vs. 50%, p=0.0003).

Conclusion: There was an increased incidence of medical complications in the bedrest group > 24 hours. Flat bed rest after modern dural repair method may not be a necessity in all cases and may be associated with a higher incidence of medical complications.

Paper 7. Adverse events in spine surgery: A 9 month prospective analysis

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Background: Studies on spine adverse events have typically been retrospective and have utilized hospital administrative data. Street et al prospectively identified a high rate of postoperative complications by utilizing the SpineAdVerse Events Severity system AE (SAVES V2) abstraction tool. Our objective is to determine the incidence, severity and effect on length of hospital stay (LOS) for adverse events (AEs)

for patients undergoing spine surgery at an American university.

Method: AE data were prospectively collected by a nurse practitioner daily for nine months using SAVES V2 AE form. The severity of each AE was graded and estimated effect on LOS was calculated. We calculated the total number of AEs, average number of AEs per patient, the incidence of AEs and each severity grade, and the estimated effect on LOS.

Results: 91% (561/613) of patients were recorded in the AE database. 60% of patients experienced at least one AE (478 total AEs). Of patients with at least one AE, the average number was 1.43 (range 1-5). The incidence of intraoperative complications was 3.4%. The incidence of postoperative adverse events was 60% (pain control, 26.4%; pneumonia, 3.4%; delirium, 1.8%; wound complications, 7.6%). Of the patients who had at least one AE, 21% had no effect on LOS, 49% had 1-2 day increase in LOS, 20% had 3-7 day increase in LOS, and 10% had 8 day or longer LOS. Of the total number of documented AEs, 126 were grade 3 or 4 (26%) requiring either return to OR or ICU care, 3 were grade 6 (0.6%) mortality.

Conclusion: Spine surgeries are associated with a high rate of perioperative adverse events. Increased LOS and increased level of care affect patient outcomes and overall hospital costs. This study will help define our current baseline of AEs will aid in development of protocols for preemptive management.

Paper 8. Comparison Of Cranial Facet Joint Violation Rates Between Open And Percutaneous Pedicle Screw Placement Using 3-D CT Computer Navigation

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Introduction: Facet joint violation reportedly results in a higher rate of adjacent segment degeneration. Reported facet joint violation rates range from 7% to 100%. Image-guided techniques have enhanced pedicle screw placement accuracy. The aims of this study are to determine if 3-Dimensional (3D) CT 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 Nov 2006 to Dec 2011. Surgeries were conducted at one institution by three fellowship-trained spine surgeons. The cranial screws 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 intraoperative axial CT images. Grading was performed by 3 reviewers. If there was a difference in evaluation, consensus was reached to arrive at a single grade for each screw.

Chi-square was used to determine significance between the open and percutaneous group ($\alpha=0.05$).

Results: 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%) ($p<0.001$). There is a trend of an increasing likelihood of facet joint violation as one moves caudally from L1 to L5 reflecting the difficulty of avoiding the facet joints at the more caudal levels due to facet orientation and presence of the iliac crests.

Conclusions: The use of intra-operative CT 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 cranial facet violation rate than the open technique. Screws inserted percutaneously have more lateral entry points which tend to avoid the facet joint. None of the violations in the percutaneously inserted screws showed complete impingement.

Paper 9. A Novel Nanocapsule for BMP-2 Delivery with Alleviated Inflammatory Reaction

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Bone morphogenic protein 2 (BMP-2) is commonly used to promote bony fusion in spinal surgery, but there significant concerns exist about the inflammatory response it causes and the quality of bone. We herein report a novel protein delivery system based on protein nanocapsules capable of controlled release and of alleviating immune response.

Method: The synthesis of the nanocapsules was achieved using a simple encapsulating technique (Scheme 1). The protein is first incubated with positively charged monomer, neutral monomer and degradable crosslinker. Electrostatic and hydrogen-bonding interactions enrich the monomers and crosslinkers around the protein molecules. In-situ free-radical polymerization is then initiated to form a thin polymer layer around the proteins, yielding the protein nanocapsules (denoted as nBMP2).

In vitro ELISA test was done to test the controlled release of BMP-2 protein from nanocapsule. Rat posterolateral spinal fusion model was introduced to compare the osteogenic effect of nBMP-2 and BMP-2. Rat soft tissue inflammation model was employed to compare inflammation reaction and soft tissue swelling.

Results: ELISA test showed that the initial protein concentration of nBMP-2 sample was significantly lower than BMP-2 sample; however, it did not decrease afterwards but increased slightly, peaking and surpassing BMP-2 on day 3. It decreased more slowly than BMP-2 afterwards. Fusion rate tested by X-ray, CT and manual assessment after spinal fusion surgery was similar between nBMP-2 and BMP-2. Quantified CT examination showed BMP-2 group had a greater new bone volume; however, nBMP-2 yielded better bone quality. This was

confirmed by histology test. Soft tissue edema volume measured by MRI showed that nBMP-2 group had significantly less inflammation reaction volume compared with BMP-2, which was also confirmed by histology.

Discussion: The polymer network formed around the protein core protects BMP-2 from interaction with the immune system. It can be degraded gradually to release the core protein. With this strategy, the immunogenicity of the therapeutic protein can be reduced without sacrifice of therapeutic effect.

Conclusion: By using this novel protein nanocapsule the inflammatory effect of BMP-2 is reduced without compromising the osteogenic effect.

Paper 10. Treatment Of Gait And Sensory Changes In Experimental Disc Herniation Radiculopathy By Local And Sustained Anticytokine Delivery

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Introduction: Disc-herniation induced radiculopathy may arise from both mechanical compression and biochemical inflammation of apposed neural elements. This study evaluated how local administration of anticytokine treatment affects established gait and behavioral changes in an animal disc-herniation disease model. The selected agent was a tumor necrosis factor (TNF) soluble decoy receptor (sTNFRII). We also observed the efficacy of this treatment co-administered with an in situ forming chitosan carrier sustaining drug release over time.

Methods: Sprague-Dawley rats underwent surgical procedure including harvesting autologous nucleus pulposus (NP) from a tail intervertebral disc and exposure of the L5 dorsal root ganglion (DRG). Control animals (n=6) underwent exposure only, and experimental animals received NP placement onto the DRG with no treatment (n=6), local delivery of sTNFRII (n=6), local placement of chitosan (n=6), and combined delivery of sTNFRII with chitosan (n=6). Animals were evaluated at one week for mechanical allodynia by Von Frey testing, for stance symmetry by incapacitance meter measurement, and for gait symmetry by digitized video analysis.

Results: Persistent mechanical allodynia was observed in rats subjected to NP stimulation compared with controls, with 50% withdrawal threshold dropping from 15g preoperatively to 3g postoperatively (Figure 1). This heightened sensitivity had the functional consequence of stance asymmetry in the injured group, with animals preferentially loading the contralateral hindlimb. Treatment with sTNFRII alone or in combination with chitosan reversed the mechanical allodynia and restored symmetry of stance, whereas such effects were not observed with the drug carrier alone.

Conclusions: Non-compressive disc herniation leads to mechanical

allodynia and altered stance symmetry in an animal disease model. Such changes could be effectively reversed by local immunomodulator treatment effectively, either alone or when administered with a sustained-release carrier, further implicating the role of pro-inflammatory cytokines in this phenotype. Further work will elucidate the benefit of sustained local drug release in this model.

Paper 11. Gait Abnormalities And Sensory Changes Accompany Neuroinflammation In Mouse Model Of Disc Herniation Neuropathy

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Introduction: Intervertebral disc (IVD) herniation causes radiculopathy by mechanical compression and biochemical irritation of nearby neural structures. Animal models of radiculopathy describe demyelination, slowed nerve conduction, and heightened pain sensitivity following application of autologous nucleus pulposus (NP) to the DRG. This study investigated how IVD-induced neuroinflammation leads to mechanical hyperalgesia and locomotor disability in a mouse model, alongside the evidence to support autoimmune reactivity as a putative pathomechanism against which therapy can be implemented.

Methods: Seven-week old mice (C57BL/6) were used for this experiment. Donor heterologous nucleus pulposus (NP) was obtained from littermate animals. Experimental animals underwent mid-thigh exposure of the sciatic nerve. Those in the sham group were thereafter closed. Those in the NP group underwent placement of non-compressive NP placed onto the exposed sciatic nerve segment. Animals were evaluated every two days for mechanical allodynia and

thermal hyperalgesia, and on alternating days for functional gait and stability using RotaRod assessment of 30 second ramp from 0 to 40 RPM. Serum cytokine content was measured after animal sacrifice, and immunohistochemistry tested sciatic nerve, DRG tissue, spinal cord, and brain for evidence of cellular activation.

Results: Sensory testing revealed mechanical allodynia in NP-treated mice compared with sham animals at all timepoints. Summarized in Figure 1A ($p < 0.01$), this was a robust effect that persisted for the duration of the experiment. RotaRod analysis (Figure 1B, $p < 0.01$) revealed dysfunctional balance among the injured animals, trending toward recovery over the course of the study. Immunohistochemistry of sectioned spinal cords exhibited microglial activation in the dorsal horn of injured animals, alongside decreased presence of IB4-positive peptidergic terminals. Similar serum levels of TNF α were observed between groups ($p = 0.43$), whereas a two-fold increase in serum IL-17 was noted among the NP animals compared to sham controls ($p < 0.01$).

Conclusions: This study provides support for investigating NP-associated neuroinflammation in a mouse model, alongside a potential autoimmune mechanism that underlies its development. Mechanical hypersensitivity and balance abnormalities were noted in experimental animals, metrics that may serve to assess future work involving therapeutic interventions to rescue animals from the phenotype of inflammatory neuropathy.

Paper 12. Femoral Nerve Strain at L4-5 is Minimized by Hip Flexion and Increased by Table Break when Performing Lateral Lumbar Interbody Fusion

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Introduction: Anatomic studies have demonstrated that nerves and blood vessels have excursion with extremity range of motion. Nerve tension has been documented in the clinical setting as a pain generator. For instance, the femoral nerve stretch test, straight leg raise, and Lasegue test all can cause pain in patients that have lumbar disc herniation. Animal models have shown that relatively low strains can decrease or even block neural blood flow. The purpose of this study was to determine the effect of hip range of motion on femoral nerve strain near the L4-5 disc space as it pertains to the XLIF procedure.

Methods: Five cadavers with intact proximal femurs were placed in the lateral position as though undergoing the L4-5 XLIF procedure. The lumbar plexus was dissected to identify the femoral nerve. Radiographic markers were implanted into the nerve. A spherical marker was implanted in L5 to scale dimensions on the radiographs.

With the operating table initially flat (0° table break), the pelvis was stabilized to the table to minimize movement during hip flexion. The table was oriented to provide true A-P and lateral fluoroscopic C-arm images aligned with the L5 superior endplate.

Lateral and A-P fluoroscopic images were digitally recorded with 0° initial table break and the hip at 0, 20, 40 and 60° flexion. The table was then broken to 40°, and images were recorded at the same hip flexion angles. The contralateral side of the specimens was evaluated using the same methods. Images were analyzed to determine the position of the markers with respect to coordinate systems created at the L5 superior endplate. Nerve strain for each condition was calculated from the change in distance between the markers with respect to baseline, divided by the baseline distance (L/L). Baseline was the lowest nerve strain condition, which was with the table at 0° and the hip flexed to 60°. The position where the nerve crossed the L5 superior endplate was also determined.

Results: Table break results in preloading the femoral nerve when approaching L4-5. Nerve strain was highest with the table broken to 40° and the hip at 0° (average 6-7 %). Strain in the femoral nerve decreased with increasing hip flexion for both table break angles. Hip flexion can reduce the preload on the femoral nerve in cases where the table is broken to 40 degrees for access to L4-5, however residual strain may exist unless table break is reduced. Anterior displacement of the nerve by approximately 1.5 mm was noted at 40° table break compared with 0°.

Conclusion: Strain values with table break of 40° approached those associated with reduced neural blood flow in animal studies. Table break should be minimized beyond that needed to access L4-5. These data may be considered when attempting to minimize post-operative dysesthetic leg pain after extreme lateral interbody fusion at L4-5.

Paper 13. Nerve Injury After Lateral Lumbar Interbody Fusion: A Review Of 919 Treated Levels With Identification Of Risk Factors

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Introduction: Although lateral lumbar interbody fusion (LLIF) has been reported as a way to mitigate the morbidity associated with direct anterior or posterior approaches, concerns remain about its safety regarding injury of the lumbar plexus as it travels within the psoas muscle. The purpose of this study was to address risk factors for iatrogenic nerve injury in a large cohort of patients undergoing LLIF.

Methods: The medical charts of patients who underwent LLIF for degenerative spinal conditions were retrospectively reviewed. Factors that may affect the neurologic outcome were investigated in a subset of patients who underwent stand-alone LLIF.

Results: 451 patients (males/females: 179/272) met the inclusion criteria and were followed for a mean of 15 months (range, 6-53 months). Average age at the time of surgery was 63 years (range, 24-90 years). A total of 919 levels were treated. Immediately after surgery, 38.5% of the patients reported anterior thigh/groin pain, while sensory and motor deficits were recorded in 38% and 23.9% of the patients, respectively. At the last follow-up, 4.8% of the patients reported anterior thigh/groin pain, while sensory and motor deficits were recorded in 24.1% and 17.3% of the patients, respectively. Among 87 patients with minimum follow-up of 18 months, persistent sensory or motor deficits were recorded in 9.6% and 2.3% of the patients, respectively. Among patients with stand-alone LLIF the level of fusion was identified as a risk factor for postoperative lumbar plexus injury (Table 1).

Conclusions: This is the largest series of patients underwent LLIF

Table 1. Risk factors for development of neurologic deficit and thigh pain after stand-alone LLIF.

Risk Factors		Motor Deficit (% of number of patients treated)				Sensory Deficit (% of number of patients treated)				Thigh Pain (% of number of patients treated)			
		Immediately Post-op		Last Follow-up		Immediately Post-op		Last Follow-up		Immediately Post-op		Last Follow-up	
			p-value		p-value		p-value		p-value		p-value		p-value
Gender	Male	21	0.894	13	0.396	33	0.551	18	0.963	25	0.005*	4	0.936
	Female	37		17		52		31		72		8	
Obesity		20	0.631	9	0.840	29	0.632	17	0.641	33	0.801	3	0.999
Laterality	Right	25	0.480	14	0.988	41	0.728	22	0.790	41	0.193	5	0.797
	Left	33		16		44		27		56		7	
Surgeon	1	23	0.179	14	0.098	33	0.455	23	0.285	54	0.002*	7	0.156
	2	16		7		24		16		23		5	
	3	6		4		4		0		3		0	
	4	13		5		24		10		17		0	
Level Fused	T12-L1	0	0.999	0	0.999	0	0.999	0	0.999	0	0.999	0	0.999
	L1-L2	8	0.760	6	0.405	11	0.531	3	0.963	11	0.160	1	0.999
	L2-L3	26	0.694	21	0.007*	46	0.098	28	0.113	48	0.494	5	0.693
	L3-L4	41	0.638	22	0.999	64	0.436	39	0.197	73	0.485	7	0.248
	L4-L5	42	0.257	21	0.617	62	0.077	33	0.821	64	0.880	10	0.193
Number of Levels Fused	≥2	39	0.887	23	0.182	63	0.038*	36	0.206	69	0.178	7	0.581
	≥3	16	0.924	12	0.097	30	0.024*	17	0.166	27	0.593	4	0.999
	≥4	4	0.738	5	0.005*	30	0.507	1	0.374	3	0.347	0	0.999
Length of Surgery (min)		165.1	0.704	154	0.514	173	0.084	160	0.772	165	0.680	151	0.548

with a total of 919 levels treated. Another advantage of this study is the large number of patients with follow-up of more than 18 months, a time point which is considered crucial for the characterization of a nerve defect as transient or permanent and, thus, the identification of the true prevalence of permanent neural deficits after LLIF. Although immediately after surgery LLIF is associated with increased prevalence of thigh pain, motor, and sensory deficits, our results support that the majority of these deficits are transient. The level of fusion appears to be a risk factor for lumbar plexus injury.

Paper 14. Outcomes of Two Different Techniques Using the Lateral Approach for Lumbar Interbody Arthrodesis

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Introduction: Interbody arthrodesis for the lumbar spine has been performed historically through open surgical approaches. Recently, there has been substantial growth in the utilization of the minimally invasive lateral approach with sparse outcomes data reported.

Methods: This is a retrospective review performed with multiple surgeons from Orthopaedic and Neurosurgery backgrounds. All patients at a single institution undergoing lateral fusions from July 2008 until July 2012 were reviewed. Data extraction included demographics, peri-operative parameters as well as radiographic analysis of fusion. Two different approach techniques were identified: 1) shallow docking (SD) superficial to the psoas with directly visualized dissection through the psoas, and 2) traditional transpsoas (TP) dissection using neuromonitoring. Outcome measures included radiographic fusion, adverse event (AE) rate, revision surgery rate, Visual Analog Scale (VAS), and Oswestry Disability Index (ODI) scores.

Results: 121 patients were identified, 80 female and 41 male. Average age was 63.2 years (22-86). When looking at all medical and surgical AE's, 31 patients (25.6%) had one or more AE. 22 patients (18.2%) had a total of 24 neurologically-related AE's. 15 patients (12.4%) had anterior/lateral thigh dysesthesias, 6 (5.0%) had radiculopathic pain and 3 (2.5%) had post-operative weakness. Specifically for lumbar plexus related AE's, 24.0% rate with the SD group and a 14.1% rate in the TP group, $p < 0.083$. 96.9% of patients had Grade A/B anterior fusion based on most current radiographs. VAS scores for back and leg pain improved from 7.1 to 4.0 ($p < 0.004$) and 6.3 to 3.8 ($p < 0.02$), respectively. ODI scores improved from 57.6 to 26.0 ($p < 0.01$).

Discussion/Conclusion: In this study, 18.2% of patients sustained a post-operative neurologic AE following lateral interbody fusions.

These episodes of paresthesias, weakness and radiculopathy were felt to be secondary to lumbar plexus stretch and ischemia. The TP approach appeared to have the lowest rate of neurologic-specific AE.

Paper 15. Clinical Outcomes And Radiographic Correction Of Coronal Segmental Angulation And Lumbar Lordosis Following Stand-alone And Supplemented Minimally Invasive Lateral Lumbar Interbody Fusion With 1 Year Follow Up

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Introduction: Most published studies with extended follow up report on patients that have undergone lateral lumbar interbody fusion (LLIF) surgery in adjunct with posterior stabilization procedures. We report our results in patients that underwent exclusive stand alone LLIF and compare their radiographic and clinical outcomes to those that have undergone LLIF in conjunction with posterior stabilization.

Methods: Sixty patients (31 stand-alone LLIF and 29 with supplementary posterior stabilization) were followed for 1 year. Patient reported Visual Analog Score (VAS) for back and leg pain, Oswestry Disability Index (ODI) and Short Form-36(SF-36) (PCS & MCS), were recorded. Radiographic evaluations included segmental coronal angulation, regional lumbar lordosis and the fusion status.

Results: At one year follow up in 31 patients who underwent stand-alone LLIF there was a statistically significant improvement in their mean VAS (Back and Leg Pain), ODI, SF-36(PCS+MCS) scores, and in their segmental coronal angulations (SCA) at the L3-4 and L4-5 levels. The mean SCA at L1-2 (3.3 to 2.3; $p = 0.36$) and L2-3 (3.8 to 1.9; $p = 0.17$) and the regional Lumbar lordosis (47.8 to 50.1, $p = 0.17$) improved but did not reach statistical significance. In 29 patients who underwent supplemented posterior stabilization there was a statistically significant improvement in their mean VAS (Back and Leg Pain), ODI, SF-36(MCS) scores, regional lumbar lordosis and in their SCA at all operated levels. The mean SF-36(PCS) scores improved from 24.5 to 21.5; $p = 0.15$. Successful fusion was achieved at 122/128 levels (95%).

Discussion: There is paucity of information on results of stand-alone LLIF and LLIF supplemented with posterior stabilization evaluated as exclusive from one another. There are reports in the literature which have found stand-alone LLIF sufficient to correct lumbar lordosis. In our study regional lumbar lordosis improved in all patients but did not reach statistical significance in patients who had a stand-alone LLIF.

Mean Value	Segmental Coronal Angulation								Lumbar Lordosis		VAS (Back Pain)		VAS (Leg Pain)		ODI		SF-36 PCS		SF-36 MCS	
	L1-2		L2-3		L3-4		L4-5													
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
LLIF	3.3	2.3	3.8	1.9	4	0.6	4	0.3	47.8	50.1	6.6	3.6	4.6	1.5	45.9	30.6	26.5	15.8	36	20.5
P value	0.36		0.17		<0.01		<0.01		0.17		0.01		<0.01		0.01		<0.01		<0.01	
LLIF+ Posterior Stabilization	6.3	2.4	5.4	1.2	3.2	0.9	5	1	45.3	48.8	7	4.1	5.2	3	47	35	24.5	21.5	36.2	25.9
P value	<0.01		<0.01		<0.01		<0.01		0.03		<0.01		<0.01		<0.01		0.15		<0.01	

Conclusion: LLIF surgery supplemented with a posterior stabilization is more likely to improve lumbar lordosis than a stand-alone LLIF.

Paper 16. Cancer Risk from Recombinant Human Bone Morphogenetic Protein-2 Exposure in Spinal Fusion

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Background: The FDA reported a higher incidence of cancer in spinal fusion patients exposed to recombinant human bone morphogenetic protein-2 (rhBMP-2) compared to the control group in a randomized controlled trial of a high-dose rhBMP-2 product, AMPLIFY. Large-scale data from clinical practice is unavailable. Using a large database of Medicare patients, our purpose is to compare the incidence of new malignant neoplasms after spinal fusion with and without exposure to rhBMP-2.

Methods: We identified Medicare patients who underwent spinal fusion between 2005 and 2009 (n=467,916). BMP was used in

110,808 patients (23.7%). We retrospectively compared the incidence of 24 invasive malignancies in patients with or without exposure to rhBMP-2. Patients with pre-existing cancers were excluded.

Results: The cancer incidence per 100,000 patient-years was 2,076 in the rhBMP-2 group and 2,212 in the control group, yielding an estimated relative risk of developing cancer in the BMP group of 0.938 (95% CI: 0.913 - 0.964). Thus, the relative risk reduction in the BMP group was 6.2%. In the rhBMP-2 group, 6,557 (5.9%) patients developed an invasive cancer compared to 24,477 (6.5%) patients in the control group. The relative risk of developing cancer after rhBMP-2 exposure was 0.98 in males (95% CI: 0.94-1.02) and 0.93 in females (95% CI: 0.90-0.97). The control group showed a higher incidence of each type of cancer except pancreatic cancer. The average follow up was 2.85 years in the rhBMP-2 group and 2.94 years in the control group.

Conclusions: Exposure to rhBMP-2 did not increase the risk of cancer; in fact, we observed a statistically significant lower incidence. It is possible that rhBMP-2 is protective, but we do not believe this to be true. Other explanations include varied surgical indications, demographic factors for which we could not adjust, and selection bias. In conclusion, it appears that recent clinical use of rhBMP-2 is not associated with an increased risk of cancer.

Paper 17. A Comparison of Spinal Fusion Capacity of BMP-2 Direct- and Indirect-Binding Nanogels Designed for Bone Regeneration

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Introduction: Recombinant bone morphogenetic protein-2 (rhBMP-2) has improved fusion rates in the lumbar spine, yet reported complications, including radiculopathy, seroma formation, and bone resorption, have provoked considerable interest in its safety profile. Improvements in carrier technology, such as our previously described nanofiber scaffold comprised of BMP-2-binding peptide amphiphiles, may allow surgeons to avoid undesired complications associated with rhBMP-2 through more targeted and efficient growth-factor delivery. The aim of this study was to compare the osteoinductive capacity of this BMP-2 direct-binding nanogel (BMP-2PA) with that of a novel nanogel comprised of heparin-binding peptide amphiphiles (HBPA), which indirectly binds various endogenous anabolic signaling proteins, including BMP-2.

Methods: Posterolateral lumbar intertransverse spinal fusion (L4-L5) was performed on 24 Sprague-Dawley rats assigned to groups treated with one of two scaffolds: HBPA [HBPA+heparan sulfate (HS)-loaded absorbable collagen sponge (ACS)] or BMP-2-binding nanogel (BMP-2PA). Each scaffold was pre-loaded with 0.1µg rhBMP-2 (per animal), a dose that does not fuse the rat spine when preloaded onto ACS alone. Fusion was assessed via DV radiographs and manual palpation. Spines were scored by three blinded observers using an 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: The HBPA/HS/ACS scaffold elicited significantly higher fusion scores relative to BMP-2PA ($p = .038$). The fusion rate was also higher in the HBPA/ACS group (58%) relative to the BMP-2PA group (33%, Figure 1).

Discussion: HBPA incorporated onto a heparan sulfate/ACS scaffold demonstrated improved spine fusion capacity relative to a BMP-2PA nanogel equivalently pre-loaded with a low dose of rhBMP-2. The heparan-binding peptide amphiphiles likely improve bone formation through indirect binding of not only exogenous and endogenous BMP-2, but also other endogenous pro-osteogenic growth factors, such as BMP-7 and VEGF.

Conclusions: Further studies will evaluate the HBPA scaffold pre-loaded with a combination of low-dose pro-osteogenic growth factors with the hope of achieving reproducible fusion without adverse

effects associated with supraphysiologic doses of rhBMP-2. This technology could further reduce the threshold rhBMP-2 dose required for spine fusion.

Paper 18. Beyond Complications: rhBMP-2 Effects on Fusion Rates in Lumbar Spine Surgery

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Introduction: Recombinant human bone morphogenetic protein-2 (rhBMP-2) received FDA approval in 2002 as an alternative to iliac crest bone growth (ICBG) for anterior lumbar interbody fusion (ALIF). rhBMP-2 is commonly utilized in ALIF to improve fusion rates. Utilization of rhBMP-2 off-label is also widespread in posterior lumbar interbody fusion (PLIF)/ transforaminal lumbar interbody fusion (TLIF) and posterolateral spine fusion (PSF). Reports of equivalent or superior fusion rates and low complication rates with rhBMP-2 compared to ICBG motivated its utilization. However, recent reports have highlighted complications of rhBMP-2 in these procedures. Thus, understanding the effect on fusion rate of rhBMP-2 is important in deciding whether its benefits outweigh possible complications.

Methods: A systematic review for clinical studies published between May 2000 and May 2012 comparing fusion rates with or without rhBMP-2 for ALIF, PLIF/TLIF, and PSF was performed. A total of 25 studies (20 prospective and 5 retrospective) consisting of 2067 patients was fully reviewed and summarized.

Results: Average fusion rate at 24 month follow up was 97.4 for ALIF, 96.7 for PLIF/TLIF, and 93.7 for PSF with rhBMP-2 and 82.4, 77.8, and 82.8 without rhBMP-2, respectively. Of the studies reporting fusion rates 24 months post-surgery, 2 out of 6 for ALIF, 0 out of 2 for PLIF/TLIF, and 3 out of 7 for PSF showed significantly improved fusion rates in patients who received rhBMP-2.

Conclusions: Although numerous studies showed a trend toward higher fusion rates in ALIF and PSF patients treated with rhBMP-2, only a few showed a significant advantage. Notably, none of the identified studies showed significantly higher fusion rates in PLIF/TLIF with rhBMP-2. Thus, there are currently limited data supporting the use of rhBMP-2 in ALIF, PSF, and particularly in PLIF/TLIF patients. Future studies should aim at definitely elucidating whether benefits outweigh risks to warrant its use in these operations.

Paper 19. Incidence, Etiology and Clinical outcomes of Reoperation in Adult Spinal Deformity Surgery

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Introduction: Reoperations after primary and revision surgery for adult spinal deformity are an important determinant of the cost and value of care for adult deformity. The purpose of this paper is to measure the rate of reoperation, the causes of reoperation, and the outcomes of surgery in a consecutive series of patients with adult deformity.

Materials: Retrospective study of a consecutive series of patients who underwent adult spinal deformity surgery at a single institution from 2005 to 2010 with a minimum follow-up period of 2 years. Inclusion criteria included a minimum age at surgery of 20 years and fusions ≥ 5 levels. Data included patient-based measures of health status, radiographic data, and revision status.

Results: The cohort included 145 consecutive patients (mean age 59 years; female 122, male 23). The cumulative reoperation rate was 53.8% (78 patients) for all patients. The survival rate (avoidance of revision surgery) was 68% at 1 year, 57% at 2 years, and 52% at 3 years. Revision patients were as likely to require reoperation as patients undergoing primary surgery. ($P=0.657$). Reasons for reoperation included infection ($N=15$, 10.3%), pseudarthrosis ($N=15$, 10.3%), adjacent segment problems ($N=18$, 12.4%), implant failure ($N=8$, 5.5%), painful implant ($N=13$, 9%), neurological problems ($N=7$, 4.8.0%), and other causes ($N=2$, 1.4%). Multivariate analysis by Cox proportional hazards model identified smoking (Hazard ratio: 2.1, $P=0.009$) and preoperative pelvic incidence (PI) - lumbar lordosis (LL) mismatch ($\geq 10^\circ$) (Hazard ratio: 2.0, $P=0.025$) as independent factors predicting reoperation. Pre-operative health status was similar in the primary and revision cohorts. Both cohorts had a significant improvement in health status after surgery. At final follow-up, patient who required reoperation reported less improvement of health status than those who did not require reoperation.

Discussion: Reoperation after adult spinal deformity surgery is common. Patients undergoing primary surgery were as likely to require reoperation as patients undergoing revision surgery. Significant risk factors for reoperation included smoking status and preoperative PI / LL mismatch. Reoperation is a significant cost, and results in a less reliable improvement of health status at final follow-up compared with patients who did not require reoperation.

Paper 20. The Biomechanical Consequences of Rod Reduction Following Thoracic Ponte Osteotomy and Lumbar Facetectomy

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Introduction: When a residual mismatch occurs between the rod and pedicle screw head, using a rod persuasion device has been found to reduce pedicle screw pull-out strength (POS) in the thoracic spine. However, posterior-only Ponte osteotomies in the thoracic spine, and facetectomies in the lumbar spine, are performed during many deformity surgeries to improve flexibility/correction of the spine and offset forces of the rod reduction and deformity correction maneuvers. We investigated the ability of complete facet osteotomies in the thoracic and lumbar spine to counteract the reduction in POS seen with the rod reduction technique.

Methods: 15 thoracic and 9 lumbar three-level, fresh-frozen human cadaveric specimens were prepared. Thoracic Ponte osteotomies and lumbar facetectomies were performed on each segment. Instrumentation was performed at all levels with polyaxial titanium pedicle screws. 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 at the middle level and then reduced using a rod-reduction device. On the left side (paired control), a rod with no residual rod-screw mismatch was placed. To simulate screw depth adjustment as an alternative to rod reduction, a screw from the bottom level of each three-segment specimen was backed out one complete revolution. Biomechanical testing was performed with tensile load to failure "in line" with the screw axis and POS was measured in Newtons (N).

Results: Thoracic: After rod reduction, thoracic pedicle screws had significantly decreased POS compared to the control group (40% decrease; 419 ± 426 N vs 708 ± 462 N; $p=0.002$), and remained statistically significant after adjusting for BMD as a covariate ($p=0.002$). Eleven (73%) of the pedicle screws had visible pull-out/failure during the reduction attempt and occurred irrespective of BMD.

Lumbar: Rod reduction significantly decreased lumbar pedicle

screw POS compared to the control group (36% decrease; 961 ± 352 N vs 613 ± 563 ; $p=0.048$), and also remained statistically significant after adjusting for BMD as a covariate ($p=0.048$). Two of nine screws (22.2%) had outright failure during rod reduction, with visible pedicle screw pull-out.

Screw Depth Adjustment: In both the thoracic and lumbar specimens, no significant difference was detected in POS between the backed-out screw and paired control (thoracic: 824 ± 402 N vs 790 ± 364 N; $p=0.41$, lumbar: 790 ± 390 N vs 635 ± 374 N, $p=0.16$).

Conclusion: Despite thoracic Ponte osteotomies and lumbar facetectomies, the rod reduction device still significantly decreased pedicle screw pullout strength; 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 suboptimal pedicle screw fixation.

Paper 21. Does Curve Magnitude/Deformity Correction Correlate with Pulmonary Function after Adult Deformity Surgery?

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Summary: We evaluated the relationship of pre-op curve magnitude and deformity correction with pulmonary function in 76 adult patients following spinal deformity surgery. Pre-op main thoracic (MT) curve magnitude correlated negatively with pre-op pulmonary function, and MT deformity correction correlated negatively with %pred PFTs. This suggests that a greater MT deformity correction may result in significantly less decline in pulmonary function than smaller curve corrections. Sagittal curve magnitude/deformity correction and pulmonary function did not demonstrate a significant relationship.

Introduction: The effect of surgical correction on pulmonary function of adult spinal deformity patients is unknown. The purpose of this study was to determine if a correlation exists between curve magnitude, deformity correction and postoperative pulmonary function (PFTs) following adult spinal deformity surgery.

Methods: We prospectively collected PFTs on 76 adult deformity patients (70F, 6M, avg age 41.2) undergoing primary surgical treatment for idiopathic scoliosis at a single institution and followed them for 2 years (avg 2.93). Radiographs for all pts were analyzed for main thoracic (MT) and sagittal T5-T12 (Sag) curve magnitude/correction.

Results: For all patients, there was a significant change in MT Cobb correction from 53.2 to 20.8 deg (avg -32.5 deg, $p=0.00$), Sag Cobb from 35.3 to 28.8 deg (avg -6.50 deg, $p=0.00$), and a significant decline in absolute and %pred PFTs after surgery, with %pred FEV1 and %pred FVC decreasing 5.86% ($p=0.00$) and 3.54% ($p=0.01$), respectively. We found pre-op MT curve magnitude significantly correlated (moderate, negative) with pre-op absolute and %predicted PFTs ($r=0.364$ to 0.506 ; $p=0.001$). The amount of MT deformity correction was also significantly correlated (weak, negative) with changes in %pred FEV1 and %pred FVC [change%pred FEV ($r=-0.238$, $p=0.04$); change%pred FVC ($r=-0.249$, $p=0.03$)], and there was no significant relationship between Sag deformity correction and PFTs.

Conclusion: Pre-op MT curve magnitude in adult spinal deformity patients negatively correlated with pre-op pulmonary function (PFTs). There was also a negative correlation between MT deformity correction and %pred PFT change, which suggests that greater MT curve correction may result in significantly less decline in pulmonary function than smaller curve corrections.

Paper 22. Pulmonary Function Following Adult Spinal Deformity Surgery: Minimum Two Year Follow-Up

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Walter Reed National Military Medical Center

Summary: We performed the largest study to date evaluating pulmonary function tests (PFTs) following surgery in 164 adult spinal deformity patients with minimum 2-year follow-up. Our results demonstrate significant decline in all measures of pulmonary function following deformity surgery, with a clinically significant decline ($\geq 10\%$ predFEV1) in pulmonary function in 27% of patients. However, we found patients with pre-op pulmonary impairment ($< 65\%$ pred FEV1) may actually benefit from deformity correction surgery. Revision surgery more frequently (35% v 23%) results in a clinically significant decline in PFTs.

Introduction: Pulmonary function following adult spinal deformity remains uncertain. We hypothesized patients with pre-op PFT impairment ($< 65\%$ pred FEV1) and those undergoing revision surgery may be at risk for exacerbated decline in pulmonary function.

Methods: PFTs were prospectively collected on 164 adult spinal deformity patients (150F, 14M, avg age 45.9) undergoing surgical treatment at a single institution, with minimum 2 yr follow-up (avg 2.81). There were 100 (61%) primary and 64 (39%) revision surgery patients, and the majority had posterior only surgery (77%). Radiographs for 154 patients were analyzed for main thoracic (MT) and sagittal T5-T12 (Sag) curve magnitude/correction.

Results: For all patients, there was a significant change in MT Cobb from 47.4 to 24.9 deg (avg -22.5, $p=0.00$), and Sag Cobb from 35.5 to 30.0 deg (avg -5.41, $p=0.00$). We also found a significant decline in absolute and %pred PFT, with %pred FEV1 and %pred FVC decreasing 5.26% ($p=0.00$) and 5.74% ($p=0.00$), respectively. A clinically significant decline ($\geq 10\%$ pred FEV1) was observed in 27% of patients. PFT impairment increased from 14 (8%) patients pre-op to 23 (14%) patients after surgery, but was not statistically significant ($p=0.31$). Interestingly, patients with pre-op PFT impairment had a significant improvement in absolute and %pred FEV1 after surgery compared to those without pre-op impairment (2.8% v -6.19%, $p=0.03$), with no significant differences in MT/Sag curve correction between the two groups. Revision surgery patients had no difference in post-op %pred PFTs, however there were significantly more patients with a clinically significant decline in PFTs [23 (35%) v 22 (22%), $p=0.03$].

Conclusion: We performed the largest study to date evaluating pulmonary function tests in adult deformity patients, and found a significant decline in all measures of pulmonary function at 2 years following surgical correction. Surprisingly, patients with pre-op PFT impairment had improvement in absolute and %pred PFTs postoperatively. Revision surgery more frequently results in a clinically significant decline in PFTs.

Paper 23. The Effects of Time, Temperature, and Media on Nucleated Cell Survival in Bone Marrow Aspirate from Lumbar Vertebral Bodies

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Introduction: Bone marrow aspirate (BMA) from the iliac crest and the vertebral body have been shown to promote spinal fusion. The nucleated cell count (cells/ml) of BMA has been associated with

this positive effect. Nucleated cell counts have been shown to be proportional to alkaline phosphatase producing cells (osteogenic cells) in prior studies. Factors such as aspiration volume, age, and gender have been associated with nucleated cell counts in BMA.

This study was performed to evaluate the potential effect of controllable factors to optimize survival of cells in BMA once it has been harvested. Time since aspiration, storage temperature, and storage media were evaluated.

Methods: Using a cannulated pedicle tap, 4 ml of vertebral BMA were obtained from left and right adult lumbar pedicles during instrumentation for degenerative or deformity issues. Using a hemocytometer, nucleated cell counts were determined from aliquots of these specimens. For aliquots from the right pedicles, cell counts were performed at times zero, 0.5 hours, 1 hour, 2 hours, and 4 hours after aspiration when left at 20°C. For aliquots from the left pedicles, cell counts were repeated after one hour of storage at 0°, 20°, or 37° C, as well as after one hour in alpha minimal essential medium (aMEM), saline, or no medium at 20°C.

Results: Preliminary data has been collected on 28 pedicles and the following cell counts are expressed as 106 cells/ml.

With time, nucleated cell counts decrease: at time zero 5.36 ± 0.76 , at 0.5 hours 3.59 ± 0.57 , at one hour 3.34 ± 0.54 , at 2 hours 2.91 ± 0.64 , and at 4 hours 2.48 ± 0.37 . Cell counts had decreased by approximately half at 2 hours post aspiration.

These initial data show no trend or statistical difference between nucleated cell counts after one hour at 0°, 20°, or 37° C (4.95 ± 1.83 , 5.16 ± 1.04 , and $37^\circ 6.26 \pm 1.18$, respectively). These data also show no trend or statistical difference between nucleated cell counts after one hour in saline, aMEM, or in no medium (5.23 ± 0.81 , 5.22 ± 1.27 , 4.64 ± 1.00 , respectively).

Discussion and Conclusion: The vertebral body is a readily available source of BMA in spinal instrumentation cases. We expected that handling conditions of the BMA prior to implantation might significantly affect cell viability. Preliminary data suggest that BMA cell counts slowly decrease with increasing time from aspiration (decrease by approximately half by two hours), but that choice of temperature and medium for storage of vertebral BMA does not significantly affect nucleated cell counts.

Paper 24. In Vivo Tissue Engineering of the Intervertebral Disc with an Injectable Biopolymer Containing Growth Factors and Allogenic Bone Marrow-Derived Stromal Cells

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Introduction: A study was undertaken to examine the regenerative potential of intradiscal, biopolymer-mediated delivery of a combination of growth factors, a protease inhibitor and allogenic marrow-derived stromal cells in a model of acute disc injury.

Materials and Methods: Marrow was aspirated from the distal femur and tibiae of New Zealand White rabbits. After 24 hours of culture, non-adherent cells were removed and the adherent cells were cultured to characterize osteogenic and chondrogenic differentiation capacity.

Thirty New Zealand White rabbits underwent aspiration of the nucleus pulposus at L1-L2 and L3-L4. Following aspiration, one disc was randomized to be untreated, while the remaining disc was filled with a Chitosan hydrogel, Chitosan with TGF- β 3 and BMP-4, Chitosan with TGF- β 3, BMP-4 and TIMP-2, Chitosan with allogenic stromal cells, or Chitosan with TGF- β 3, BMP-4, TIMP-2 and stromal cells. Six weeks after implantation, quantitative T2 mapping MRI and histology was used to evaluate disc regeneration.

Results: Stromal cells demonstrated the capacity to differentiate down both the osteogenic and chondrogenic pathways when cultured in specific media. When exposed to normal defined media augmented with TGF- β 3, BMP-4 and TIMP-2, chondrogenic lineage was also observed.

Loss of disc height and endplate changes marked levels that received disc aspiration alone. Quantitative T2-mapping of the spines similarly demonstrated that the implantation of growth factor- or stromal cell-loaded hydrogels resulted in proteoglycan content closer to that of healthy discs. Safranin-O/Fast Green-stained sections further reinforced MRI findings relative to proteoglycan content with growth factor- and stromal-cell loaded hydrogels showing greater proteoglycan content when compared to defect only discs, or discs treated with hydrogel alone.

Discussion: This study demonstrated that stromal cells possess the ability to differentiate toward a chondrogenic lineage when exposed to a combination of TGF- β 3, BMP-4 and TIMP-2. These results were translated into an animal model of acute disc injury, indicating that Chitosan-mediated delivery of biomolecules with or without stromal cells is a promising method for regenerating the intervertebral disc.

Conclusion: Intradiscal delivery of anabolic growth factors, a protease inhibitor and marrow-derived stromal cells via Chitosan hydrogels represents a promising tissue engineering-based method to affect disc regeneration.

Paper 25. Annular repair using high density collagen gel: In vivo outcome in a rodent spine model

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Weill Cornell Medical College

Introduction: Lumbar discectomies decompress the affected nerve root leaving the annular defect untreated, which increases the risk for

reherniation. Several different approaches have been investigated to repair annulus fibrosus (AF) defects. This is the first study to test a biological substance in vivo. We used high density collagen gel in a needle puncture rat tail model. Needle puncturing leads to extrusion of NP tissue with consecutive degenerative changes. Restoring annular integrity may help to retain the NP material and therefore inhibit these changes.

Methods: We used type I collagen in a 15mg/ml concentration which has been proven superior in prior biomechanical in vitro studies. The animals were subdivided into three groups. The first group (n=14) was openly punctured with simultaneous collagen injection into the defect. The second group (n=9) was punctured and injected with riboflavin cross-linked collagen. The third group (n=6) was punctured and left untreated to serve as control. All animals underwent postoperative X-Ray and MR imaging at a 1 week, 2 week and 5 week time point. X-rays were used for disc height measurements. A T2 MRI sequence was used to study morphological degenerative changes. We developed a new algorithm to assess the NP volume and hydration quantitatively based on T2 relaxation time measurements. After 5 weeks the specimen were sacrificed and the tails collected for histological assessments.

Results: The control group developed severe signs of degeneration after 5 weeks on MRIs and histological sections (Fig.1). The NP volume and disc height dropped to 3% and 53%, respectively, compared to adjacent healthy discs. In the non-cross-linked collagen group disc height of 66% was maintained with a NP volume drop to 9%. On MRI and histological sections the discs showed signs of moderate degenerative changes. The cross-linked collagen group showed only mild degenerative changes on MRIs. The discs maintained a NP volume of 48% and a disc height of 77%. Histological section revealed healthy NP tissue in the disc space. The outer part of the disrupted annulus showed a fibrous cap which appeared to seal the defect.

Conclusions: Cross-linked high density collagen gel has the ability to partially restore annular integrity and reduce degenerative changes of a punctured IVD in a rat tail spine.

Fig. : Top row, histological sections stained with Safranin-O for proteoglycans, bottom row corresponding T₂ weighted MRI at 1 month. **Picture A**, untreated punctured disc. Severe degenerative changes. The NP is completely replaced by fibrous scar tissue. Safranin-O stain is negative. Corresponding MRI shows a highly degenerated black imploded disc. **Picture B**, HDC injected disc. Mild degenerative changes on histological slides. The NP stains positive for Safranin-O. Less NP matrix tissue visible and less distinct border to the AF compared to healthy discs. MRI shows degenerative changes with reduced NP signal intensity and size, the border to the AF is not distinct. **Picture C**, cross-linked HDC injection. Histological slide and corresponding MRI show no signs of significant degeneration.

Paper 26. The Mechanistic Role of Dioxin in Smoking-Mediated Inhibition of Bone Healing

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Introduction: Smoking is known to inhibit bone healing and lead to increased rates of pseudarthrosis after spine surgery. The historical notion that nicotine exclusively inhibits bone healing has not been fully substantiated. Dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin, TCDD), a carcinogenic component of cigarette smoke, demonstrates negative impact on bone quality however the mechanism of its action remains poorly understood. We hypothesize a significant inhibitory effect on bone healing by dioxin. This study aims to investigate the effect and mechanism of TCDD on in vitro osteoblastic activity.

Methods: MG63 human preosteoblasts were cultured under standard or osteogenic conditions. Cellular alkaline phosphatase activity was quantified with colorimetric assay. Mineralization was quantified using alizarin red staining and subsequent destaining with cetylpyridinium. A scratch assay was performed to evaluate the rate of cell migration after various treatment parameters. Rates of cell adhesion to fibronectin and absorbable collagen sponge (ACS) were also evaluated after dioxin treatment.

Results: ALP and mineralization activity were both decreased in MG63 cells after treatment with dioxin under osteogenic conditions, however this decrease was absent with nicotine. Dioxin, but not nicotine, significantly reduced the rate of preosteoblast migration; this effect was reversed with co-treatment with the aryl hydrocarbon receptor (AHR) antagonist, alpha-naphthoflavone (ANF) or with supplementation with exogenous CXCL12 (Figure 1). In contrast, dioxin had no effect on the rate of adhesion preosteoblasts to fibronectin or ACS.

Discussion: A multitude of factors likely play a role in smoking-mediated inhibition of bone healing. Our data indicate that through activation of the AHR pathway, dioxin may impact osteogenesis via inhibition of the CXCR4/CXCL12 axis. At least in part, these effects appear to be distinct from the effects of nicotine on these osteogenic factors.

Conclusions: Smoking is a known risk factor for complications in bone healing after fractures or surgery, yet few studies have investigated the inhibitory role of dioxin. Elucidation of the molecular mechanisms of dioxin action in smoking-mediated bone healing inhibition could facilitate the development of potential therapeutic agents to reverse such effects in the smoking population. Our follow-up studies will quantify the impact of dioxin on spinal fusion rates in vivo.

Figure 1. Average percentage wound closure of MG-63 cells after treatment with TCDD, nicotine, or vehicle control. Distances were calculated 15 hr post-scratch. * p < 0.05

Paper 27. Quality of Life Outcomes with Minimally Invasive Transforaminal Lumbar Interbody Fusion: A Long Term Analysis of 304 Consecutive Patients

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Introduction: Long-term prospective outcomes in patients undergoing minimally invasive spinal fusion for debilitating back pain has not been well studied.

Methods: Minimally invasive transforaminal lumbar interbody fusion (MITLIF) was performed on 304 consecutive patients (184 females, 120 males) from December 2003 to September 2010 using a paramedian muscle-sparing approach. Mean age was 62.4 years (range: 19-93). Diagnosis included lumbar spondylolisthesis (n=236) and degenerative disc disease (n=82), based on radiographic (X-ray, MRI, CT-scan) evaluations. The majority of cases were at L4-L5 (n=152) and L5-S1 (n=88). Other cases included L1-L2 (n=4), L2-L3 (n=15), L3-L4 (n=33), and multi-level cases (n=12). Fusion was assessed using lumbar CT-scans. A key criterion for fusion was the presence of osseous bone bridging between vertebrae. Functional outcomes were measured using the visual analog scale (VAS) and Oswestry disability index (ODI), and quality of life outcomes were measured using the Short-Form 36 (SF-36) questionnaire. Patients were assessed pre-operatively, at two weeks, six months, and twelve months post-operatively, and prospectively followed-up with over a 2-7 year duration (mean follow-up time: 47 months).

Results: Estimated blood loss and hospital stay was 128.4 mL's and 4.4 days, respectively. The mean final follow-up time was 47 months (range: 2-7 years). Short-term VAS scores improved significantly from 7.0 pre-operatively to 4.5 at 2 weeks follow-up. Mid/long-term VAS scores were 4.8 and 3.6 (p<0.001) at 12 and 47 months follow-up, respectively. ODI scores improved from 43.2 pre-operatively to 28.3 and 28.8 (p<0.001) at 12 and 47 months follow-up, respectively. SF-36 mental component scores (MCS) improved from 43.8 pre-operatively to 48.0 and 49.7 (p<0.001) at 12 and 47 months follow-up, respectively. Similarly, SF-36 physical component scores (PCS) improved from 30.6 pre-operatively to 40.0 and 38.9 (p<0.001) at 12 and 47 months follow-up, respectively. Overall, VAS scores displayed a 50.0% improvement, ODI scores displayed a 34.6% improvement, SF-PCS displayed a 29.4% improvement, and SF-MCS displayed a 13.5% improvement from baseline at 47 months follow-up.

Conclusions: MITLIF resulted in a high rate of spinal fusion and a very low rate of adjacent segment disease requiring re-operation. This study presents a large, long-term, prospective outcomes analysis of MITLIF revealing clinically and statistically significant outcome improvement out to seven years. This study, therefore, endorses the practicality of using minimally invasive surgical techniques in lieu of traditional open surgery to promote prompt recovery and good long-term outcomes.

Paper 28. A Multi-Center Evaluation of Clinical and Radiographic Outcomes Following High-Grade Spondylolisthesis Reduction and Fusion

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Introduction: A retrospective review of the clinical and radiographic outcomes from a multi institutional study treating high grade Spondylolisthesis with reduction and circumferential fusion. The

objective was to assess the safety of surgical reduction and the ability to correct slip correction. We report on patient outcome measures at most recent follow up.

Methods: Twenty five patients, aged 19- 72 years with high grade spondylolisthesis (Meyerding grade 3-4) underwent open decompression, and reduction with instrumented circumferential fusion on levels ranging from L1 to the Ilium (A total of 17 interbody cages were placed, 15 TLIF, 1 PLIF and 1 ALIF); 5 patients required sacral dome osteotomies. Pre and post-operative calculations measuring the Meyerding grade, slip angle and sacral inclination were recorded to objectively quantify the spinal deformity correction. Prolo and ODI scores at the most recent follow up were calculated. The average follow up was 21.3 months.

Results: At the most recent follow up the mean Meyerding grade improved from 3.4 to 1.5($p<0.01$), the mean slip angle improved from 17.3 to -5.1 ($p<0.01$). The mean sacral inclination improved from 41 to 42.2 ($p=0.31$). There was one intra operative complication resulting in a neurological deficit (4%) and one construct related complication (4%). There were no cases of nonunion or device failure. The mean Oswestry Disability Index and Prolo scores at a mean follow up of 21.3 months were 20% (minimum disability) and 8.2 (grade 1, normal function being a score of 9 and 10) respectively. The mean VAS score improved from 7.7 to 2.4 ($p<0.01$).

Discussion: Reduction of high grade slips has been reported to portend a high complication rate. Due to the rarity of high-grade lumbosacral Spondylolisthesis the best evidence on its most effective treatment available to date is limited to retrospective case series. Most retrospective series predate modern techniques of transpedicular instrumentation, which makes any conclusions from these publications of limited relevance. Reduction of a high grade slip, in conjunction with wide neural element decompression and instrumented arthrodesis is safe, effective, and durable with low rates of neurologic injury

Conclusion: The results of this study reinforce that open decompression and slip reduction of high grade Spondylolisthesis rectifies the local deformity resulting in clinical and radiographic improvements.

Paper 29. Sacrectomy And Adjuvant Radiotherapy For The Treatment Of Sacral Chordomas - A Single Centre Experience Over 27 Years

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Introduction: There are few long- term studies on treatment of sacral chordomas with >20 patients, and factors related to survival are not fully understood. We report our results in 21 patients treated at a single center.

Methods: Patients were treated with en bloc resection +/- adjuvant radiotherapy with minimum follow-up ≥ 2 years. Demographics, treatment details, complications and recurrence were evaluated. Retrospective cohort design was used to assess the impact of recurrence and other factors on sacral chordoma survival. Analysis included summary statistics as applicable, hypothesis testing with Mantel- Hansen -Cox analysis, log- rank test, Cox proportional hazard model, and Kaplan-Meier survival estimates.

Results: There were 21 patients (12 males, 9 females) with mean age 61 years (16-79 years) and mean follow-up of 5.8 years (max 19.2 years). Tumor stage was IB in 20 and IIIB in 1 and mean size was 10.5 cm. Fourteen patients underwent combined AP en bloc resection and 7 underwent posterior resection, 18 received adjuvant radiotherapy. Margins were positive in 5, marginal in 6 and wide in 10. Last roots preserved were L5 (4), S1 (10), S2 (5) and S3 (2). After treatment, normal bowel and bladder control were present in 4 and 5

patients respectively. Complications included wound infections (4), significant wound complications (9), fistula (2), DVT (1) and PE (1). Median survival was 7.2 years for all patients. Eight (40%) had local/metastatic recurrence. Mean interval before recurrence was 2.5 years (1-5 years). None of the 8 patients treated in the past nine years had any recurrence. Patients who were treated for recurrence survived a mean of 5.7 years (0.8- 9 years) after first recurrence. Apart from a marginally statistically significant association with proximal extent of tumor ($p=0.05$) there were no significant factors for recurrence. There was a statistically significant association of recurrence and survival ($RR=3.8$, 95% CI, 1.0-15.3, $p=0.04$). Tumor size was marginally associated with survival, ($HR=1.07$, 95%CI 1.0-1.19).

Conclusions: Despite the complications, increased long-term survival can be achieved with en bloc resection and adjuvant radiotherapy of sacral chordomas. Proximal extent of tumor and size may be related to recurrence and survival. As surgeon experience has increased, recurrence rates have diminished.

Paper 30. A Quantitative Proteomic Analysis of the Non-Chondrodystrophic and Chondrodystrophic Canine Nucleus Pulposus: Whither the Notochord?

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Introduction: The morphology and cellular configuration of the intervertebral disc (IVD) nucleus pulposus (NP) varies dramatically between the notochordal cell-rich non-chondrodystrophic (NCD) and the chondrocyte-like cell rich and notochordal cell poor chondrodystrophic (CD) canine as does their respective susceptibility to degenerative disc disease. Here through the use of iTRAQ quantitative proteomic analysis we have for the first time determined the differential protein/peptide 'fingerprint' of the NCD and CD canine NP.

Methods: We identified differences in protein/peptides contained within the NCD and CD canine NPs using quantitative iTRAQ proteomic analysis. NPs obtained from the IVDs of 8 (4 NCD and 4 CD) dogs were mechanically homogenized/centrifuged and identical aliquots of soluble proteins from the supernatant were then extracted in the presence of protease inhibitors and analyzed using the 4-plex iTRAQ analysis. We separated the proteins/peptides on a nano-LC column and the eluting peptides were analyzed a minimum of two times each on either a QStar Elite or the 5600 Triple TOF instrument and the subsequent MS data were then analyzed using ProteinPilot

Protein ID	Mean NCD:CD Expression Ratio	Mean CD:NCD Expression Ratio
Fibronectin	0.4	6.75
Decorin	0.15	7.15
COMP	0.23	2.9
CILP	0.42	3.85

Table 1: iTRAQ Expression Ratios of Canine NP homogenates

software. Those proteins demonstrating consistent differential expression in either the NCD or CD samples that were greater than two-fold relative to the reference pool were selected for further investigation.

Results: Dramatic differences in the expression of a number of important extracellular matrix-related proteins within the NPs of these two canine sub-species were detected. Significant differences in protein expression were: Fibronectin, decorin, biglycan, cartilage intermediate layer protein (CILP), cartilage oligomeric protein (COMP), fibromodulin, biglycan, and isoform B of proteoglycan-4 (lubricin) all of which were dramatically under expressed in the NCD canine NP as compared to the CD canine NP (Table 1).

Conclusions: We have determined that the small leucine rich proteoglycans (SLRPs) or interstitial proteoglycans such as decorin, biglycan as well as fibromodulin were far more abundant in the CD NP homogenate as compared to the NCD canine. Furthermore, ECM-related molecules such as fibronectin and (CILP) were expressed in much more abundance by the fibrous/degenerative CD NP. All of the ECM proteins referenced here in particular fibronectin and CILP have been shown to increase with increasing age, DDD and osteoarthritis and some are associated with growth factor repair inhibition. It is possible that the NP tissue homogenates yielded elevated ECM proteins due to spontaneous degenerative changes underway in the CD as compared to the NCD NP, making this animal an ideal biological entity with which to study the biology of DD.

Paper 31. Tissue-engineered Intervertebral Discs: In Vivo Outcome In The Rodent Spine

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Weill Cornell Medical College

Introduction: Tissue-engineered intervertebral discs (TE-IVD) are a potential biological approach for the treatment of degenerative

disc disease. Compared to conventional implants, TE-IVDs have the potential to mimic physiological properties of native discs. We evaluated our biological implants in the rat tail spine according to biochemical, mechanical, radiological and histological parameters.

Methods: The nucleus pulposus (NP) and annulus fibrosus (AF) cells of our TE-IVDs were harvested from sheep IVDs and embedded in alginate (NP) and collagen (AF), respectively. The discs were implanted between the 3rd and 4th vertebrae of the rat tail spine. The first group of animals (n=12) was sacrificed after 6 months and the explanted segments were studied for their biochemical composition and mechanical properties specifically for equilibrium modulus and hydraulic permeability.

A second group (n=8) was sacrificed after 8 months with follow-up MRIs obtained at 1, 5, and 8-month time points to study the disc height and the morphological appearance of TE-IVDs. MRI based T2-relaxation time (RT) measurements were performed to assess the water content and volume of the (NP), T1ρ-RT measurements to assess its proteoglycan content. After euthanization the segments were collected for histological assessments. A control group (n=10) underwent simple discectomy.

Results: Biochemical analysis after 6 months showed that the TE-IVDs contained collagen and proteoglycan distributions similar to those of the native AF and NP. Mechanical tests revealed properties comparable to intact native discs.

Over 8 months the disc height of TE-IVDs remained constant between 68-74% of healthy control discs. MRIs showed a TE-IVD morphology comparable to native discs (Fig. 1, III). T2-RT measurements revealed a similar NP water content with a lower NP volume compared to healthy discs (Fig. 1, IV) T1ρ-RT measurements indicated proteoglycan synthesis in TE-IVDs.

Histological slides showed an annulus fibrosus consisting of an organized fiber structure encapsulating the NP (Fig. 1, I,II) The NP matrix appeared amorphous, stained for proteoglycans and contained chondrocyte resembling cells. The discectomy group showed complete collapse and no signs of viable disc tissue.

Conclusions: TE-IVDs demonstrated similar properties as native discs in vivo and remained viable over 8 months. The discs showed evidence of dynamic adaptation to the host environment with matrix production and cell proliferation. TE-IVDs should be explored further in larger animal studies.

Fig. 1: I, Histology TE-IVD, Alcian blue stain after 8 months. The NP in the center of the disc is surrounded by the AF. II, Higher magnification of I. The chondrocyte like NP cells are embedded in an amorphous matrix. The AF (blue arrow) consists of an organized matrix and spindle shaped fibroblasts. III, MRI of the same specimen. The TE-IVD (white arrow) has a similar morphological appearance as a native disc. IV, Corresponding T₂-RT image presented as a heat map. Warm colors represent high T₂ values which indicates high water binding tissue.

Paper 32. Canine Notochordal Cell-Secreted Factors Protect Murine and Human Nucleus Pulposus Cells From Apoptosis by Inhibition of Activated Caspases -9, and -3/7

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Introduction: Effective therapies that may stop or even reverse disc degeneration remain elusive. A minimally invasive method through which nucleus pulposus cell viability could be achieved would revolutionize the treatment of degenerative disc disease.

With the presented work, we have investigated if non chondrodystrophic (NCD) canine disc (IVD)-derived notochordal cell conditioned medium (NCCM) and chondrodystrophic (CD) canine IVD-derived conditioned medium (CDCM) are able to protect murine and human NP cells from apoptosis.

Methods: We developed NCCM and CDCM from hypoxic culture of freshly isolated NPs from NCD and CD canines respectively. We obtained murine NP cells from 9 different C57BL/6 mice and human NP cells from 4 patients who underwent surgery for discectomy. The cells were cultured with aDMEM/F-12 (control media), NCCM or CDCM under hypoxic conditions (3.5% O₂) and treated with IL-18+FasL or Etoposide. All media were supplemented with 2% fetal bovine serum. We then determined the expression of specific apoptotic pathways in the murine and human NP cells by recording activated caspase-8, and -9 and -3/7 activity.

Results:

murine - In the murine NP cells, NCCM inhibits IL-18+FasL- and Etoposide- mediated apoptosis via suppression of activated caspase-9 and caspase-3/7, CDCM demonstrated an inhibitory effect on IL-18+FasL mediated apoptosis via caspase-3/7 (Fig 1-A).

human - In the human NP cells, NCCM inhibits Etoposide- mediated apoptosis via suppression of activated caspase-8, caspase-9 and mainly caspase-3/7. CDCM demonstrated an inhibitory effect on Etoposide- mediated apoptosis via suppression of activated caspase-8, caspase-9 and mainly caspase-3/7, though not as effective as NCCM (Fig 1-B).

Conclusions: Soluble factors secreted by the NCD IVD NP strongly protect murine and human NP cells from induced apoptosis via suppression of activated Caspase -9 and -3/-7.

A better understanding and harnessing of the restorative powers of the notochordal cell could lead to novel cellular and molecular strategies for the treatment of DDD.

Paper 33. Post-Traumatic Stress Symptoms following Elective Lumbar Arthrodesis are Associated with Reduced Clinical Benefit

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Introduction: Post-operative Post-traumatic Stress Disorder (PTSD) symptoms can occur among elective lumbar fusion patients. While adverse impact of pre-operative depression and psychiatric distress has been described, no reports have assessed the impact of post-operative PTSD symptoms on clinical outcomes following lumbar arthrodesis. We assessed the impact of post-operative PTSD symptoms on clinical outcomes following lumbar arthrodesis.

Methods: 73 undergoing elective lumbar spinal arthrodesis patients completed the PTSD Checklist-Civilian version (PCL-C) at 3,6,9 and 12 months post-operatively. Short Form 36 and the Oswestry Disability Index (ODI) were completed pre-operatively and at 12

months post-operatively. Impact of post-operative PTSD symptoms, pre-operative psychiatric diagnoses, and Mental Composite Scores (MCS) on clinical outcome scores and likelihood of reaching Minimal Clinically Important Difference (MCID) for ODI and Physical Composite Score (PCS) was evaluated.

Results: PTSD symptoms were reported in 22% of the cohort, with significantly reduced surgical benefit measured by final ($p<0.0001$ and $p=0.003$) and total change ($p=0.013$ and $p=0.032$) in ODI and PCS scores, respectively. Likelihood of reaching MCID for both ODI and PCS was also reduced for patients reporting PTSD symptoms ($p=0.009$ and $p=0.001$, respectively). Pre-operative psychiatric diagnosis correlated only with final ODI score ($p=0.008$). Pre-operative MCS scores were significantly correlated with final ODI and PCS scores, with total change and likelihood of reaching MCID for PCS, but not for ODI score.

Conclusions: Post-operative psychological distress was strongly correlated with reduced clinical benefit among elective lumbar arthrodesis patients, and was a stronger predictor than either major psychiatric diagnosis or pre-operative MCS scores. Efforts to reduce post-operative psychological distress may enhance patient reported clinical outcomes from elective spine surgery.

Paper 34. Nutritional Status In Patients Undergoing Elective Spine Procedures

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Background: Poor nutritional status be detrimental to wound healing and the overall recovery of patients undergoing major orthopedic procedures. Studies have estimated the rate of malnutrition to be approximately 50% in surgical patients admitted to the hospital. Surrogate nutritional markers such as prealbumin and albumin can help assess nutritional status and stratify risk. Currently, there is limited data on these laboratory markers in patients undergoing spine surgery. Our goal is to establish baseline nutritional data in a spine surgery population.

Methods: This is a prospective cohort study involving a consecutive series of patients undergoing spine procedures in a two month period. Serum prealbumin and albumin levels were drawn on patients in the post-operative period. Patient demographic, diagnostic and procedural factors were recorded.

Results: Nutritional markers were collected in 102 patients (60 female, 42 male; average age 53.2, range 25-93). Cases performed including 85 degenerative, 12 deformities, 4 traumas, and 1 tumor. The average BMI was 28.61 (range 14.6-46.4). Average albumin level was 3.2 g/dL (range 2.2-4.5 g/dL) and 72% of patients had level < 3.5 g/dL and 28% were at < 3.0 g/dL. Patients with albumin levels > 3.5 g/dL were on average younger than patients with levels < 3.5 g/dL (49 vs. 55.6, $P<0.05$). Average BMI was similar between the two groups (28.94 vs. 27.68, $P=0.16$). Average prealbumin level was 20.2 mg/L (range 7-38 mg/L) with 31% of patients < 18 mg/L, 18% of patients 11-15 mg/L, 6% < 11 mg/L. Patients with prealbumin > 18 mg/L were on average younger than patients with levels < 18 mg/L (51.5 vs. 59.8, $P<0.05$), BMI was similar between the groups (28.92 vs. 28.46, $P=0.36$).

Conclusion: Our study found 72% of patients with low albumin levels with 28% considered to be malnourished (< 3.0 g/dL). Based on prealbumin risk stratification created by Bernstein et al, we found 18% of patients (11-15 mg/L) were at increased risk of morbidity and mortality and 6% at significant risk (5-10.9 mg/L). This highlights a potentially modifiable risk factor for patients undergoing spine surgery. This study may provide a basis for futures clinical evaluation and preemptive treatment before spine surgery.

Paper 35. Incidence Of Vitamin D Deficiency In Patients Undergoing Elective Spinal Fusion

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University of Utah

WITHDRAWN

Paper 36. Recovery Room Radiographs Not Found to Have Incremental Utility Above Intra-operative Images after Lumbar Fusion Procedures

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Yale School of Medicine

Introduction: Two sets of images are commonly obtained at the conclusion of lumbar fusion procedures: intraoperative fluoroscopic images overseen by the surgeon near the time of wound closure, and plain film images taken later in the recovery room. The purpose of this study is to evaluate the potential incremental utility of obtaining images in the recovery room when intraoperative images have already been viewed and saved for documentation.

Methods: We identified a consecutive series of lumbar fusion procedures performed by either of two spine surgeons at our institution. From these, we selected all cases for which the picture archiving and communication system (PACS) contained at least one AP and one lateral image from both intraoperative and recovery room series. A panel of three reviewers assessed fluoroscopic and recovery room

series for both radiographic adequacy and visibility of issues with construct placement. In order to be considered adequate, a series had to enable the viewers to rule out or identify all potential issues with surgical constructs.

Results: 190 cases were reviewed, of which 42 were anterior lumbar interbody fusions (ALIFs), 90 were posterolateral lumbar fusions, 26 were transforaminal lumbar interbody fusions (TLIFs), and 32 were anterior-posterior fusions. All intraoperative series were adequate, while only 90% of recovery room series were adequate (Figure 1). Recovery room series had visible issues with construct placement in 4 cases. In all cases, however, the issue was also clearly visible on the intraoperative series, was found to be acceptable clinically, and did not alter management in any way.

Discussion: We found that intraoperative fluoroscopic imaging is more likely to be adequate than recovery room imaging. Even with a directed critical evaluation, no issues with construct placement were noted on recovery room series that were not already documented on intraoperative series.

Conclusion: Plain film imaging in the recovery room after lumbar fusion procedures has low clinical utility. It seems that this may be eliminated from practice in situations where intraoperative images have been viewed and saved.

Paper 37. Instrumentation And Equipment Related Inefficiency In Spine Surgery: Potential For Cost Savings

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University of Massachusetts

Introduction: Spine procedures represent a large portion of health-care expenditure in the orthopedics specialty. Studies have shown that intra-operative waste has exacerbated the high cost of surgeries. Our objective is to identify and quantify the incidence of pre- and intra-operative equipment related events that generate inefficiency.

Methods: Data was collected over a 9-month period. A data collection instrument was developed to record procedure related details and instrument/equipment related issues. Administrative records of equipment issues were also obtained for the same period. For each case with equipment related issues, estimates of cost increase and time delay was made. Operating cost of OR time is based on average of published data (\$40.66/minute).

Results: 53% of the spine procedures (325/613) were recorded in the database. Equipment related issues occurred in 43.5% of cases. Issues included missing equipment (19.2%), improperly packaged pans (7.1%), improperly maintained equipment (16.2%), and other (1.0%). Unanticipated extra pans were opened in 18.6% of the cases (total of 91 pans, range 1-5). In cases requiring extra pans, the average cost increase was \$135.6 (range \$26.05 to \$742.75). Comparing cases with pre-operative equipment issues and those without: the difference in the first cases of the day is 15 minutes (\$609.9, 29 vs. 14 minutes, $P < 0.05$), the difference in the rest of the cases is 7.8 minutes (\$317.1, 48 vs. 40.2 minutes, $P = 0.06$). Examining the administrative record of the cases in our study, hospital record captured 46 (14%) equipment related issues.

Discussion: Perioperative inefficiency in spine surgery can be material or temporal. Material inefficiency is demonstrated by the high incidence of equipment related issues. Indirect costs such as delay in OR start time can be a contributor to overall hospital waste. Our method was more capable of capturing equipment issues than administrative process (43.5% vs. 14%).

Figure 1: Representative examples of the radiographic inadequacies on recovery room series. (A and B) Intraoperative and recovery room lateral views, respectively, of an L4-L5 posterolateral fusion. The recovery room view had cranial-caudal mal-positioning of the emitter. (C and D) Intraoperative and recovery room lateral views, respectively, of an L3-L5 posterolateral fusion. The recovery room view had cranial-caudal mal-positioning of the emitter. (E and F) Intraoperative and recovery room lateral views, respectively, of an L4-L5 posterolateral fusion. The recovery room view had cranial-caudal and anterior-posterior mal-positioning of the emitter.

Paper 38. Negligible Impact Of Electronic Health Records On Outpatient Volume And Coded Level Of Service - A Report From Two Departments In An Academic Medical Group

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Introduction: Recent media coverage (New York Times) reports that the implementation of electronic health records (EHR) may be associated with substantial increases in Medicare payments, in part due to an increase in the coded level of service facilitated by EHR. There additionally exists concern within many medical groups that the transition to EHR could be associated with a decrease in total patient volume.

Methods: Departments in our academic medical group began transitioning to EHR in 2011 (Epic, Verona, WI). We identified all outpatient encounters that occurred on a monthly basis before and after the transition in in two such departments.

Results: We found that mean monthly volume of outpatient encounters in the internal medicine practice during the 12 months before EHR was not different from that during the 12 months after (613 v 587, $p=0.439$). Similarly, in the department of orthopaedics, the mean monthly volume of outpatient encounters during the 17 months before EHR was not different from that during the 7 months after (2157 v 2317, $p=0.156$; Figure 1A). The greatest change in coding level in the medicine practice was a 1.2% increase in level 4 coding, offset mostly by a complementary decrease in level 3 coding. Similarly, the greatest change in coding in the department of orthopaedics was a 3.1% increase in level 4 coding, offset mostly by a complementary decrease in level 3 coding. In both departments, the minor changes across all 5 coding levels accounted for small but statistically significant upward shifts in coding ($p<0.001$; Figure 1B).

Discussion: There was no perceptible change in patient volume with the transition to EHR. The changes in coding level associated with the transition are minor relative those reported by the media.

Conclusion: The massive shifts in coding supposedly facilitated by the transition to EHR did not occur at our center. Indeed, we found it remarkable how little an impact the transition had on both patient volume and coding level. We hope these issues will be investigated further, on a larger scale, and with longer follow up as the implementation of EHR continues in centers across the country.

Paper 39. Initial In Vivo Efficacy of a Novel, Injectable Cellular Therapy for Degenerative Disc Disease

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Introduction: Degenerative disc disease (DDD) is a primary cause of back pain, which affects over 65 million people in the US and costs over \$100B in care annually. Treatments for DDD are limited and do not result in repair/regeneration of the disc. We have identified a method to isolate stem and progenitor cells directly from human disc tissue and form therapeutic cell clusters called 'discospheres'. The goal of the present study was to test the in vivo efficacy of a novel tissue engineering therapy composed of human discospheres and a scaffold carrier, called Injectable Discosphere Cell Therapy (IDCT).

Methods: Using a previously validated model, lumbar discs of 3 New Zealand rabbits were accessed surgically and punctured with a needle to induce degeneration ($n=4$ discs/animal). After two weeks, therapy or cell-free control was injected into the injured discs. Additionally, injured and uninjured control discs were maintained in each animal. Every 2 weeks for 6 weeks, disc height was measured using radiographs and normalized to week 0 values, resulting in a Disc Height Index (DHI). After 6 weeks, the rabbits were euthanized; the discs were harvested and prepared for histology. Sections were stained with H&E or Alcian blue, and blindly scored by a certified pathologist for abnormality, assigning a score of 0 to 2 for AF/NP border, AF organization, NP extra-cellular matrix, and NP cellularity (AF - annulus fibrosus; NP - nucleus pulposus) and summing the 4 results (0=normal, 8=abnormal).

Results: Injection of IDCT resulted in significant improvements in the DHI at both 4 and 6 weeks, compared to all control groups (Figure 1A). Histological findings correlated with the DHI results; abnormal scores were significantly lower for IDCT-treated discs compared to injured control discs (Figure 1B). H&E images of an entire disc demonstrate degeneration after injury and regeneration with IDCT (Figure 1C). Also, although the IDCT was xenograft, no immune response was identified.

Conclusions: Our findings show that IDCT is a potential therapy for DDD, with regenerative effects on tissue architecture and restoration of disc height. More work is warranted to optimize the formulation and determine the mechanism of action for repair.

Paper 40. Patterns of Lumbar Disc Degeneration

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Introduction: Lumbar intervertebral disc degeneration is a common finding on magnetic resonance imaging (MRI). The patterns of degeneration are less well understood, specifically the patterns associated with aging. The purpose of this study was to use kinetic MRI (kMRI) to provide baseline data on the pattern of lumbar disc degeneration, in a predominantly middle aged population.

Methods: We performed a cross-sectional study of 1095 patients (471 female, 624 male) with a mean age of 44.29 years (range 16-99) who underwent upright, multi-position, lumbar kMRI for symptoms of lower back pain with or without radiculopathy. Lumbar discs were classified as non-degenerative or degenerative based on T2-weighted kMRIs. Prevalence and location of skipped-level lumbar degenerative disc(s) (SLDD) and contiguous-multilevel disc degeneration (CMDD) were assessed.

Results: The summary score of the degenerative lumbar discs correlated with age. Disc degeneration moved cephalad with age. The degree of disc degeneration worsened from L1-2 to L5-S1. Single-level disc degeneration was the most common at L5-S1 (60.3%), and the least common at L2-L3 (1.4%). Two-level disc degeneration was the most common at L4-L5 and L5-S1 (53.5%), the least common was L1-2 and L3-4 (0.8%). The most common three-level degenerative disc combination was L3-4, L4-5, and L5-S1 (55.7%); the least common was L1-3, L3-4, and L4-L5 (0%). The most common four-level degenerative disc combination was L2-3, L3-4, L4-5, and L5-S1 (50.5%); the least common was L1-2, L2-3, L3-4, and L5-S1 (5.8%). SLDD (26.5%) was less common than CMDD (73.5%). The most common combinations of SLDD were: L3-4 and L5-S1 (48.3%) in two-level SLDD; L2-3, L4-5 and L5-S1 (37.2%) in three-level SLDD; L1-2, L3-4, L4-5, L5-S1 (53%) in four-level SLDD.

Conclusions: This cross-sectional study using kMRI elucidates the prevalence of natural patterns of lumbar disc degeneration in symptomatic middle-aged patients. Severe disc degeneration is more common in the lower lumbar spine than the upper lumbar spine. Contiguous-multilevel disc degeneration is more common than skipped level disc degeneration. Severe degenerative disc disease progresses from the lower to the upper lumbar spine with age. This aging pattern may play a role in adjacent level disc degeneration associated with fusions.

Paper 41. Interobserver and Intraobserver Reliability of Magnetic Resonance Imaging in Lumbar Spine Pathology

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Introduction: Conditions of the lumbar spine are highly prevalent in the population, and magnetic resonance imaging (MRI) is commonly used to evaluate and diagnose lumbar pathologies. MRI is not without its limitations, however, and few studies have examined its reliability across a variety of lumbar spine conditions. This study was a systematic investigation of the interobserver and intraobserver reliability of MRI in evaluating 12 common lumbar spine pathologies.

Methods: A retrospective diagnostic investigation was performed on 75 patients who underwent lumbar MRI at our institution. For each subject, T2-weighted sequences were independently evaluated by 4 reviewers (2 orthopaedic surgeons and 2 musculoskeletal radiologists).

Images were assessed using specific criteria for disc hydration, disc space height, endplate changes, spondylolisthesis, central and foraminal stenosis, disc herniation, facet joint degeneration, presence of transitional vertebrae, and bone marrow signal changes. The first 10 subjects were re-evaluated to determine intraobserver reliability. Interobserver agreement, intraobserver agreement, and Fleiss' kappa statistical analysis were performed.

Results: The overall interobserver absolute agreement was 76.9% (95% CI, 72.7%-81.0%). When stratified by pathology, interobserver agreement ranged from 65.1% to 92.0%, with disc hydration and disc height assessments demonstrating the lowest agreement, while transitional vertebrae and spondylolisthesis had the highest agreement. The specialty of the reviewer had no significant effect on the interobserver agreement. The average interobserver Fleiss' kappa coefficient was 0.431, suggesting moderate overall agreement, though it ranged from fair to substantial agreement (range 0.282-0.618) depending on the pathology.

The overall intraobserver absolute agreement was slightly higher at 81.3% (95% CI, 75.8%-86.7%), with a narrower range than interobserver agreement, from 74.5% to 91.5%. The lowest agreements were found in foraminal disc herniation and facet joint degeneration, while endplate changes and spondylolisthesis had the highest agreements.

Conclusions: In this study assessing the reliability of MRI in evaluating 12 common lumbar spine pathologies, we demonstrate significant ranges in reliability across different lumbar conditions, with interobserver variability greater than intraobserver variability. Given the prominent role of MRI in the diagnosis of lumbar spine conditions and subsequent treatment, it is important for clinicians to realize the inherent variations in its interpretation.

Paper 42. Biomechanical Evaluation Of S2 Alar Iliac Screws: The Effect Of Length And Quad-cortical Purchase As Compared To Iliac Fixation

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George Washington University

Introduction: Multiple techniques exist for spinal fixation distal to S-1 pedicle screws including transiliac bars, iliac screws, and ilio-sacral screws. Alternatively, the S2 Alar-iliac (S2AI) screw utilizes either an open or a percutaneous approach, with an altered S2 alar screw trajectory to obtain purchase in the ilium (I). The primary objective of the present study was to compare the biomechanical strength of the S2AI screw to traditional iliac fixation.

Methods: Seven human cadaver spines (L1-Pelvis) were fixed at L2 proximally and Pubis distally, and were tested on the 6 DOF spine simulator. A load control protocol with an unconstrained pure moment of 10 Nm was used in Flexion-Extension, Lateral Bending, and Axial Rotation, for a total of three load / unload cycles. The range of motion (ROM) was normalized to intact (100%). The test sequence for all the specimens was: 1) Intact; 2) L3-S2AI65mm; 3) L3-S2AI80mm; 4) L3-S2AI quad-cortical purchase (QC); 5) L3-S1+190mm; 6) L3-S1.

Results (Figure 1): All the instrumented constructs significantly reduced ROM compared to intact.

The L3-S1 construct was less stable than all other instrumented constructs, and was significant in flexion-extension. There was statistically no significant difference between the S2AI screw constructs and the Iliac screw construct with offset connector. Similar trends were observed at L4-5 and L5-S1, without any significance with L3-S1 construct.

Conclusion: The current study concluded that the test constructs using S2AI screws are biomechanically as stable as the test constructs using Iliac screws, in all loading modes. 65mm S2AI screws were biomechanically equivalent to 90 mm iliac screws and 80mm S2AI screws. Quad-cortical purchase did not statistically significantly improve the biomechanical strength of S2AI screws. No construct

required offset connectors to connect the S2AI screws with the cephalad instrumentation.

Paper 43. Pedicle Screw Re-Insertion Using Previous Pilot Hole and Trajectory Does Not Reduce Fixation Strength

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Walter Reed National Military Medical Center

Introduction: During pedicle screw instrumentation, a low current reading (<6-10mA) with intraoperative evoked electromyogram (EMG) stimulation of a pedicle screw warrants complete removal to palpate the tract and reassess for pedicle wall violation. Often no violation is found and the same screw is re-inserted along the same trajectory without additional redirection. Previous studies have reported significantly decreased insertional torque during reinsertion. However, fixation strength has never been evaluated biomechanically.

Methods: 31 thoracic and 9 lumbar individual fresh-frozen human cadaveric vertebral levels were evaluated. Each level was instrumented bilaterally with 5.5mm (thoracic) and 6.5mm (lumbar) titanium

polyaxial pedicle screws. A paired comparison was performed for each level, and randomized between control and the test group with screw re-insertion, which was performed by completely removing the screw, palpating the tract, and then re-inserting along the same trajectory. Screw insertional torque (IT) was measured with each revolution, and peak IT reported in inch-pounds (in-lb). Screws were tensile loaded to failure "in line" with the screw axis and pullout strength (POS) measured in Newtons (N).

Results: Thoracic Re-insertion: No significant difference was detected for pedicle screw POS between re-inserted (RI) and control screws (732±307 N vs 742±320 N; p=0.78). No significant difference was also found with IT between the initial test screw (INI) and control ((7.28±3.51 in-lb vs 7.69±4.45 in-lb; p=0.33). However, IT for RI screws (5.14±4.18 in-lb) was significantly decreased compared to INI and control screws (29% decrease, p=0.00; 33% decrease, p=0.00). Lumbar Re-insertion: There were similar findings for lumbar pedicle screws, with no significant difference for pedicle screw POS between RI and control screws (943±344N vs 803±422N; p=0.09), as well as a significant IT decrease between RI and control screws (6.38±4.61 in-lb vs 9.56±3.84 in-lb; p=0.04).

Correlation Analysis: Test group screws in both the thoracic and lumbar spine had significant, strong correlations between initial screw IT and pullout strength (r=0.79, p=0.00; r=0.93, p=0.00). There was a moderate correlation between re-insertion IT and pullout strength in the thoracic spine (r=0.56, p=0.00), but no significant correlation for the lumbar spine (r=0.218; p=0.57).

Conclusion: Despite a significant reduction in pedicle screw IT with re-insertion along a previous tract, there was no significant difference in pedicle screw pullout strength; which is the most clinically significant aspect of immediate stability. Therefore, when the surgeon must completely remove a pedicle screw for tract inspection, re-insertion along the same trajectory may be performed without significantly compromising screw fixation strength.

Paper 44. Biomechanical Contribution of Transverse Connectors in the Setting of a Thoracic Pedicle Subtraction Osteotomy

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Introduction: Little data is available to guide longitudinal construct planning after a pedicle subtraction osteotomy (PSO) in the thoracic spine. Previous investigations have suggested the role of transverse connectors (TC) in enhancing torsional rigidity following long segment thoracic pedicle screw-rod instrumentation. However, the biomechanical effect of augmentation with one or two TC after PSO in the thoracic spine has not been previously evaluated.

Methods: Seven fresh-frozen human cadaveric thoracic spines (T3-T11) were prepared, maintaining all osteoligamentous structures, and intact range of motion testing was performed with non-destructive loading (±6 Nm) in a six-degree-of-freedom spine simulator. The specimens were then instrumented from T4-T10 with bilateral 5.5-mm polyaxial titanium pedicle screws and 5.5-mm contoured rods, and then a PSO performed at T7. Range of motion was subsequently analyzed in the unaugmented construct, with 1 TC (T8-T9) and then 2 TC (T5-T6 and T9-T10). Range of motion (ROM) was analyzed in axial rotation, flexion-extension, and lateral bending loading planes over T4-T10 and at the PSO level (T6-T8), using a repeated measures ANOVA with Sidak correction for multiple comparisons.

Results: After PSO and instrumentation with a thoracic pedicle screw-rod construct, T4-T10 ROM was significantly reduced in all planes of motion from the intact condition (p<0.05). Augmentation of the longitudinal construct with either 1 or 2 TC did not significantly increase construct stability in flexion-extension and lateral bending

compared to the unaugmented construct ($p>0.05$). In contrast, during axial rotation, T4-T10 ROM was reduced by 43% following addition of 2 TC ($p<0.05$), and was also reduced by 26% following 1 TC ($p>0.05$), but did not reach statistical significance. Focal segmental stability (T6-T8) at the PSO level had similar improvement in axial rotation stability following the addition of transverse connectors, with a 48% decrease in axial rotation after 2 TC ($p<0.05$), and addition of 1 TC decreased axial ROM by 29%, but again did not reach statistical significance ($p>0.05$).

Conclusion: Two transverse connectors significantly improved torsional rigidity by 43%, with no differences in stability for all planes of motion with the use of one transverse connector. Therefore, in the setting of a PSO and long segment pedicle screw-rod construct, augmentation with at least two transverse connectors may be considered in order to improve torsional rigidity.

Paper 45. Time to Development, Clinical and Radiographic Characteristics, and Management of Proximal Junctional Kyphosis in Adult Thoracolumbar Instrumented Fusion

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Introduction: Proximal junctional kyphosis (PJK) is a well recognized mode of failure following instrumented thoracolumbar deformity surgery. Though significant literature exists on pathogenesis and risk factors, data on management remains scarce. The present retrospective analysis was aimed to study time to development, clinical and radiographic characteristics, and management of PJK following adult thoracolumbar instrumented fusion.

Methods: Retrospective review of medical records and radiographs of 289 consecutive adult (>18 yrs) thoracolumbar deformity patients who underwent posterior segmental instrumentation using all pedicle screw construct with incorporation of at least five segments into the fusion construct was conducted. Patients with history of spinal surgeries prior to the index procedure were not excluded. The proximal junctional angle was measured as the angle between the inferior end plate of the upper-most instrumented vertebra (UIV) and the superior endplate of the UIV+1 or UIV+2, with PJK defined as proximal kyphotic angle $>10^\circ$.

Results: PJK occurred in 32 patients (11%) at a mean FU of 34 months ($1.3-61.9 \pm 19$ months). Presence of a compression fracture in the proximal junctional region (UIV, UIV+1, or UIV+2) at follow up was seen in 25 cases (78%) and pseudarthrosis within the construct developed in 11 (34%). Of the 32 cases of PJK, 16 (50%) were revised (mean of 1.7 revisions, range: 1-3 revisions) at a mean follow up of 9.6 months (range: 0.7-40 months) primary indications for revision being pain ($n=16$), myelopathy ($n=6$), instability ($n=4$), and instrumentation protrusion ($n=2$). Comparison of pre- and post-index surgery radiographic parameters showed no significant change in sagittal balance (9.6 vs. 8.0 cm, $p=0.76$), but there was a significant increase of lumbar lordosis (24° vs. 42° , $p<0.001$) and T5-T12 kyphosis (30° vs. 53° , $p<0.001$). Though there was a trend toward decrease in the mean PT following index procedure, this did not reach statistical significance. There was no relation between absolute PJK angle and revision surgery for and a higher angle did not portrayed requirement of revision surgery.

Conclusion: The susceptibility to PJK may relate to development of an exaggerated reciprocal change in thoracic kyphosis to offset a significant increase in lumbar lordosis. In the absence of direct relationship between a greater PJK angle and worse clinical outcome, clinical symptoms and neurological status rather than absolute reliance on radiographic parameters should drive the decision to pursue revision surgery. Long term follow up of patients is critical to monitor development of clinical symptoms which might require surgical management.

Paper 46. Incidence and Risk Factors for Proximal Junctional Kyphosis in Older Patients with Spinal Deformity

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University of Utah

Introduction: Proximal junctional kyphosis (PJK) is a well-recognized complication of adult spinal deformity correction. Previously published studies have focused on all age groups and identified age older than 55 years as a consistent risk factor. Other risk factors remain controversial. This study is the first to assess risk of PJK and proximal junctional failure (PJF) specifically in the older patient population.

Methods: Retrospective review of 198 consecutive patients over age 55 years, treated operatively at a single institution for spinal deformity. Radiographic measurements and demographic data were reviewed preoperatively, early postoperatively, and at final follow-up. PJK was defined by the Gattes criteria. Early onset of PJK was defined as occurring within the first 6 months after surgery. PJF, risk for revision surgery, and risk factors for PJK were reported.

Results: The mean age of the 198 patients reviewed was 68 years (range 55-85), with mean follow-up of 32 months (12-107). Forty-two patients were fused to the upper thoracic spine (T2-T5) and 156 in the lower thoracic or upper lumbar spine. The overall incidence of PJK was 47% for the entire population of older patients, most were mild and did not require revision surgery. Two-thirds of PJK cases developed within the first 6 months after surgery. The overall proximal junctional failure rate was 32.3% and the overall revision rate 14.6%. The incidence of PJF and rate of revision surgery were both higher in the surgeries with an UIV in the lower thoracic or upper lumbar spine than upper thoracic spine ($p=0.0007$ and 0.04 respectively). Other risk factors include pre-operative lumbar lordosis $<30^\circ$, thoracic kyphosis decrease from pre to postoperative $>20^\circ$, and severe global sagittal imbalance.

Conclusions: The incidence of PJK after adult deformity surgery in patients over 55 years of age was 47%, with overall revision rate of 14.6%. PJK developed early in most cases. PJK, proximal junctional failures and revisions were significantly higher when the UIV was in the lower thoracic or upper lumbar spine. Risk factors identified include the level of thoracic or thoracolumbar kyphosis and presence of sagittal imbalance.

Paper 47. Age, Sagittal Deformity and Operative Correction are Risk Factors for Proximal Junctional Failure (PJF) Following Adult Spinal Deformity (ASD) Surgery

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Introduction: PJF is a significant complication following ASD surgery. Risk factors for PJF are poorly understood. Purpose: Evaluate risk factors for clinically significant PJF following ASD surgery.

Methods: Multi-center, case-control analysis of consecutive PJF patients following ASD surgery. PJF defined as kyphosis increase $>10^\circ$ from upper instrumented vertebra (UIV) to two levels above (UIV+2) from preop value, and UIV or UIV+1 fracture, dislocation, or implant failure. PJF patients were matched to patients without PJF (NOPJF) from a prospective ASD database. Matching criteria: levels fused and UIV. Groups divided by level of UIV: thoracolumbar (TL; UIV=T9-T11) or upper thoracic (UT; UIV=T2-T5). Risk factors included: age, sagittal vertical axis (SVA), thoracic kyphosis (TK),

lumbar lordosis (LL), pelvic incidence minus lumbar lordosis (PI-LL), and pelvic tilt (PT).

Results: TL group differences between PJF (n=37) and NOPJF (n=21) included age (59.2 vs 43.7 years), preop TK (40.5° vs 29.6°), preop LL (18.8° vs 43.6°), preop PI-LL (35.9° vs 17.5°), and change in LL (30° vs 9.6°), respectively (p<0.05). UT group differences between PJF (n=15) and NOPJF (n=33) included age (67.8 vs 59.5 years), preop SVA (68.3 vs 1.6 mm), preop PT (26.8° vs 17.5°), preop PI-LL (19.2° vs 0.61°), preop TK (55.2° vs 33.7°), and change in SVA (69 vs 49 mm), respectively (p<0.05). PSO was more common in all PJF patients (29% vs 6%) and more UT PJF patients were fused to pelvis than NOPJF (73.3% vs 39.4%), respectively (p<0.05). Revision surgery was performed more frequently for PJF than NOPJF (TL 35% vs 9%; UT 67% vs 18%; respectively; p<0.05).

Conclusions: Case-control analysis of ASD surgical patients demonstrated risk factors for PJF include age, sagittal deformity and sagittal correction. PSO and fusion to pelvis are also risk factors. Revision surgery is more frequent among patients experiencing PJF. Further research is needed to identify methods to prevent PJF in ASD patients requiring large sagittal correction.

Paper 48. Occupant and Crash Characteristics in Patients with Thoracolumbar Spine Injuries Following Motor Vehicle Collisions

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Introduction: Motor vehicle collisions (MVC) are a leading cause of thoracolumbar (TL) spine injury in all ages. Our objective was to analyze specific patterns of TL spine injuries in MVC; correlate these patterns with restraint use, crash characteristics and demographic variables; and study their associations with extra-spinal injuries and overall injury morbidity.

Methods: Retrospective study of patients with TL spine injuries (T1-L5) obtained from the Crash Injury Research and Engineering Network (CIREN) database from 1996 to 2011. Demographic, injury and crash data from each patient was analyzed for correlations between type of T-L spine injury, associated extra-spinal injuries and overall injury severity score (ISS), type and use of seat belts and airbags, and other crash characteristics.

Results: TL injuries were identified in 631 of 4572 vehicle occupants, of whom 299 sustained major TL spine injuries and 332 sustained minor TL spine injuries. Compression fractures were most prevalent in the elderly, burst fractures and fracture-dislocations in young and middle-aged adults, flexion-distraction injuries in patients below forty, and extension injuries in patients above fifty. The commonest clinically significant extra-spinal injuries (Abbreviated Injury Scale grade 2 or more) associated with TL spine injuries involved the thorax (seen in 65.6% of 631 patients). As opposed to patients with major TL spine injuries, those with minor TL spine injuries showed a strikingly more common association with pelvic (58.13% of 332 patients versus 17.4% of 299 patients), and abdominal (51.8% versus 31.44%) injuries of AIS 2 or more. 53.31% of the patients with minor TL spine injuries had an ISS of 25 or more, as opposed to only 39.46% of the patients with major TL spine injuries. Among occupants wearing a three-point seat belt, 36.8% sustained TL spine injuries, while only 12.64% of the unbelted patients sustained TL spine injuries. Three-point belted individuals were more likely to sustain burst fractures, while two-point belted occupants sustained flexion-distraction injuries most often, and unbelted occupants had a predilection for fracture-dislocations of the TL spine. Three-point seat belts were protective against neurologic injury, higher ISS and fatality.

Conclusions: TL spine fracture patterns are influenced by age of

occupant and type and use of seat belts. Despite a reduction in injury severity and mortality, seat belt use is associated with an increased incidence of TL spine fractures. Minor TL spine fractures correlated with a greater incidence of associated pelvic and abdominal injuries and higher ISS scores, signifying their importance in predicting overall injury severity. Further advancements in automobile safety measures should focus on reduction of TL spine injuries in belted occupants.

Paper 49. MRI Evaluation Of Postoperative Epidural Fluid Collections

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Thomas Jefferson University

Introduction: Interpretation of postoperative MRI can be challenging after lumbar fusion. We tried to identify specific MRI characteristics of epidural fluid collections associated with infection, hematoma, or cerebrospinal fluid (CSF). We tried to identify specific MRI characteristics of epidural fluid collections

Methods: The study population includes consecutive patients between 2006 and 2010 who had MRIs performed within two weeks after elective surgery for evaluation of possible CSF fluid collection, hematoma, or infection. Patients with known previous infection (discitis/osteomyelitis) or inadequate MRIs were excluded. MRIs were retrospectively evaluated by a musculoskeletal radiologist and orthopedic spine attending who were blinded to the pathological diagnosis for characteristics of the fluid collection. MRI characteristics: osseous involvement, disk location, anterior vs posterior vs antero-posterior, soft tissue involvement, iliopsoas involvement. Characteristics include volume of lesion, loculation, satellite lesions, multiple loci, destructive characteristics, mass effect upon thecal sac. Enhancement was scored based upon the following variables: rim enhancement, smooth vs. irregular, thin vs thick, heterogeneity, diffuse enhancement, nonenhancement, rim thickness. General fluid collection intensity and complexity on T1, T2, and T1 post-contrast images was scored as high, medium, low. Chi square test was used to compare the incidence of imaging characteristics between patient groups (infection, hematoma, and CSF).

Results: Thirty three patients were identified who met inclusion criteria. There were 13 (39%) with infection, 9 (27%) with hematoma, and 11 (33%) with CSF collection. Factors that were associated with infection were osseous involvement (R 0.392, p=0.024) and destructive characteristics (R 0.461, p=0.007). Factors that were correlated with hematoma include mass effect (R 0.515, p=0.002) and high T1 signal intensity (R 0.411, p=0.019), absence of thecal sac communication (R -0.389, p=0.025), and absence of disk involvement (-0.346, p=0.048). Pseudomeningocele was associated with thecal sac communication (R 0.404, p=0.02), absence of mass effect (-0.48, p=0.005), low T1 signal (-0.364, p=0.04), and low T2 complexity (R-0.479, p=0.005).

Conclusion: Specific characteristics of the postoperative MRI can be used to distinguish infection from noninfectious fluid collections. The strongest predictors of infection were osseous involvement and destructive bony changes. Hematoma was associated with mass effect on the thecal sac, high T1 signal intensity, and absence of communication and absence of disk involvement. CSF collections were distinguished by absence of mass effect, low T2 signal complexity, low T1 signal intensity, and communication with the thecal sac.

Paper 50. Relation of Type of Lumbosacral Transitional Vertebra to the Degree of Degeneration of the Transitional Disc and of the Adjacent Segment Disc

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Introduction: It is not well known if certain types of lumbosacral transitional vertebra (LSTV) might be protective for disc degeneration or exposing its adjacent cephalic segment (ACS) to a higher amount of disc disease. These questions were subject of this study, as it can affect surgical decision-making.

Methods: We retrospectively included 92 (42 male; mean age 58.1±16years) subjects with LSTV grade 2 or higher (according to the Castellvi classification) as the case group and 94 (41 male, mean age 50.5±15.6 years) subjects without LSTV as control group after IRB approval. Degeneration of the last three segments of the spine was quantified using the Pfirrmann and Modic classifications. Additionally, annulus tears were documented. The Pfirrmann grades of disc degeneration (DD) were simplified to slight (e.g. grade 1-4) and severe DD (e.g. grade 5) and Modic changes (MC) simplified to either being present or not for the statistical analysis. Chi-square statistics were used to analyze differences in occurrence of degenerative changes in both groups.

Results: While the control group showed a relevant amount of severe DD (31%) and MC (20%) at the most caudal segment, the transitional disc in case of LSTV was not as affected (3% and 1%, p<0.001). However, the two ACSs showed a higher amount of degeneration (severe DD:39% and 21% and MC:31% and 15%) if compared to the control subjects (severe DD:16% and 6% and MC:11% and 3%; each p<0.01). These observations as well as the prevalence of annulus tears correlated to the grade of LSTV.

Conclusions: Increased grade of LSTV seems protective for the disc at the transitional level, is however associated with increased degenerative changes at the cephalic adjacent segments.

Poster Abstracts

Poster 1. The Anti-inflammatory Effects of Perioperative Methylprednisolone on the Soft Tissue Inflammation Induced by rhBMP-2

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UCLA

Introduction: The use of recombinant human bone morphogenetic protein-2 (rhBMP-2) has been proven to improve spinal fusion rates.. However, potential complications following rhBMP-2 use are related to its proinflammatory effects. Corticosteroids like dexamethasone (DP) abolish proinflammatory cytokines production and cellular immune responses in a dose-dependent pattern. The anti-inflammatory effects of human dose equivalent (HDE) DP on a rodent model of rhBMP-2 induced inflammation has not yet been studied and might lead to clinical use. The purpose of our study was evaluate the effect of DP on the local soft tissue inflammatory response to rhBMP-2.

Materials and Methods: 24 8-week-old male Lewis rats were divided into 5 groups. Four groups received the standard 20-µg dose of BMP bilaterally on absorbable collagen sponge carriers (ACS) implanted intramuscularly in the lumbar paraspinal muscles. The four experimental groups received intraperitoneal injections of 0 mg, 15 mg, 30 mg or 60 mg of DP at preop, 12 hours post op and 24 hours post op. In the control group ACS with 20 µL of PBS was implanted bilaterally. Rats were assessed by magnetic resonance imaging (MRI), gross morphology and histology. 2 observers measured the inflammation value of gross specimen, MRI images and histological samples. One-way ANOVA was used for comparison.

Results: Obvious inflammatory exudates were observed in the rhBMP-2 group. Fewer cases of inflammatory exudates were observed in the low steroid group than in the medium or high steroid group. The histological study showed that the administration of DP decreased the inflammatory area and average infiltration lengths induced by the rhBMP-2 in a dose-dependent manner. The MRI images also demonstrated a pattern of decreased inflammatory volume.

Discussion: Our study suggests that a very low dose of DP was equally sufficient as a pharmacological dose to decrease rhBMP-2 induced inflammation and edema in a rat model.

Conclusion: Low dosage perioperative administration of DP is effective in controlling the inflammation induced by rhBMP-2 and the dosage used in our study might be considered when attempting to control the inflammatory response of rhBMP-2.

Poster 2. Is Limb Length Discrepancy Related To Degenerative Scoliosis?

Nicholas Molby; Eric Chen; Gursukhman Sidhu; Kris Radcliff; Alexander Vaccaro

Rothman Institute

Purpose: The etiology of degenerative, de-novo scoliosis is largely indeterminate. Although a significant number of patients with degenerative scoliosis present with limb length discrepancy (LLD), the relationship between LLD and scoliosis is unknown. The hypothesis of this study was that pelvic obliquity and/or LLD results in compensatory lumbar scoliosis.

Methods: Retrospective, case series. Consecutive patients undergoing fusion for lumbar conditions (degenerative scoliosis or spondylolisthesis) were identified. Those with previous lumbar surgery or lower extremity surgery that may affect limb length (hip replacement,

Abstracts of the 2013 Meeting of the Lumbar Spine Research Society

hip ORIF, femur ORIF) were excluded. Based on the preoperative radiographs, the discrepancy in the iliac crest height, coronal L1-S1 endplate angles, distance from L1 bisector to the sacral center, number of degenerative scoliosis curves, and individual curve angulations were measured.

Results: Limb length discrepancy was present in 86% of patients with a degenerative scoliosis. There were 120 patients with a single curve > 5 degrees and pelvic obliquity > 2cm. Of the patients with a single curve, the apex of scoliosis was opposite the high iliac crest side in 79% patients and ipsilateral in 21% of patients, ($p<0.001$). There were 350 patients with a double curve. The apex of scoliosis was opposite the high iliac crest side in 45% of patients and ipsilateral in 55% of patients, ($p<0.05$).

Conclusion: The majority of patients with degenerative scoliosis had pelvic obliquity and limb length discrepancy. The apex of scoliotic curvature was opposite to high side pelvic obliquity in the majority of patients with single curves and the net effect of both deformities was a reduction in the magnitude of trunk shift. In patients with double curves, the apex of scoliotic curvature was ipsilateral to the lower curvature and opposite the upper curvature. These results suggest that pelvic obliquity has different roles in maintaining trunk height in patients with single and double curves.

Poster 3. Incidence and Risk Factors for Cardiac Complications following Lumbar Spine Surgery

Steven J. Fineberg; Matthew Oglesby, BA; Alpesh A. Patel, MD; Kern Singh, MD

Rush University Medical Center

Introduction: Cardiac complications are potentially serious unplanned events of surgical procedures. The incidence of these complications are not well characterized after lumbar spine surgery. A population-based database was analyzed to determine the incidence

and mortality of cardiac complications, and identify risk factors associated with lumbar decompression (LD) and lumbar fusion (LF).

Methods: Data from the Nationwide Inpatient Sample was obtained from 2002-2009. Patients undergoing LD or LF for degenerative etiologies were identified. Patient demographics, incidence of cardiac complications, co-morbidities, and mortality were assessed in the 2 surgical subgroups. Statistical analysis was performed using Independent-Student's T-test for discrete variables and χ^2 -test for categorical data. Logistic regression identified independent predictors for cardiac complications. A p-value of <0.0005 was used to denote significance.

Results: 578,457 lumbar spine procedures were identified in the United States from 2002 to 2009. There were 292,177 LDs and 286,280 LFs performed during this time period. The overall incidence of cardiac complications was 6.7 per 1,000 cases. Cardiac events occurred more frequently in the LF group with a rate of 9.3 per 1,000 cases, compared to the LD group with a rate of 4.0 ($p<0.0005$) (Table 1). Patients with cardiac events in the LD group were 13 years older than patients without events ($p<0.0005$), and LF-treated patients were 7.9 years older ($p<0.0005$). Regardless of surgical approach, patients with cardiac complications had statistically increased CCI scores, increased hospitalizations, costs, and mortality when a cardiac event was present ($p<0.0005$). Logistic regression analysis demonstrated independent predictors for cardiac complications to include age ≥ 65 years, male gender, congestive heart failure, valvular heart disease, coagulopathy, fluid/electrolyte disorders, and pulmonary circulation disorders.

Conclusions: Our results demonstrated an overall incidence of 6.7 cardiac complications per 1,000 lumbar spine surgeries from 2002 to 2009. Patients in the LF cohort were more likely to experience cardiac events than patients in the LD cohort. Cardiac events tend to occur in patients with noted risk factors and result in increased hospitalizations, costs, and mortality. Based on these findings, we believe patients with specified risk factors should be monitored closely and medically optimized in the peri-operative period.

Poster 4. Incidence and Mortality of Thromboembolic Events after Lumbar Spine Surgery

Steven J. Fineberg, MD; Matthew Oglesby, BA; Alpesh A. Patel, MD; Miguel Pelton, BS; Kern Singh, MD

Rush University Medical Center

Introduction: Pulmonary embolism (PE) and deep venous thrombosis (DVT) are potential complications that may occur after orthopaedic procedures. Incidences of these complications are not well characterized after lumbar spine surgery. A population-based database was analyzed to identify incidence, risk factors, and mortalities associated with lumbar decompressions and fusions.

Methods: Data from the Nationwide Inpatient Sample of the Healthcare Cost and Utilization was obtained each year between 2002-2009. Patients undergoing lumbar decompression (LD), or lumbar fusion (LF) for lumbar radiculopathy, herniated nucleus pulposus, degenerative disc disorder, and spinal stenosis were identified. Acute PE and DVT incidences and mortality rates were calculated. Co-morbidities were calculated using a modified Charlson Co-morbidity Index (CCI). Statistical analysis was performed using Student T-test for discrete variables and χ^2 -test for categorical data. Logistic regression was used to identify independent predictors of thromboembolic events. A p-value of <0.0005 was used to denote statistical significance.

Results: A total 578,457 LDs and LFs were identified from 2002-2009. DVT incidences were 2.4 and 4.3 per 1,000 cases in the LD and LF groups respectively (Table 1). PE incidences were 1.0 and 2.6 per 1,000 cases in the LD and LF groups (Table 2). LF patients with thromboembolic events were younger, had fewer co-morbidities,

Comparison Group	Lumbar Decompression		P-value	Lumbar Fusion		P-value
	No Cardiac Comp	Cardiac Comp		No Cardiac Comp	Cardiac Comp	
Total (n=5000)	291,001	1,176		283,608	2,672	
Cardiac Comp Incidence (per 1,000 cases)	4.0			9.3		<0.0005
Age (years)	55.0	68.0		55.1	63.0	
Age Group (%)			<0.0005			<0.0005
18-44	29.6	8.2		25.7	13.6	
45-64	37.5	24.2		45.1	32.9	
65-74	18.2	26.5		18.9	30.0	
≥ 75	14.7	41.1		10.4	23.5	
Gender (% Female)	45.4	44.4	0.48	56.0	54.3	0.08
Race						
Caucasian	84.3	84.3		83.8	84.0	
Black	6.0	7.6		6.3	6.7	
Hispanic	5.6	4.6	0.22	6.0	6.1	0.64
Asian	1.3	1.3		1.0	0.7	
Native American	0.4	0.2		0.4	0.3	
Other	2.5	1.9		2.5	2.3	
Charlson Co-morbidity Index	2.43	4.01	<0.0005	2.46	3.49	<0.0005
LOS (days)	2.5	6.2	<0.0005	4.4	7.9	<0.0005
Costs (US dollars)	\$7,172	\$15,964	<0.0005	\$25,736	\$39,427	<0.0005
Mortality (per 1,000 cases)	0.7	40.0	<0.0005	1.2	31.9	<0.0005

LOS = Length of stay

Table 1: Patient Characteristics with Deep Vein Thrombosis

	Lumbar Decompression (LD)			Lumbar Fusion (LF)			LD	LF	
Total (n = count)	291,465	712	P-value	285,038	1,242	P-value	711	1,242	P-value
Comparison Group	No DVT	DVT		No DVT	DVT		DVT	DVT	
Average Age (years)	55.0	66.7	<0.0005	55.1	61.6	<0.0005	66.7	61.6	<0.0005
Percentage									
0-44	29.5	9.1	<0.0005	25.7	11.6	<0.0005	9.1	11.6	<0.0005
45-64	37.5	30.2		45.0	42.3		30.2	42.3	
65-75	18.3	24.0		18.9	26.1		24.0	26.1	
>75	14.7	36.7		10.4	20.0		36.7	20.0	
Charlson Comorbidity Index	2.44	4.12	<0.0005	2.46	3.61	<0.0005	4.12	3.61	<0.0005
DVT Incidence (Per 1,000 cases)	2.4			4.3			2.4	4.3	<0.0005
Mortality (Per 1,000 cases)	0.8	14.1	<0.0005	1.4	21.8	<0.0005	1.4	2.2	0.229
LOS (days)	2.5	12.1	<0.0005	4.4	14.5	<0.0005	12.1	14.5	<0.0005
Costs (US dollars)	\$7,161	\$25,794	<0.0005	\$25,733	\$56,320	<0.0005	\$25,794	\$56,320	<0.0005

and incurred higher costs than LD patients. Statistically significant independent predictors of DVT were pulmonary circulation disorders, coagulopathy, fluid/electrolyte disorders, deficiency anemia, obesity, teaching hospital status, and larger hospitals. Predictors for the development of a PE were pulmonary circulation disorders, fluid/electrolyte disorders, anemia, African-American ethnicity and teaching hospitals status.

Conclusions: Patients undergoing LD or LF have an inherent risk towards thromboembolic events. DVT and PE are more common after LF procedures and occur in younger and healthier age groups than LD patients. Pre-operative pulmonary circulation disorders, fluid/electrolyte disorders, deficiency anemia, and teaching hospital status were significant risk factors for both DVT and PE. A thorough peri-operative assessment to identify patients at risk for thromboembolism is needed. Preventative measures, based upon these risk factors, may decrease the incidence of thromboembolic events.

Poster 5. Post-Operative Venous Thromboembolism after Spine Surgery

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Introduction: Deep vein thrombosis and pulmonary embolism are serious complications that can occur after spine surgery. Current literature on this topic does not address the heterogeneity of spine procedures and indications. The purpose of this study was to evaluate the incidence of venous thromboembolic events (VTE) after spine decompression and fusion.

Methods: We used state-level administrative databases to identify patients who underwent spine surgery; patients were tracked for a diagnosis of VTE during the index hospitalization or within 90 days of discharge. Primary diagnosis included (1) structural (scoliosis, stenosis, spondylolisthesis), (2) complication of prior spine surgery, (3) trauma, (4) infection, and (5) cancer. Risk factors were evaluated using a cox proportional hazards model.

Results: A total of 363,825 patients were included in this study

Table 1

Procedure	Number	Age	Female	Revision	Multi-day Staged	LOS	Mortality	Structural	Trauma	Cancer	Complication	Infection
Cervical	112,934	57.5	46.3%	4.7%	8.6%	7.1	1.2%	0.7	0.2	0.0	0.0	0.0
Cervical Decompression	11,935	58.7	39.4%	-	0.9%	4.0	0.3%	95.4%	1.7%	0.9%	0.8%	1.3%
Atlas-Axis Fusion	1,879	60.0	53.0%	3.0%	7.3%	9.3	2.1%	51.2%	42.8%	2.0%	3.6%	0.4%
Cervical Anterior Fusion	86,243	52.9	52.5%	1.8%	0.8%	2.6	0.3%	94.5%	3.8%	0.3%	1.1%	0.3%
Cervical Posterior Fusion	9,709	59.6	43.5%	6.4%	4.2%	7.6	1.3%	72.3%	18.4%	3.3%	5.5%	0.6%
Cervical AP Fusion	3,168	56.1	43.0%	7.6%	29.6%	12.0	1.9%	60.5%	30.2%	2.7%	4.1%	2.5%
Thoracolumbar	20,744	47.7	51.1%	4.1%	10.5%	10.5	1.2%	65.2%	22.3%	5.9%	2.6%	4.0%
TL Decompression	7,134	61.7	48.4%	-	1.2%	4.2	0.4%	60.5%	30.2%	2.7%	4.1%	2.5%
TL Anterior Fusion	1,344	46.5	50.6%	1.7%	4.1%	12.2	1.9%	89.4%	3.5%	2.2%	2.1%	2.8%
TL Posterior Fusion	11,043	39.2	53.9%	5.1%	3.6%	9.7	1.0%	45.8%	33.2%	12.9%	1.6%	6.5%
TL AP Fusion	1,223	43.7	51.7%	5.6%	33.2%	16.2	1.5%	59.0%	26.8%	8.3%	4.0%	1.9%
Lumbosacral	226,691	54.7	51.3%	5.4%	5.6%	4.4	0.2%	74.6%	13.8%	5.3%	2.9%	3.4%
LS Decompression	115,210	56.8	44.4%	-	0.5%	2.4	0.1%	59.0%	26.8%	8.3%	4.0%	1.9%
LS Anterior Fusion	9,614	49.9	52.5%	3.7%	1.4%	4.5	0.2%	51.2%	23.5%	11.8%	3.3%	10.2%
LS Posterior Fusion	89,425	59.5	55.8%	5.4%	1.4%	4.6	0.2%	97.9%	0.9%	0.2%	0.5%	0.5%
LS AP Fusion	12,442	52.6	52.7%	7.1%	19.2%	5.8	0.2%	90.5%	4.1%	0.7%	3.9%	0.8%
Cross Junctional (Cerv/TL, TL/LS)	3,456	53.3	56.7%	18.1%	22.5%	11.4	1.2%	93.7%	2.4%	0.4%	3.2%	0.2%

(36.9% decompression only, 63.1% fusion). The overall VTE rate was 1.39%, but varied greatly depending on surgical approach [See Table 1]. Additionally, VTE rates were significantly different for each diagnosis group: Structural 1.0%, Complication 2.0%, Trauma 6.4%, Infection 10.7%, and Cancer 8.4% ($p < 0.001$). VTE's diagnosed after initial discharge were found at different hospitals in over 40% of cases. Adjusting for diagnosis, gender, and age, and medical diagnoses associated with VTE, independent risk factors for VTE included spine fusion ($HR = 1.71$, $p < 0.001$), a prone position ($HR = 1.76$, $p < 0.001$), and multiple procedures throughout the hospitalization ($HR = 2.69$, $p < 0.001$).

Conclusions: The results of this study show different rates of VTE depending on indication and surgical procedure. While structural and revision spine surgery had lower rates of VTE, cases indicated by trauma, infection, or cancer had significantly elevated rates of VTE. Additionally, patients having multiple procedures, patients in a prone position, and patients undergoing spine fusion were at increased risk of VTE. Importantly, this study also highlights that a significant portion of VTE are diagnosed at hospitals other than where the index procedure was performed. These results may help surgeons better risk stratify patients to estimate those at increased risk of VTE.

Poster 6. Comparison of Pulmonary Function in Adults Younger and Older than age 60 Undergoing Spinal Deformity Surgery

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Summary: We evaluated the impact of adult spinal deformity surgery on pulmonary function for patients over age 60, with minimum 2 year follow-up. We found older patients have no significant difference in %predicted PFTs compared to younger patients postoperatively, and no differences in the rate of clinically significant PFT decline ($\geq 10\%$ pred FEV1). However, older patients more frequently (23% v 12%) experience PFT impairment ($< 65\%$ pred FEV1) after spinal deformity surgery.

Introduction: The objective of this study was to determine differences in pulmonary function in adult patients who are either younger (Y) or older (O) than age 60 following spinal deformity surgery. We hypothesize that older age may further exacerbate impairment of pulmonary function following spinal deformity surgery.

Methods: 128 consecutive adult deformity patients with idiopathic scoliosis undergoing surgical treatment were evaluated at a single institution with minimum 2 year follow-up. Prospectively collected PFTs, clinical records and radiographs were analyzed.

Results: There were 102 patients in Y group (avg age 39.3+14.1 yrs) and 26 in O group (avg age 63.7+2.7 yrs), with similar F/U ($Y = 2.9$ v $O = 2.6$ yrs, $p = 0.27$). There were no differences in average preop main thoracic (MT) curve magnitude ($Y = 50.0$ deg, $O = 54.8$ deg, $p = 0.27$), however O patients had significantly greater # of lumbar (5.9 v 4.2 , $p = 0.00$), thoracic (9.1 v 7.3 , $p = 0.00$), and total (15.0 v 11.5 , $p = 0.00$) levels fused. We also found O patients had significantly lower absolute pre-op FEV1 (2.1 v 2.6 L, $p = 0.02$) and FVC (2.7 v 3.3 L, $p = 0.05$), but no differences in %pred PFTs. This relationship remained at 2 yrs, with lower absolute FEV1 (1.9 v 2.5 L, $p = 0.00$) and FVC (2.5 v 3.1 L, $p = 0.00$). A clinically significant decline in PFTs (greater than 10% pred FEV1) occurred in 8 (31%) O patients and 26 (25%) Y patients, which was not statistically different. ($p = 0.63$). We also observed pre-op PFT impairment (less than 65%pred FEV1) in 1 (4%) O patient, which significantly increased to 6 (23%; $p = 0.02$) O patients postoperatively, compared to Y group experiencing no change in the number of patients ($n = 12$, 12%) with PFT impairment postoperatively.

Conclusion: Despite age related reduction in PFTs, older patients

(over age 60) had no significant difference in %pred PFTs compared to younger patients following spinal deformity surgery. We found older patients have no significant difference in %predicted PFTs compared to younger patients postoperatively, and no differences in the rate of clinically significant PFT decline ($\geq 10\%$ pred FEV1). However, older patients more frequently (23% v 12%) experience PFT impairment ($< 65\%$ pred FEV1) after spinal deformity surgery.

Poster 7. Disc Space Preparation In Unilateral Transforaminal Lumbar Interbody Fusion: A Comparison Of Minimally Invasive And Open Approaches

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Introduction: Minimally invasive surgical (MIS) approaches to transforaminal lumbar interbody fusion (TLIF) have been developed as an alternative to the open approach. The purpose of this study is to compare the adequacy of disc space preparation through MIS and open approaches to TLIF. We hypothesize that there is no difference in disc space preparation comparing the two approaches.

Methods: 40 lumbar levels (i.e. L1-2 to L5-S1 in 8 fresh cadaver specimens) were randomly assigned to open and MIS groups. The MIS approach/disc space preparation was performed through a tubular retractor. Time of discectomy, number of instrument passes, and endplate violations were recorded for each level. The percent disc removed by volume and mass was determined for each approach. A digital imaging software program (ImageJ, U.S. National Institutes of Health, Bethesda, MD) was used to measure the percent disc removed by area for the total disc and for each quadrant of the endplate (i.e. anterior ipsilateral, anterior contralateral, posterior ipsilateral, and posterior contralateral). Measurements were made by two independent observers in a blinded fashion.

Results: The open approach was associated with a shorter discectomy time (9.3 minutes vs. 11.5 minutes, $p = 0.01$) and fewer endplate violations (1 vs. 3, $p = 0.04$) when compared to an MIS approach. No significant difference was found in number of instrument passes (33.5 vs. 31.1, $p = 0.42$), percent disc removed by volume (79.5% vs. 76.8%, $p = 0.41$), percent disc removed by mass (77.1% vs. 75.1%, $p = .55$), and percent total disc removed by area (72.8% vs. 71.1%, $p = 0.63$) between the open and MIS approaches, respectively. The percent disc removed by area for each of the 4 quadrants was similar in both the MIS and open groups. The posterior contralateral quadrant was associated with the lowest percent of disc removed compared to the other 3 quadrants in both open and MIS groups (49.9 % and 59.7%, respectively).

Conclusion: MIS and open approaches to TLIF are similar in regards to the adequacy of disc space preparation. The least amount of disc by percentage is removed from the posterior contralateral quadrant, regardless of the approach.

Poster 8. Supraspinal Modulation of Gait Abnormalities Associated with Non-Compressive Radiculopathy may be Mediated by Altered Neurotransmitter Sensitivity

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Introduction: Radiculopathy resulting from intervertebral disc herniation involves mechanical compression and biochemical inflamma-

tion of apposed neural elements. Heterotopic disc placement induces early and persistent allodynia alongside pathological asymmetry of gait. Nevertheless, the mechanisms responsible for resolution of patient symptoms remain elusive, and has hitherto been uninvestigated in animal models. This study evaluated the inflammatory and analgesic molecular profile observed at the dorsal root ganglion (DRG) and midbrain periaqueductal grey and red nucleus in an animal disc-herniation disease model.

Methods: Radiculopathy was induced in Sprague-Dawley rats by harvesting autologous nucleus pulposus (NP) from a tail intervertebral disc followed by exposure of the L5 dorsal root ganglion (DRG). Control animals (n=12) underwent exposure only and experimental animals received NP placement onto the DRG (n=12). Animals were evaluated (1 or 4 weeks) for mechanical allodynia and gait symmetry. Following sacrifice, the midbrain was evaluated by immunohistochemistry for neurotransmitter receptor expression.

Results: Persistent mechanical allodynia occurred in rats subjected to NP stimulation at 1 and 4 weeks, although gait asymmetry and impaired propulsive impulse was only noted at the early (1 week) time point with late normalization (4 weeks). Immunohistochemical evaluation of the ventral periaqueductal grey revealed persistently high glutamate receptor expression, high serotonin receptor expression at 1 week with late normalization, and early normal opioid receptor expression with late escalation at 4 weeks. (Figure 1)

Conclusions: Persistent mechanical allodynia with only transient gait abnormality in non-compressive disc herniation suggests early deficits to be mediated by both spinal and supraspinal mechanisms. Early midbrain serotonin and glutamate receptor expression may aggravate early allodynia while late opioid receptor expression may permit adaptive response to normalize gait.

Poster 9. Outcomes of Anterior, Posterior, and Circumferential Lumbar Fusions

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Introduction: Lumbar fusions are commonly performed through anterior or posterior approaches, or both for degenerative pathologies. Epidemiology, complications and costs differences based upon surgi-

cal approach are not well known. A population-based database was analyzed in order to characterize these differences on a national level.

Methods: Data from the Nationwide Inpatient Sample database was obtained from 2002-2009. Patients undergoing lumbar fusion for degenerative etiologies were identified and separated into three cohorts: anterior lumbar fusion (ALF), posterior lumbar fusion (PLF), and anterior & posterior spinal fusion (APLF). Patient demographics, co-morbidities, hospitalization days, costs, complications, and mortality were compared. Students T-test was used to assess for differences between continuous data and χ^2 -test for categorical data. A p-value of <0.0005 was used to denote significance.

Results: A total of 222,312 lumbar fusions were identified in the database from 2002-2009. PLF was the most commonly performed procedure comprising 82.6% of cases (p<0.0005)(Table 1). Patients in the PLF group were older with more co-morbidities than the ALF and APLF groups (p<0.0005). ALFs had significantly increased costs and complication rates compared to the PLF group. Specific complications that were higher in ALFs were DVTs and infections, while neurologic complications were more common in PLFs. APLFs incurred the greatest costs and hospitalizations, and had the highest complication rates of all three groups. There was no significant difference in mortality amongst the three groups.

Discussion: Patients undergoing lumbar fusion for degenerative conditions have increased hospitalizations, costs, morbidity and mortality when both anterior and posterior techniques are used. In-hospital costs and mortality were lowest in the PLF group despite older patients with more co-morbidities undergoing PLF. Comparison of the ALF and PLF groups demonstrates that DVTs and infection are more frequent complications of anterior approaches while neurologic complications are more common posteriorly. Our study concludes that patients undergoing circumferential lumbar fusions are at substantially increased risk for complications and need to be monitored more closely. Furthermore, when choosing between surgical approaches (ALF vs. PLF), the surgeon must consider specific complications that are more common to each approach while educating the patients on potential risks.

Table 1- Comparison of Anterior, Posterior, and Anterior/Posterior Lumbar Fusion						
	Anterior Fusion	Posterior Fusion	Anterior-Posterior Fusion	ALF vs. PLF	ALF vs. APLF	PLF vs. APLF
Count (unweighted)	20,089	183,716	18,507	p-value	p-value	p-value
Age (mean)	47.9	57.1	50.5	<0.0005	<0.0005	<0.0005
% Male	44.9	43.6	45.6	<0.0005	0.17	<0.0005
% Female	55.1	56.4	54.4	<0.0005	0.17	<0.0005
CCI	1.71	2.68	1.99	<0.0005	<0.0005	<0.0005
Race (% Caucasian)	83.3	84.4	82.3	<0.0005	0.002	<0.0005
Insurance						
Medicare	17.2	36.6	20.7			
Medicaid	6.1	4.1	4.5	<0.0005	<0.0005	<0.0005
Private/HMO	58.2	46.6	56.0			
Other	18.5	12.8	18.9			
Teaching Hospital (%)	52.4	51.6	48.7	0.04	<0.0005	<0.0005
LOS (Days)	4.1	4.2	5.3	0.36	<0.0005	<0.0005
Costs	\$27,442	\$25,556	\$39,330	<0.0005	<0.0005	<0.0005
Mortality (per 1000 cases)	1.8	1.2	2.0	0.009	0.72	0.002
Overall Complications (per 1000 cases)	49.4	44.0	67.8	<0.0005	<0.0005	<0.0005
PE	2.5	2.4	4.4	0.82	0.001	<0.0005
DVT	6.7	3.3	7.4	<0.0005	0.39	<0.0005
Infection	13.1	6.2	16.4	<0.0005	0.007	<0.0005
Cardiac	8.6	8.9	13.5	0.62	<0.0005	<0.0005
Hematoma	14.7	13.2	19.1	0.07	0.001	<0.0005
CSF Leak	0.5	1.5	1.0	0.001	0.13	0.07
Shock	0.9	0.7	1.5	0.32	0.08	<0.0005
Neuro Comp	2.4	7.8	4.6	<0.0005	<0.0005	<0.0005

*All complications listed as incidence per 1000 cases.

Poster 10. Meta-analysis of Adult Degenerative Scoliosis Surgical Treatment Outcomes: Results of University of Minnesota and Scoliosis Research Society Evidence-Based Medicine Task Force.

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Introduction: There is increasing awareness of adult degenerative or “de novo” scoliosis and its surgical treatment when indicated can be challenging and resource intense. Surgical randomized controlled trials are rare, and observational studies pose limitations due to heterogeneity of surgical practices, techniques, and patient populations. Pooled analysis of the current literature may identify effective treatment strategies and guide future efforts at prospective clinical research. The purpose of this meta-analysis was to synthesize existing data on the outcomes of surgical intervention for adult degenerative scoliosis.

Methods: Pubmed, Medline, Cochrane and Web of Science databases were searched using key words and limited to the English language. Abstracts were reviewed by fellowship-trained spine surgeons and were further evaluated if they contained surgically treated cohorts of adults (>18yrs) with degenerative scoliosis. Full text articles were reviewed as a team to determine inclusion, and relevant data abstracted. All meta-analyses were conducted on using random effects models and heterogeneity was estimated with I². Random-

effects metaregression models were used to investigate the association of treatment effects with baseline levels of each outcome.

Results: The literature search yielded 482 articles, and of those, 24 articles with 34 surgically treated groups (n=805) met inclusion criteria and were abstracted by a team of 8 spine surgeons and methodologists. Available outcomes included: Cobb angle correction, coronal and sagittal balance, visual analog scale for pain (VAS) and Oswestry Disability Index (ODI). Despite significant heterogeneity among studies, random-effects meta-analysis did show significant improvements in Cobb angle (-11.13 degrees, 95% CI: -13.86, -8.40), coronal balance (- 7.674mm, 95% CI: -10.49, -4.86), VAS (-3.24, 95% CI: -4.5, -1.98) and ODI (27.18%, 95% CI: -34.22, -20.15) after surgical treatment (p<0.001). Meta-regression models showed that the pre-operative values for Cobb angle, coronal balance and VAS were statistically significantly associated with surgical treatment effect (p<0.05).

Conclusion: Exhaustive literature review yielded 24 studies reporting pre- and post-operative data regarding the surgical treatment of adult degenerative scoliosis. No randomized controlled trials were identified. Despite significant heterogeneity, a limited meta-analysis did show significant improvement in Cobb angle, coronal balance, and VAS following surgical treatment of adult degenerative scoliosis.

Poster 11. Comparison of Symptomatic Cerebral Spinal Fluid (CSF) Leak Between Patients Undergoing Minimally Invasive Versus Open Lumbar Foraminotomy, Discectomy or Laminectomy

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Introduction: Iatrogenic dural tears are an established risk of all spinal procedures. When incompletely repaired, potential clinical complications may present as post-operative CSF leak symptoms: positional headaches, pseudomeningocele, and/or a CSF-cutaneous fistula. The application of minimally invasive spine surgical (MISS) techniques may potentially change the management of dural injuries and diminish their clinical impact.

Methods: We retrospectively studied 863 patients who underwent 1 or 2 level discectomy, foraminotomy, or laminectomy by either a MISS or "open" technique. Clinical variables included: operative time, CSF leaks, hospital stay, days with lumbar drain, days of post-operative flat bedrest, and post-operative intervention. Statistical analyses include univariate analysis (Student t-test, ANOVA, OR, Chi2) and bivariate analysis (logistic regression).

Results: In the MISS group, there were 15 CSF leaks (4.7%). There were 49 CSF leaks (9.0%) in the open group. Eight patients in the open group required lumbar drainage compared to zero patients in the MISS. Twelve patients required reoperation for persistent CSF leak in the open group compared to zero patients in the MISS group. The mean operative time in patients with CSF leaks was 115.9 minutes in the open group and 101.1 minutes in the MISS group. The mean hospital stay in patients with CSF leaks was 3.2 days in the open group and 2.4 days in the MISS group. Patients undergoing open spine surgery were two times more likely to have a CSF leak (OR=2.3, 95%CI = 1.2, 3.7, p=.01). Patients undergoing MISS had fewer return trips to the operating room for CSF leak repairs (open=25% of open CSF leak cases, MISS=0%, p<.01).

Discussion: Previous smaller comparison studies failed to show a higher rate of CSF leak in open vs MISS lumbar surgeries. However,

in the current study, both the incidence and clinical implication of the dural injury was significantly different.

Conclusions: There is a statistically significant decreased rate of CSF leak between a MISS approach and an "open" surgical approach. Furthermore, CSF leaks in "open" surgery have a higher probability of requiring lumbar drainage or reoperation to repair the durotomy.

Poster 12. Lasting Improvement Of Visual Estimation Of Lumbar Spine Range Of Motion After One Training Session

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Introduction: Lumbar range of motion (ROM) is a common measure of functional impairments and surgical outcomes. ROM is routinely assessed by visual estimation in clinical practice, but such assessments have been shown to be unreliable and inaccurate.

Methods: To investigate if training might improve visual estimation of ROM, six examiners at our institution visually estimated ROM of six healthy subjects fitted with a radiographically validated electrogoniometer device while an impartial investigator recorded goniometric measurements. 900 independent visual estimations of 180 distinct movements were recorded.

These six examiners then received verbal and visual instruction in ROM assessment. Visual estimation and goniometric measurement of ROM of those six subjects were then repeated immediately after and one month following this training session, totaling 2700 observations of 540 distinct movements. T-tests were used to compare means.

Results: Initial mean error of visual estimation relative to goniometric measurement in the plane of flexion-extension was 15.4 ± 2.3 (mean absolute error $\pm$ 95% CI, in degrees), in lateral bending 12.6 ± 1.9 , and in axial rotation 52.3 ± 9.1 .

Immediately after the training session, errors were unchanged in flexion-extension 17.8 ± 1.8 and in lateral bending 11.4 ± 1.4 but were significantly improved in axial rotation 14.4 ± 2.0 (p<0.0001).

One month following the training session, the errors in flexion-extension and lateral bending remained unchanged at 15.8 ± 1.6 and 10.2 ± 1.2 while significant improvement remained in the plane of axial rotation 10.3 ± 1.5 (p<0.0001).

Discussion and Conclusion: A single training session improved the accuracy of visual estimation of ROM in the plane of axial rotation by over 70%. Analysis of intraclass correlation also indicates almost perfect reliability after training. As we increase emphasis on functional assessments of outcomes, more formalized instruction of ROM assessment may be necessary.

Table 2: Characteristics of Patients with CSF Leak After Undergoing Open Vs. MISS Spine Surgery (n=863)

Characteristic	Open (n=544)	MISS (n=319)	Total (n=863)	OR* (p-value)
CSF Leak				
Yes	49 (9.0)	15 (4.7)	64 (7.4)	2.0 (.012)
CSF Visualized Intra-Operatively				
Yes	37 (75.5)	13 (86.6)	50 (78.1)	4.6 (.082)
Primary Repair				
Duraseal	37 (100.0)	13 (100.0)	50 (100.0)	.299
Gel-Foam	3 (8.1)	5 (38.4)	8 (16.0)	7.6 (.014)
Suture	27 (73.0)	2 (15.4)	29 (58.0)	8.0 (.004)
Native Tissue	7 (18.9)	1 (7.7)	8 (16.0)	.393
Patch	27 (73.0)	5 (38.5)	32 (64.0)	.119
Duragen				
Flat Bedrest				
Days (mean, SD)	1.73 (1.78)	0.8 (0.56)	1.52 (1.64)	.030
Lumbar Drain				
Days (mean, SD)	0.63 (1.5)	0 (0.0)	0.48 (1.4)	.052
Re-Operation				
Primary Repair	12 (2.2)	0 (0.0)	12 (1.4)	.004
Blood Patch	4 (0.7)	1 (0.3)	5 (0.6)	.391
Infection	16 (2.9)	6 (1.9)	20 (2.3)	.236
Fusion	12 (2.2)	14 (4.4)	26 (3.0)	.056
Hemorrhage	1 (0.2)	3 (0.9)	4 (0.5)	.145
ASD**	3 (0.6)	0 (0.0)	3 (0.3)	.250
SCS***	1 (0.2)	3 (0.9)	4 (0.5)	.145
Total#	80 (14.7)	50 (15.6)	130 (15.1)	.386
Length of Stay				
Days (mean, SD)	1.49 (1.82)	1.21 (1.83)	1.38 (1.82)	.030
0 days (count, %)	148 (27.2)	123 (38.6)	271 (31.4)	1.7 (.001)
≤ 1 day (count, %)	370 (68)	256 (80.3)	626 (73.5)	1.9 (.001)
> 1 day (count, %)	101 (18.6)	43 (13.5)	144 (16.7)	1.5 (.001)

*OR calculated where appropriate (Maental-Haenszel), p<.05 significant, where appropriate Student t-tests and Chi² were used. **Adjacent Segment Disease. ***Spinal Cord Stimulator. #The total number of re-operations exceeds the sum of itemized re-operations because some patients were taken back for more than one indication.

Poster 13. Cost Analysis Of Single Level Lumbar Fusions

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Background: Unsustainable health care spending has led to an increased emphasis on cost-effectiveness and value-based care. The costs of spinal surgery are highly variable, and opportunities for cost saving may be identified in areas with the highest variability between providers, and the most significant cost contribution. The purpose of this paper is to analyze the determinants of direct costs of an episode of care for single level lumbar fusions and to identify potential areas for cost reduction.

Methods: Retrospective study design of a consecutive series of patients treated with single level fusion for lumbar degenerative pathology. Demographic data, surgical data, and direct cost data were collected for each patient.

Results: The cohort included 534 adult patients who underwent primary single level lumbar fusions at a single institution between 2008 and 2012. The range in cost of care was \$7,201-\$73,727 (median \$21,790). Comorbidities were a significant contributor to variability in the cost of care. Services accounted for 38% of the total cost of care and were highly dependent on operative time (OR staffing 41% of services costs=\$3600). The use of implants contributed 36% of the total cost of care, with the highest individual components of costs for BMP (\$4,912) and interbody cages (\$2,918). Surgical approach was an independent predictor of cost. Circumferential fusion with an anterior and posterior approach (\$29,712) was more expensive than anterior only (\$23,936), TLIF (\$23,174) direct lateral only (\$20,089) or posterior (\$18,880) alone.

Conclusion: Implants and intra-operative services were the primary drivers of cost in single level lumbar fusions. Because service charges are largely time-dependent, variations in surgical approach and intra-operative efficiency significantly affect cost of care. Variability in the use of services such as neuromonitoring and cell saver suggests areas for potential cost savings by reducing variability between practitioners. Highly variable costs between types of implants emphasize the importance of assessing whether the extra cost for a device is justified by an incremental difference in outcome. Areas of high cost and high variability offer potential targets for cost savings and quality improvements.

Poster 14. Radiographic Correction And Clinical Outcomes Of Combined Lateral Lumbar Interbody Fusion (LLIF) And Open Screw Fixation With And Without Smith-petersen Osteotomies In Degenerative Scoliosis Patients

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Introduction: We retrospectively evaluated degenerative scoliosis patients treated with combined lateral lumbar interbody fusion (LLIF) with open pedicle screw fixation and compared clinical outcomes, lumbar lordosis (LL), and the change in segmental LL as a function of the post-operative increase in LLIF disc space height in patients treated without (Group-1) or with (Group-2) Smith-Petersen osteotomies.

Materials and Methods: Adult deformity patients undergoing combined LLIF and open posterior pedicle screw instrumentation at the UC San Diego Medical Center between January 2009 and September 2011 were reviewed. Patients were divided into those without osteotomy (Group-1; 10 patients) or those with posterior osteotomy (Group-2; 9 patients). Pre- and post-operative scoliosis radiographs (PA,

lateral) and CT/MRIs, as well as Oswestry Disability Index (ODI) and VAS scores, were reviewed. Regional and segmental lumbar lordosis (LL) were compared between groups, and pre- and post-operative disc space heights were measured and the increase was compared to the change in lordosis across each lumbar segment.

Results: Mean follow-up was 13.2 months (2-33) for Group-1 and 11.3 months (5-19) for Group-2. Mean regional LL improved from 35° pre-operatively to 42.4° post-operatively (17.4%) in Group-1, and from 23.1° to 37.3° (38%) in Group-2.

For Group-1 and Group-2, respectively, mean disc height increased by 2.7mm (23%) and 5.8mm (38%) in L4-L5, 1.9mm (18%) and 4.3mm (38%) in L3-4, 2.3mm (23%) and 5.5mm (46%) in L2-3, and 3.1mm (36%) and 5.5mm (50%) in L1-2. For Group-1 and Group-2, respectively, mean segmental LL improved from 21.5° to 24.8° (15%) and 18° to 22.5° (20%) in L4-L5, 12.2° to 14.7° (20%) and 4.4° to 7.2° (62%) in L3-L4, 3.5° to 7.1° (103%) and 1.9° to 11.3° (509%) in L2-L3, and 4.2° to 5.2° (23%) and 3.5° to 6.7° (92%) in L1-L2. Clinically significant improvements in VAS pain scores (70.4% vs 32.7%). Both groups made clinically significant improvements in VAS and ODI scores, with osteotomy patients demonstrating greater improvements in LL (17.4% vs 38%), and VAS pain scores (70.4% vs 32.7%).

Conclusions: In degenerative scoliosis patients, LLIF plus pedicle screw fixation produces clinically meaningful improvements in pain and function. As anticipated, regional and segmental lumbar lordosis improves more in those treated with osteotomy. The group without osteotomy had greater pre-operative disc space heights, which may have affected the decision to perform osteotomy.

Poster 15. Complications of Anterior and Posterior Lumbar Fusion with Use of Bone Morphogenic Proteins

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Introduction: The use of bone morphogenic proteins (BMP) as an adjunct to spinal fusion has increased since FDA approval in 2002. The incidence of post-operative complications with the use of BMP, though reported in case series and larger IDE trials, is not well characterized after lumbar fusions. A population-based database was analyzed with regards to patient demographics, costs, complications, and mortality.

Methods: Data from the Nationwide Inpatient Sample database was obtained from 2002-2009. Patients undergoing 1-2 level anterior or posterior lumbar fusion (ALF/PLF) for degenerative etiologies were identified and separated into cohorts ("BMP" and "No BMP"). Patient demographics (e.g. age, gender), co-morbidities, hospitalization days, costs, complications, and mortality were assessed for both cohorts. Student T-test and χ^2 -test were used to assess for significant differences. A p-value of <0.0005 was used to denote significance.

Results: A total of 18,554 ALFs and 160,970 PLFs (1 or 2 levels) were identified from 2002-2009. 51.7% of ALFs and 34.1% of PLFs utilized BMP (Table 1). Patients receiving BMP in both surgical groups were significantly younger with less co-morbidities ($p<0.0005$). Both surgical groups had shorter hospitalizations and increased costs when BMP was utilized ($p<0.0005$). The average hospital cost increased by \$1,038 with BMP in ALFs and increased \$5,271 in PLFs. Overall complication rates were lower with BMP in the ALF group ($p<0.0005$), but not with BMP use in the PLF group ($p=0.003$). Both surgical groups (ALF and PLF) with BMP utilization experienced significantly lower infection rates ($p<0.0005$).

Discussion: The use of BMP as an adjunct in lumbar fusions (2002-2009) is common occurring in 51.7% of ALFs and 34.1% of PLFs. Patients in the BMP cohorts incurred greater in-hospital costs despite having shorter hospitalizations, which may be accounted

	ALF			PLF			ALF		
	No BMP	BMP	p-value	No BMP	BMP	p-value	No BMP	BMP	p-value
Count	8,967	9,587		106,104	54,866		9,587	54,866	
Frequency (%)	48.3	51.7		65.9	34.1		51.7	34.1	<0.0005
Age	48.0	46.5	<0.0005	56.5	55.9	<0.0005	46.5	55.9	<0.0005
%Female	54.1	55.1	0.17	56.5	56.6	0.82	55.1	56.6	0.005
CCI	1.77	1.50	<0.0005	2.61	2.54	<0.0005	1.50	2.54	<0.0005
LOS (days)	4.2	3.5	<0.0005	4.0	3.9	<0.0005	3.5	3.9	<0.0005
Costs	\$24,318	\$25,356	<0.0005	\$22,380	\$27,651	<0.0005	\$25,356	\$27,651	<0.0005
Complications (per 1000)	52.0	52.3	<0.0005	39.3	36.1	0.003	52.3	36.1	0.10
Pulmonary Embolism	2.0	1.7	0.59	2.1	2.0	0.50	1.7	2.0	0.54
DVT	7.6	4.1	0.002	2.9	2.6	0.25	4.1	2.6	0.01
Infection	15.9	7.6	<0.0005	5.9	4.2	<0.0005	7.6	4.2	<0.0005
Cardiac (M.I.)	7.8	6.5	0.28	7.9	7.5	0.38	6.5	7.5	0.30
Hemorrhage/hematoma	14.6	10.3	0.008	11.3	11.3	0.88	10.3	11.3	0.39
CSF Leak	0.7	0.2	0.13	1.5	1.4	0.60	0.2	1.4	0.002
Neurologic	2.8	1.5	0.05	7.3	6.7	0.22	1.5	6.7	<0.0005
Post-op Shock	0.6	0.5	0.92	0.5	0.3	0.60	0.5	0.3	0.41
Mortality (per 1000)	1.9	1.1	0.189	1.1	0.6	0.008	1.1	0.6	0.06

*ALF=anterior lumbar fusion, PLF=posterior lumbar fusion, BMP=bone morphogenetic protein, CCI=Charlson co-morbidity index, LOS=length of stay

for by the direct costs of BMP. Interestingly, patients receiving BMP had fewer infections. This study cannot definitively determine whether placement of BMP, a healthier patient population, or other factors were responsible for the decreased infection rate. We believe these outcomes warrant further investigation in a matched cohort to determine if utilization of BMP in lumbar fusions truly decreases the incidence of post-operative infections.

Poster 16. Trends in Complications After Lumbar Spine Surgery from 2002–2009

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Introduction: Lumbar surgery for degenerative spinal conditions are common but controversial. The frequency of complications after lumbar decompressions (LD) and lumbar fusions (LF) varies widely in the reported literature. The purpose of this study was to analyze a population-based database to describe national complication trends of these two procedures.

Methods: Data from the Nationwide Inpatient Sample database was obtained from 2002-2009. Patients undergoing LD or LF for degenerative etiologies were identified. Eight categories of complications were tabulated in the 2 groups using ICD-9 codes. These included pulmonary embolism (PE), deep vein thrombosis (DVT), infections, cardiac complications, hematomas, CSF leaks, post-operative shock, and neurologic complications. Statistical analysis was performed using χ^2 -tests for categorical data, Spearman's correlation for 8-year trends. A p-value of 0.01 was used to denote statistically significant trends.

Results: A total of 578,457 LDs and LFs were identified from 2002-2009 (Table 1). Both surgical groups demonstrated significant trends of increasing ages, co-morbidity scores, and costs during this time period (Table 2). LFs had higher complication rates at all time points compared to the LD group. Over the 8-year period there were significant trends in the LD group of increasing overall complications: spe-

cifically increasing rates of DVTs, infections, hematomas ($p<0.01$). Overall complication rates did not change after LFs from 2002-2009. Increasing rates of post-operative shock from 2002-2009 was the only statistically significant trend in the LF group ($p=0.005$), while increasing rates of DVTs approached significance ($p=0.02$).

Conclusion: Our findings demonstrate that from 2002-2009, patients undergoing lumbar procedures had increasing trends of age and co-morbidities reflecting increases in surgical challenges and complexity. These changes in patient demographics may explain the increasing complication rates after LDs. Both groups demonstrated a trend of increasing costs, which may be explained by increasing ages and co-morbidities of patients as well as the increasing complication rates. It also should be noted that the complication rate in the LF group was approximately double that of the LD group for all years. Despite a trend of increasing risk factors during this 8-year period, mortality did not change significantly.

	2002	2003	2004	2005	2006	2007	2008	2009	Total
Total (Count)									
LD	42,839	44,213	36,723	38,601	34,330	34,664	32,370	28,437	292,177
LF	29,323	30,934	31,005	33,628	35,580	36,927	44,038	44,845	286,280
									P-value
Overall	25.1	25.3	30.7	28.4	32.4	30.5	34.3	39.2	0.001
LD	46.7	46.8	50.0	52.2	49.0	49.4	45.8	47.7	0.92
LF									
PE	0.8	0.8	1.1	0.8	1.1	0.8	1.0	1.7	0.16
LD	2.3	2.0	3.0	2.9	2.2	2.7	2.8	3.0	0.27
LF									
DVT	1.7	2.3	2.4	2.5	2.2	2.6	3.0	3.2	0.007
LD	3.6	4.2	4.3	4.5	4.4	4.3	4.5	4.5	0.02
LF									
Infections	4.9	5.4	7.4	6.1	7.5	7.6	10.4	12.6	<0.0005
LD	7.7	9.1	8.2	8.1	8.8	8.9	8.0	8.2	0.89
LF									
Cardiac (M.I.)	3.6	4.2	4.2	3.9	3.6	4.2	4.0	4.6	0.34
LD	8.4	8.8	9.7	10.0	8.5	10.3	8.8	10.0	0.19
LF									
Hematoma	5.9	4.5	5.9	6.2	6.7	6.5	7.3	8.3	0.001
LD	15.1	12.6	13.5	16.7	15.2	14.4	12.6	13.2	0.59
LF									
CSF leak	1.2	1.2	0.8	1.4	1.3	1.2	1.2	1.8	0.23
LD	1.8	1.6	1.6	1.5	1.1	1.3	1.5	1.6	0.20
LF									
Post-operative shock	0.16	0.07	0.11	0.10	0.15	0.14	0.03	0.25	0.82
LD	0.4	0.5	0.5	0.8	0.9	0.8	0.8	1.2	0.005
LF									0.87
Neurologic Complications									
LD	6.7	6.9	8.8	7.4	9.8	7.6	7.5	6.8	0.61
LF	6.9	8.0	9.1	7.7	7.9	6.7	6.8	6.1	0.58

*All complications are listed as number of complications per 1,000 procedures; M.I.= myocardial infarction; PE= pulmonary embolism; DVT= deep venous thrombus; CSF= cerebrospinal fluid.

-Statistical analysis was performed using Spearman's Correlation to assess for significant trends.

-Rho reported only for significance at <0.01.

Grey HIGHLIGHTED AREAS designate Statistical Significance

Poster 17. Correlating the Accuracy of Navigated Pedicle Screw Insertion with Screw Dimensions and Pedicle Anatomy in the Lumbar Spine

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University of Minnesota

Introduction: The use of pedicle screw based constructs in lumbar arthrodesis is now widely accepted; this acceptance is largely based on the rigid fixation that can be achieved in this procedure. Since the inception and adoption of pedicle screws in lumbar surgery, the rates of fusion have increased dramatically. One of the concerns that exist in relation to the use of pedicle screws is the potential for misplacement. This study aims to see if there is a correlation between the dimension of screws and of pedicles' anatomy and how this may relate to the accuracy of screw placement.

Methods: A review was conducted of lumbar screw insertions at our institution in patients over 18 years, using the navigated method (StealthStation® TREON™, Medtronic, Louisville, CO). Accuracy of the screw insertion was measured using a standardized method; the magnitude of a cortical breach in the pedicle was represented by a letter: A (no breach), B (<2mm), C (>2mm, <4mm), D (>4mm, <6mm) and E (>6mm). Measurements were made of the anatomic dimensions of the pedicles. The combination of these two systems allowed for a direct correlation to be made between the accuracy of screw insertion, screw dimensions and pedicle anatomy.

Results: All screws were within the A+B classification, with 64(91%) and 6(9%) being classified as A and B respectively. Pedicle width became sequentially larger from L1 to L5. The level of accuracy was marginally higher in the lower segments (L4 and L5) than in the upper segments (L1-L3).

Conclusions: Anatomic pedicle widths were found to be much larger than the width of the screws, likely contributing to the level of accuracy observed. Of note, the dichotomy between in the level of accuracy between the lower and upper lumbar vertebrae, that has previously been reported, was replicated in this study. Few studies have correlated the dimensions of the pedicle with the accuracy - a comparison with another study doing so, by Sugimoto and colleagues, shows the average isthmus width of pedicles of patients in our series to be larger, which may be accounted for by geographic anatomical variations.

Poster 18. Perioperative Effects Associated with the Surgical Treatment of Degenerative Spondylolisthesis: Interbody versus No Interbody

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Introduction: Degenerative spondylolisthesis (DS) is a common disorder that, failing non-operative treatment is generally managed with surgical decompression and concomitant posterior arthrodesis. At present, the risk:benefit ratio of including an additional interbody arthrodesis has not been clearly delineated in the literature. The purpose of this study is to compare the perioperative effects of performing an interbody and posterior arthrodesis versus posterior instrumented fusion (PIF) alone in patients undergoing surgery for DS.

Methods: A retrospective review of 174 patients diagnosed and treated for a single level DS from January 1, 2000 – August 1, 2011 at a single institution. Patients received either a single level lumbar interbody fusion with PIF or PIF alone, and periop-

erative and early postoperative effects were recorded. Operative time, blood loss, complications, hospital stay, and immediate radiographic measures (ie. effects on disk height and lumbar lordosis) were compared.

Results: We identified 174 patients who received a single level lumbar interbody fusion with PIF (n=89) or PIF alone (n=85). Statistically significant factors between the interbody and non-interbody groups include: average age, 59 vs. 70 years (p> 0.05); operative time, 200 vs. 143 minutes (p<0.001); blood loss, 355 vs. 269 cc (p<0.001); mean change in disc height, 2.1 vs. 0.6 mm (p<0.001) and post-op radiculitis, 14.9% vs. 3.4% (P=0.003). Infection, dural tear, and reoperation rates were equivalent. Subgroup analysis of the patients with post-op radiculitis did not reveal a statistically significant difference with regard to BMP-2 usage or cage height. Eighty-seven percent of patients with symptoms of post-op radiculitis resolved by 3 months.

Conclusion: The ideal surgical approach when treating patients with DS remains in question. This study suggests, that when comparing PIF with or without additional interbody fusion, that the immediate perioperative effects of interbody fusion may carry a higher risk profile; including longer surgery, higher blood loss and increased risk of postoperative radiculitis.

Poster 19. Nerve Injury And Recovery After Lateral Lumbar Interbody Fusion With And Without Bone Morphogenetic Protein-2 Augmentation: A Cohort Controlled Study

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Hospital for Special Surgery

Introduction: Although multiple lines of evidence suggest that recombinant human bone morphogenetic protein-2 (rhBMP-2) use during anterior or transforaminal lumbar interbody fusion is associated with an increased risk of nerve injury, data on the effects of the application of rhBMP-2 close to the dorsal root ganglion (DRG) and the lumbar nerve roots during lateral lumbar interbody fusion (LLIF) is still lacking. The purpose of this study was to compare the incidence of neurologic injury and impaired neurologic recovery in patients undergoing LLIF with and without rhBMP-2 use.

Methods: The medical charts of patients underwent LLIF for degenerative spinal conditions were retrospectively reviewed. Patients

Table 1. Odds ratios for neurologic deficit and postoperative thigh or groin pain in patients treated with or without rhBMP-2.

		Immediate Post-op			6 Months Follow-up			Last Follow-up		
		OR	Lower	Upper	OR	Lower	Upper	OR	Lower	Upper
Sensory Deficit	rhBMP-2	0.805	0.465	1.721	1.193	0.609	2.339	1.753	0.872	3.525
	Autograft/Allograft									
Motor Deficit	rhBMP-2	1.661	0.857	3.220	2.015	1.024	3.968	3.060	1.499	6.248
	Autograft/Allograft									
Anterior thigh/groin pain	rhBMP-2	1.987	1.017	3.884	4.043	1.261	12.968	16.47	0.934	294.1
	Autograft/Allograft									

rhBMP-2: recombinant human bone morphogenetic protein 2; OR: odds ratio, CI: confidence intervals

were divided into 2 groups according to the use or not of rhBMP-2: Group 1 (rhBMP-2 use; n=72) and Group 2 (autograft/allograft use; n=72) were matched according to the age at the time of surgery, gender, weight, BMI, side of approach, total number of segments treated, levels treated, use of supplemental posterior fusion, and length of follow-up.

Results: At the last follow, a persistent sensory deficit was identified in 29 patients who underwent LLIF with rhBMP-2 and 20 patients in whom autograft/allograft was used ($p=0.113$). At the same time point, a persistent motor deficit was recorded in 35 and 17 patients in groups 1 and 2, respectively ($p=0.002$). In Group 1 a significantly higher number of patients complained for persistent anterior thigh or groin pain compared with Group 2 (8 vs. 0 patients, respectively; $p=0.007$). Table 1 shows the odds ratios for developing neurologic deficit and pain after LLIF with or without rhBMP-2.

Conclusions: This is the first study to implicate rhBMP-2 as a potential risk factor for neural deficits and pain after LLIF. Another advantage of this study was the careful comparison of a large number of treated levels with or without the use of rhBMP-2 after addressing all possible confounding factors. Our results provide evidence of an increase rate of postoperative neurologic deficits and anterior thigh/groin pain after LLIF using rhBMP-2 compared with closely matched controls without rhBMP-2 exposure. This study suggests a direct deleterious effect of rhBMP-2 in lumbar nerve roots and DRG.

Poster 20. Retrospective Safety Evaluation of recombinant Human Bone Morphogenetic Protein-2 Implantation in Lateral Lumbar Interbody Fusion

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Hospital for Special Surgery

Introduction: Due to proposed advantages, such as avoiding morbidities associated to traditional approaches for Anterior Lumbar Interbody Fusion (ALIF), the lateral approach to lumbar interbody fusion has increasingly been utilized in recent years. Recently, concerns have arisen regarding the safety of BMP-2 as a bone graft substitute in ALIF, as well as in off-label applications. The spectrum of adverse reactions to complementary BMP-2 utilization in LLIF remains to be fully elucidated.

Methods: The electronic medical records and imaging studies of 485 consecutive LLIF patients over a six year period from a single institution were retrospectively reviewed for reports on adverse reactions possibly related to use of BMP-2 as a bone graft substitute.

Results: 411 patients, mean age 62 years (range 24-88 years), underwent LLIF with utilization of BMP-2 as a bone graft substitute. Gender distribution was 1:0.62 female to male and an average of 2.04 levels (range 1-5 levels) was fused for a total of 837 included levels. No ectopic bone formation was identified within the present series. Seroma in proximity to the surgical bed was identified in two patients and one patient presented with neuritis of the sciatic nerve 4 months after her LLIF procedure. Postoperative exacerbation of previously undiagnosed multiple myeloma was seen in one patient.

Conclusions: There are a growing number of reports describing the potential of BMP-2 to form heterotopic bone or cause seroma. Abundant inflammatory responses may occur in a small, yet finite, subset of patients ("hyperresponders") and may influence clinical outcome. In our series, two out of 411 cases (0.49%) of postoperative seroma attributable to BMP-2 use were identified, and an additional two patients had complications possibly related to use of the biologic adjunct. The incidence of symptomatic BMP-2 reactions can therefore be estimated at 0.97% (4/411) within this large retrospective series. More precise definition of the safety profile of BMP-2 use in LLIF, ideally from a large prospective series, is desirable.

Poster 21. A Reliable And Simple Measurement To Identify An Osseous-bridging Transitional Vertebra On A Single Slice Mid-sagittal Mr-image Or Lateral X-ray

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Hospital for Special Surgery

Introduction: Identification of a lumbosacral-transitional vertebra (LSTV) can be challenging and should not be overlooked, as it is biomechanically relevant and might affect surgical decision-making. A simple method to identify an osseous-bridging and therefore mechanically attached vertebra is desirable and was subject of this study.

Methods: 92 LSTV were categorized by a Radiologist according to the Castellvi classification (type 2a+b, n=46; Type 3 and 4, n=46). Two independent readers (Radiologist and surgical PGY1 (blinded)) measured the vertical mid-vertebral angle (MVA). The MVA was defined as the angle between the vertical mid-vertebral lines of a segment on a single slice mid-sagittal MR image or lateral x-ray. The MVA of the lowest segment with a developed disc and the next one above were measured and the difference (Diff-MVA) was calculated in all the 92 LSTV and other 94 control non-LSTV subjects in MRI and in lateral X-rays if available (64 LSTV and 47 non-LSTV). The mean of two reads was used for statistical analysis.

Results: The Diff-MVA was significantly higher in the non-LSTV ($25\pm8^\circ$) than in the LSTV subjects (type 2a+b: $16\pm9^\circ$, type 3a+b: $-9\pm11^\circ$, type 4: $-5\pm7^\circ$, $p<0.05$). A Diff-MVA of $\leq 10^\circ$ clearly identified osseous bridging LSTV (type 3+4) with a sensitivity of 100% and a specificity of 89% on MRI and 94% and 74% on lateral X-ray, respectively. The ICC between the readers was 0.96 (CI 0.96-0.97).

Conclusions: The MVA is a simple and reliable method to identify LSTV on a single-slice mid-sagittal MR image or lateral x-ray and correlates with the degree of mechanical connection of the TV. A Diff-MVA $\leq 10^\circ$ clearly identifies indirectly the osseous bridging of the posterior elements of a non-mobile LSTV.

Figure 1. Osseous LSTV (Type 3+4) have significantly (* $p<0.001$) lower Diff-MVA than non-LSTV.

Abstracts of the 2013 Meeting of the Lumbar Spine Research Society

Poster 22. Treatment of Lumbar Spondylolisthesis Associated with Adjacent Level(s) Stenosis using Minimally Invasive (MIS) Unisegmental TLIF/Pedicle Screw Instrumentation and Adjacent Level MIS Laminectomy

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Introduction: Low back pain is the most common symptom that patients present with to spine surgeons. Many of these patients have multi-level spinal stenosis and associated spondylolisthesis, which is often treated with multi-level decompression and can have significant morbidity. A retrospective chart review was performed to evaluate patient outcomes scores associated with a more limited unisegmental transforaminal lumbar interbody fusion (TLIF).

Methods: 50 patients (mean age 65.8, range 30 - 87) presented with intractable low back pain and neurogenic claudication secondary to spondylolisthesis and adjacent level lumbar stenosis. Visual analog scale (VAS), short form-36 (SF-36), and Oswestry disability index (ODI) scores were analyzed pre-operatively and post-operatively at 6 months and at final follow-up (mean, 45.1 months).

Results: 14 males and 36 females were treated with unisegmental TLIF and adjacent level laminectomy (1 to 3 levels). Levels fused included L2-3 (n = 3, 6%), L3-4 (n = 4, 8%), L4-5 (n = 34, 68%), L5-S1 (n = 9, 18%). Average blood loss was 125.9 mL and average length-of-stay was 4.13 days. VAS scores declined from 6.9 pre-operatively to 2.6 post-operatively. ODI scores declined from 44.2 pre-operatively to 25.0 post-operatively. SF-36 physical component scores (PCS) increased from 29.3 pre-operatively to 40.3 post-operatively. SF-36 mental component scores (MCS) increased from 45.8 pre-operatively to 51.5 post-operatively. There was statistically significant ($p < 0.01$) improvement in all scales at 6 months and 45.1 months.

Conclusions: Minimally invasive surgical interventions have the advantage of having decreased complications and morbidity. Patients with multi-level spinal stenosis and spondylolisthesis can be treated with a minimally invasive single-level fusion with good results.

Poster 23. Postoperative Leg Pain And/or Dysesthesia At One Year Follow-up Following Extreme Lateral Interbody Fusion At A Single Site

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Introduction: Evidence for the use of XLIF as an effective treatment for spinal disorders is increasing in popularity. However, postoperative leg pain and/or dysesthesia are common following this procedure. We report the outcomes following an XLIF at 1-year follow-up: VAS, ODI and postoperative leg pain and/or dysesthesia.

Methods: Local IRB approved, prospective, non-randomized single center study review of 92 patients with lumbar degenerative disorders (spondylolisthesis, scoliosis, spondylosis, ASD, stenosis, DDD), mean age of 68.3 yrs (43-87), from 2007-2011. Mean follow-up was 19.6 months (8.6-61.7). Patient-reported postoperative leg pain and/or dysesthesia for 91 patients (numbness, tingling, quadriceps weakness, leg spasms, anterior thigh, lateral leg, groin and hip pain) at 2-weeks, 3-months, 6-months and 1-year. VAS and ODI scores were collected preoperatively and at 1-year. 37 patients underwent a 1-level, 28 at 2 and 27 at 3. 24 patients received anterior instrumentation: interbody implant without instrumentation (11); a tabbed interbody implant with vertebral body screws (10); an interbody implant and adjuvant titanium plate with vertebral body screws (3). 68 patients received

supplemental posterior spinal fusion (PSF) with either laminectomies and/or facetectomies.

Results: At 2-week follow-up, 53 (58%) of patients reported postoperative leg pain following the XLIF procedure. At 3 months, 15 (16.5%) continued to report postoperative leg pain. At 6-months, only 7 (7.7%) still reported pain. At 1-year, only 2 patients (2.2%) continued to report lower extremity pain and discomfort. VAS and ODI scores improved from baseline by 66% and 49%, respectively.

Conclusion: Postoperative leg pain and/or dysesthesia are a common patient complaint following surgery. Our study reports resolution of 97.8% of postoperative leg pain at 1-year follow-up. Postoperative leg symptoms appear to be approach related and self limiting following XLIF.

Poster 24. Rate Of Revision Surgery Following Standalone Lateral Transposas Interbody Fusion For Lumbar Spinal Stenosis

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Hospital for Special Surgery

Introduction: Lateral transposas interbody fusion (LTIF) provides a minimally invasive means of achieving interbody arthrodesis and indirect foraminal decompression, while potentially avoiding the morbidity associated with traditional approaches to the spine. There is a paucity of data on standalone LTIF procedures, and no prior study has examined the need for further posterior decompression in patients who previously underwent standalone LTIF. This study reports the revision rate, specifically the need for posterior decompression and/or fusion, in patients who underwent standalone LTIF for symptomatic spinal stenosis or radiculopathy.

Materials and Methods: We performed a retrospective analysis of 39 patients that underwent standalone LTIF for spinal stenosis or radiculopathy and had not had prior procedures at the affected levels. All patients had preoperative and postoperative x-rays, and from these studies, we measured disc heights, interpedicular height and neural foraminal areas. Preoperative and postoperative clinical indices were also measured, including leg pain, back pain, leg paresthesias, and leg weakness. The average followup was 75 weeks (range 11 - 178 weeks).

Results: Patients that underwent standalone LTIF had significantly decreased leg pain, back pain, and leg weakness compared to pre-operatively. There were 12.8% of patients (5 out of 39 total) who subsequently required posterior decompression after standalone LTIF for persistent symptoms. We observed no significant difference in increase in foraminal area in patients requiring reoperation, with a 64% increase in patients not requiring reoperation, and a 57% increase in patients requiring reoperation ($p > 0.05$). There was no difference in preoperative and postoperative leg pain, paresthesias, or weakness in patients requiring revision surgery compared to those who did not. However, patients requiring reoperation did have significantly more back pain at 1 year post-op.

Discussion & Conclusion: We show that standalone LTIF is an effective tool in the management of lumbar spinal stenosis and/or radiculopathy. While posterior decompression was required in a small subset of patients, indirect decompression via restoration of disc height via LTIF was sufficient for a majority of patients. The reduced morbidity associated with this minimally invasive approach makes standalone LTIF a potentially valuable treatment option for this subset of patients.

Poster 25. Quality of Life Outcomes with Minimally Invasive Lumbar Laminectomies in 119 patients

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Introduction: The lumbar spine is unique in that it is responsible for supporting a large portion of the axial skeleton. The continuous stress and strain placed on the lumbar vertebrae subject it to many disease pathologies including spinal stenosis, spondylolisthesis, and degenerative disc disease. While a traditional surgical laminectomy is a common procedure for neural decompression, the minimally invasive approach of this procedure is not well studied. This report categorizes the patient characteristics of individuals who underwent the minimally invasive laminectomy procedure.

Methods: 119 patients (49 females, 71 males) underwent minimally invasive laminectomies between April 2009 and August 2012. Diagnosis included lumbar spondylolisthesis with stenosis (n=16, 14%), degenerative disc disease with stenosis (n=4, 3%), spinal stenosis (n=78, 66%), scoliosis with stenosis (n=4, 3%), herniated disc with stenosis (n=12, 10%), and other pathologies with stenosis (n=5, 4%). Functional outcomes were measured using the visual analog scale (VAS) and Oswestry disability index (ODI). Quality of life outcomes were measured using the Short-Form 36 (SF-36) questionnaire. Patients were assessed pre-operatively and at two weeks, 3, 6, 12, 24, and 36 months post-operatively.

Results: Mean age was 69.2 years (range, 20-91) and mean BMI was 29.7. Levels decompressed included L1-2 (n=3), L2-3 (n=3), L3-4 (n=17), L4-5 (n=21), L5-S1 (n=3), or multi-level decompressions (n=72). 36 patients (30%) underwent prior lumbar surgery, 26 patients (22%) underwent prior laminectomies, and 15 patients (13%) underwent prior lumbar fusion. The most common co-morbidities in this cohort of patients included hypertension, diabetes, hypercholesterolemia, and COPD.

Mean estimated blood loss and hospital stay was 68.4 mL and 2.0 days, respectively. Infection rate was 4% (n=5), all were superficial wound infections. There were no intra-operative complications and an extremely low rate of adjacent segment disease requiring re-operation (<3%).

Conclusions: This study presents a large retrospective analysis of MIS laminectomy patient characteristics. The long term maintenance of excellent outcomes and low rate of adjacent segment diseases requiring re-operation stresses the importance of maintaining normal anatomical structures, afforded by the MIS laminectomy approach, to treat this common condition.

Poster 26. A Novel Model of Disc Degeneration in Yorkshire Swine via a Lateral Trans-Psoas Approach and Stab Injury

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WITHDRAWN

Poster 27. Epidemiological Trends in the Use of Bone Morphogenic Protein in Spinal Fusions from 2002-2009

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Introduction: The use of bone morphogenic proteins (BMP) as an adjunct to spinal fusion has increased since first obtaining FDA approval for use in anterior lumbar interbody fusions in 2002. The purpose of this study was to analyze a population-based database to describe national trends of BMP use in terms of incidence, demographics, costs and mortality.

Methods: Data from the Nationwide Inpatient Sample database was obtained from 2002-2009. Patients undergoing anterior or posterior cervical fusions (ACF/PCF), anterior or posterior lumbar fusions (ALF/PLF), or thoracic fusions were identified and frequency of BMP use was examined by year. Demographics (gender, age, etc.), costs (adjusted for inflation), and mortality were assessed. Co-morbidities were calculated using a modified Charlson Co-morbidity Index (CCI). Statistical analysis was performed using Pearson's correlation to assess for trends. A p-value of 0.01 was used to denote significance.

Results: An estimated 482,141 spinal fusions procedures utilized BMP from 2002-2009 in the United States (Table 1). The number of procedures per year that utilized BMP significantly increased from 1,734 in 2002 to 106,168 in 2009 (p<0.0005, R=0.9). ALF had the highest rates of BMP use, increasing to 53.9% of all ALFs in 2007 and then decreasing to 50.2% of ALFs in 2009 (Figure 1). PLFs

Table 1 - Procedure Outcomes by Year with BMP use										
	2002	2003	2004	2005	2006	2007	2008	2009	Total	p-value
Total Count	1,734	18,473	37,601	54,155	74,328	84,652	105,030	106,168	482,141	<0.0005
Weighted	366	3,843	7,687	11,281	15,410	17,553	21,407	20,997	98,544	<0.0005
Unweighted	0.7%	6.6%	13.9%	18.5%	23.8%	26.2%	28.0%	27.3%	19.2%	<0.0005
Frequency of BMP Use										
ACF										
Weighted	313	2,735	5,420	6,029	10,568	14,203	12,923	12,570	64,852	<0.0005
Unweighted	66	569	1,108	1,256	2,191	2,945	2,634	2,486	13,255	0.001
Frequency	0.3%	2.1%	4.6%	4.9%	8.2%	10.8%	9.2%	8.5%	6.2%	0.002
PCF										
Weighted	14	356	915	1,301	1,881	2,185	2,963	2,877	12,481	<0.0005
Unweighted	3	74	187	271	390	453	604	569	2,551	<0.0005
Frequency	0.2%	3.5%	7.6%	11.5%	15.5%	17.4%	17.5%	18.9%	12.5%	<0.0005
Thoracic										
Weighted	62	572	1,414	2,314	2,701	2,985	4,617	6,017	20,602	<0.0005
Unweighted	13	119	289	482	560	619	941	1,190	4,213	<0.0005
Frequency	0.5%	4.6%	9.7%	13.6%	17.5%	18.0%	22.7%	27.0%	15.7%	<0.0005
ALF										
Weighted	616	5,682	10,424	11,243	13,616	15,688	17,687	18,901	93,959	<0.0005
Unweighted	130	1,182	2,131	2,342	2,823	3,253	3,605	3,738	19,204	<0.0005
Frequency	3.5%	29.3%	47.4%	44.9%	50.2%	53.9%	51.9%	50.2%	44.1%	0.02
PLF										
Weighted	730	9,129	19,429	33,267	45,562	49,592	66,839	65,803	290,237	<0.0005
Unweighted	154	1,899	3,972	6,930	9,446	10,283	13,623	13,014	59,321	<0.0005
Frequency	0.7%	8.6%	18.7%	28.6%	35.3%	37.3%	41.1%	39.5%	28.3%	<0.0005
LOS (days)	4.1	4.3	4.6	4.3	4.2	4.1	4.0	4.2	4.2	0.35
ACF	1.7	2.4	2.8	2.7	2.3	2.4	2.4	2.7	2.5	0.26
PCF	9.3	6.2	7.3	5.4	6.2	6.1	6.0	6.3	6.2	0.12
Thoracic	9.1	9.3	8.7	7.9	8.7	8.6	8.4	7.9	8.3	0.05
ALF	3.9	4.1	4.8	4.5	4.3	4.0	4.1	4.3	4.3	0.96
PLF	4.8	4.6	4.7	4.3	4.3	4.2	3.9	4.0	4.1	<0.0005
Costs (adjusted)	\$25,961	\$28,844	\$29,119	\$30,746	\$29,787	\$31,005	\$30,583	\$31,836	\$29,529	<0.0005
ACF	\$17,995	\$16,337	\$17,931	\$19,767	\$18,831	\$19,606	\$18,261	\$18,357	\$18,011	0.28
PCF	\$43,158	\$25,532	\$28,919	\$27,802	\$30,577	\$33,023	\$33,062	\$33,840	\$30,852	0.87
Thoracic	\$53,638	\$59,347	\$48,378	\$53,222	\$51,328	\$53,842	\$55,769	\$57,788	\$53,110	0.61
ALF	\$23,850	\$27,802	\$32,427	\$34,670	\$33,049	\$33,985	\$36,286	\$38,831	\$33,028	0.001
PLF	\$28,318	\$29,456	\$29,096	\$30,093	\$29,878	\$31,943	\$29,755	\$30,520	\$29,284	0.06
Mortality (per 1000)	0.0	2.1	2.9	1.6	1.6	1.4	1.5	1.6	1.6	0.75
ACF	0.0	10.7	0.9	2.4	2.3	1.4	1.5	2.0	2.1	0.52
PCF	0.0	14.1	27.5	3.7	13.0	13.4	10.0	8.9	11.5	0.94
Thoracic	0.0	0.0	7.0	6.3	10.8	4.9	9.7	8.5	8.0	0.03
ALF	0.0	0.9	3.3	0.4	0.4	1.8	0.6	0.8	1.1	0.98
PLF	0.0	0.0	1.8	1.4	0.8	0.5	0.7	0.8	0.8	0.61

*ACF= anterior cervical fusion, PCF=posterior cervical fusion, ALF=anterior lumbar fusion, PLF=posterior lumbar fusion

accounted for the majority of cases that used BMP with 290,237 cases representing 28.3% of all PLFs performed from 2002-2009. There was a significant trend of older patients with increasing co-morbidities receiving BMP during this time period. Hospital costs (adjusted for inflation) significantly increased an average of \$5,875 from 2002-2009 (Table 2). Mortality did not change with utilization of BMP from 2002-2009.

Discussion: Our study demonstrates that the use of BMP has dramatically increased from 2002-2009. Interestingly, off-label use of BMP accounts for the vast majority of BMP utilization. The increase in costs from 2002-2009 is likely multi-factorial; older patients with more co-morbidities undergoing surgery as well as increasing use of BMP are likely to affect costs. Despite older patients with more co-morbidities receiving BMP, hospitalizations and mortality did not increase. Further studies are needed to identify long-term outcomes of BMP use in spinal fusions.

Poster 28. Clinical Validation of a Novel, Anatomically Based Classification of Lumbar Stenosis

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Introduction: The current descriptive terminology of lumbar stenosis ("mild," "moderate," or "severe") does not carry a direct clinical or anatomical correlation. Surgeons commonly use the presence or absence of cerebrospinal fluid space around the spinal cord as an important clinical decision making factor, although degrees of stenosis have not been qualified. The purpose of this study was to create a reproducible, clinically validated classification of central lumbar stenosis.

Methods: A classification was created as follows: Grade 0 - No stenosis; Grade 1 - Greater CSF Volume Than Rootlet Volume; Grade 2 - Less CSF Volume Than Rootlet Volume But CSF Still Present; Grade 3 - No CSF Present. A cohort of surgeons including 3 orthopedic surgery attendings, 2 neurosurgeons, and three spine surgery fellows reviewed a series of 20 cases in which an axial view and sagittal view were presented at each level. Surgeons were asked to score each level, rate spondylolisthesis and kyphosis, and "If patient had symptoms of claudication or radiculopathy, would you decompress this level (ignoring pathology at other levels in the same patient) (Yes/No)?" and "Could the pathology at this level alone cause cauda equina syndrome? (Yes/No)." ICC was calculated between observers and chi Squared percentage of patients in each grade in whom surgery was recommended were calculated.

Results: A total of 160 levels were scored by 8 surgeons. ICC for

all observers was 0.881 (95% CI 0.798-0.942). There was a statistically significant (chi squared, $p=0.0001$) increase in the percentage of patients in whom decompression was recommended in higher grades: 6% (2/33) Grade 0, 41.3% (19/46) Grade 1, 86% (36/42) Grade 2, 87.2% (34/39) Grade 3. Higher classification grades also corresponded to an increased likelihood of consideration of cauda equina syndrome: : 0% (0/33) Grade 0, 0% (0/46) Grade 1, 45% (19/42) Grade 2, 85% (33/39).

Conclusions: We created an anatomically based, simple classification system with high interobserver consistency for diagnosis and management decision making. This classification may improve communication between caregivers, accuracy of research, and qualifying degree of compressive pathology. Furthermore, consideration should be given to earlier referral of patients with high grade stenosis to specialized spine providers.

Poster 29. Complication Rates of Minimally Invasive Spinal Surgery (MIS) Compared to Open Surgery: A Systematic Literature Review

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Introduction: The use of minimally invasive techniques in spine surgery has garnered much attention since it was first described over 30 years ago. The purported benefits include superior cosmesis, reduced blood loss, decreased pain, less soft tissue damage, reduced muscle retraction, decreased use of post-operative narcotics, shorter duration of hospital stays, and quicker recovery. While much attention has been paid to the purported benefits, there is a paucity of literature comparing the potential complications of MIS with traditional surgery. In this systematic literature review postoperative complications of MIS are directly compared with those of traditional techniques.

Methods: A literature search was conducted searching Medline, Embase and the Cochrane Collaboration Library for literature since 1990 for discussing complications associated with MIS. Studies were included if they were at least level 2 evidence according to the USPSTF guidelines, they were in the English language and were sentinel procedures. The data from the studies were pooled into a single homogenous group for each complication in order to look at the overall rates of each individual complication.

Results: After our literature search, 460 overall citations were found. Applying our inclusion/exclusion criteria left 14 publications for review. Overall complication rates were not statistically significant between MIS and traditional groups. The incidence of dural tears was 1.1% (26/1339) in patients undergoing MIS versus 2.1% (20/939) for traditional surgery ($p=0.57$). The incidence of infection was 1.1% (19/1682) in patients undergoing MIS versus 2.2% (29/1332) for traditional surgery ($p=0.09$). The incidence of screw malposition was 2.8% (3/106) in patients undergoing MIS versus 1% (1/102) for traditional surgery ($p=0.48$). The incidence of root injury was 2.9% (2/70) in patients undergoing MIS versus 0% (0/142) for traditional surgery ($p=0.45$). The incidence of need for revision surgery was 3.8% (25/662) in patients undergoing MIS versus 3.2% (26/819) for traditional surgery ($p=0.93$).

Conclusion: MIS did not confer any statistically significant advantage over traditional surgery for any of the complications reviewed.

Poster 30. Effect of Body Mass Index on Early Outcomes of Minimally Invasive Degenerative Lumbar Surgery

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Saint Louis University

Introduction: This retrospective study examined the differences in early outcomes in healthy weight (Body Mass Index [BMI] 18.5-24.9 kg/m²) and severely obese subjects (BMI ≥35 kg/m²) who underwent minimally invasive (MI) fusion and decompression surgery for degenerative lumbar disease at one to two spinal levels. Outcomes were looked at as acute (time in the hospital), and early (leaving the hospital-12 weeks post-surgery).

Methods: Subjects were categorized based on their BMI (normal or severely obese). Surgical data included blood loss, hospital length of stay, pain levels (based on narcotic use), and discharge disposition to home or rehab. Data was compared between healthy and severely obese groups, using Levene's Test for Equality of Variances, t-test for Equality of Means, Pearson Chi-Square test, and Cramer's V correlation test ($\alpha \leq 0.05$ for all). SPSS software was utilized for all statistical tests.

Results: For healthy and severely obese subjects, the Levene's Test showed differences in blood loss during surgery and length of stay in the hospital to be significant ($P<0.001$ and $P=0.014$, respectively). The mean blood loss for patients undergoing surgery was 97.5mL and 349.231mL, respectively. The t-test with equal variances not assumed showed this difference to also be significant ($P=0.005$). The mean length of stay in the hospital was 2.118 nights for healthy weight, and 4.0 nights for severely obese patients. The t-test with equal variances not assumed also showed this difference to be significant ($P=0.009$). For the categorical data, the Pearson chi-squared test showed the difference in early narcotic use to be significant ($P=0.020$). The Cramer's V correlation value was also 0.020.

Conclusions: In the early post-operative setting, healthy weight subjects went home sooner and lost less blood. A surprising find was that they also used more narcotics than their obese counterparts. This study is an initial approach to whether severely obese patients fare poorly after MI degenerative lumbar surgery. Overall it shows that the use of MI spinal surgery in the severely obese population provides manageable issues for the patient, and no significant complications when compared to the healthy weight population, indicating that it is a good alternative for obese patients. Further studies need to be completed defining the role of BMI and its effect on the long term outcomes of MI lumbar fusion and decompression.

Poster 31. Bending The Cost Curve In Spinal Surgery

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UCSF

Background. The adoption and implementation of new technologies is a primary driver of the increasing rates of spending in spinal care. The purpose of this article is to introduce the concept of economic evaluation of new technologies as a factor to guide an evidence-based approach for their adoption.

Methods. The literature was reviewed for cost-utility analysis studies of four technologies in spinal care: 1) circumferential fusion versus posterolateral fusion in the management of severe, chronic low back pain; 2) total disc replacement (TDR) versus arthrodesis for single level cervical degenerative disc disease; 3) bone morphogenic protein versus autograft in posterolateral lumbar spinal fusions; and 4) the use of vertebroplasty in osteoporotic vertebral compression fractures.

Results. Cost sustaining technologies are defined as innovations that optimize value by improving outcomes or reducing cost over time. Cost-utility analyses show circumferential fusion and TDR with ProDisc-C to be cost-effective technologies in spinal surgery. Circumferential fusion was found to be dominant over a posterolateral approach with an incremental savings of US \$49,306 per QALY. Economic modeling studies show TDR with ProDisc-C to have a positive incremental cost-effectiveness over ACDF in cervical degenerative disc disease. Conflicting evidence exists for the cost-effectiveness of BMP compared to iliac crest bone graft (ICBG) in posterolateral fusions and vertebroplasty for osteoporotic vertebral fractures. A Markov model using 2-year outcomes in patients over age 60 reported a cost of \$39,967 with the use of rhBMP-2/ACS compared to \$42,286 for ICBG due to reduction in complications and need for revision surgery. This incremental advantage was not apparent at five years. A non-randomized study reported short-term cost effectiveness of percutaneous vertebroplasty compared to non-operative management for osteoporotic vertebral fractures, but this incremental difference was absent at one year follow-up. Subsequent randomized trials found no significant differences in clinical outcomes between vertebroplasty and a sham procedure, demonstrating that vertebroplasty may not add incremental value over time.

Conclusions. The adoption of new technologies in spine surgery should be guided by evidence showing that the technology is cost-sustaining and adds value to our health care system by significantly improving outcomes or decreasing costs.

Poster 32. Intra-Operative Imaging Modality: Patient and Operating Room Personnel Radiation Exposure in Spinal Surgery

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University California Davis

Introduction: To investigate the amount of ionizing radiation to which patients and operating room (OR) staff are exposed during lumbar spinal surgery with the most commonly employed modalities.

Methods: Utilizing three common imaging modalities, a C-arm, portable (CR) machine and a Metronic O-arm. Doses for radiology technologists, surgeons and anesthesiologist were obtained by selecting typical OR location. A phantom of an average patient with a body mass index of 27.4 was created using 30 sheets of 3/8-inch Lucite. Ionizing radiation exposure was measured using a calibrated Radcal Accu-pro #9096 control unit. The average kVp and mAs for a typical L5-S1 pedicle screw operation at UCD medical center was obtained and approximated during the simulation.

Results: Please see table below.

Discussion: Anesthesia and technicians are exposed to approximately the same amount of ionizing radiation during L5-S1 arthrodesis regardless of modality. Surgeons receive 10x the radiation when standing near the tube, due to patient scatter, compared to the detector when using fluoroscopy (C-arm). XR and O-arm radiation was negligible for the surgeon, due to the distance from the source. Patients receive substantially more radiation when using XR or O-arm. One XR was equivalent to 28 c-arm images, and one O-arm was equivalent to 43 c-arm images. The annual allotted occupational dose exposure per United States Nuclear Regulatory Commission is 5000mRem, or equivalent to only one O-arm spin. Surgeons and staff must be aware of the radiation dose that we are exposed to, as well as our patients. Imaging modality choice plays a significant role in radiation delivered to our patients.

Poster 33. Bone Density Measurements Are Not Critical For Predicting Allograft Mechanical Performance

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Introduction. The allograft bone industry has developed guidelines based on scientific data to optimize safety and effectiveness of allografts in surgical applications for avoidance of transmission of diseases. At the same time, mechanical properties of the allograft, which is essentially a mechanical device, remain comparatively unassessed.

We previously accumulated a substantial database (327 specimens) of structural integrity of femoral ring allograft. For each allograft, we have: side (left/right), proximal-distal location along femoral shaft, sex and age of donor, bone mineral density (BMD) measured by DEXA, minimum/maximum wall thickness, minimum/maximum diameter, estimated area, and maximum load to failure. Previous analysis of this data was limited to investigation of linear correlations between individual parameters and allograft strength.

Through comprehensive nonlinear multivariate analyses, we develop accurate and robust models for predicting the mechanical strength of allografts using various collections of parameters. We observe that BMD is not a good predictor of mechanical strength. Nonlinear models using remaining variables, which are easier to measure, report much higher accuracies.

Methods. We use support vector regression (SVR) within in the framework of 10-fold cross validation (CV) to develop predictive models. SVR is a standard mathematical technique for function estimation, which allows choice of several parameters to obtain the best linear or nonlinear fits. In CV, data is divided into training and test sets, the function is fit on training data, and predicts the test data. We tried linear as well as several nonlinear fits. Performance is measured by the root-mean-squared-deviation (RMSD) of predicted maximum load (Kilo Newtons) and the r value.

Results. Best models for BMD had RMSD=14.56, r=0.17. A polynomial model using all variables had RMSD=8.44, r=0.82. A polynomial model using remaining variables (no BMD) had RMSD=8.56, r=0.81. Also, models were more accurate for females (RMSD=7.14, r=0.81) than males (RMSD=9.51, r=0.74).

Discussion and Conclusion. We demonstrate that BMD is not

critical to estimate mechanical strength of allografts, which could be predicted accurately using only easy-to-measure parameters of the specimen and the donor.

Poster 34. Minimally Invasive TLIF Decreases Narcotic Usage, Improves Mobility, and Shortens Hospital Stay Compared to Open TLIF

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UCSF

Introduction: Previous studies comparing minimally invasive (MIS) trans-foraminal lumbar interbody fusion (TLIF) with open TLIF have demonstrated improvements in blood loss and post-operative pain while preserving fusion and complication rates. In this study, we wanted to determine whether MIS TLIF also improved post-operative functional mobility and/or decreased pain medication usage compared to open TLIF.

Methods: 78 consecutive patients who underwent either single-level open or MIS TLIF at UCSF between 2006 and 2011 were included. 51 patients underwent MIS TLIF and 27 underwent open surgery. Morphine equivalent (M.E.) dosing of narcotics was calculated using the standard formula. Functional ability was assessed using the standardized physical therapy inpatient assessment.

Results: No differences in age, gender, body-mass index, level of disease, or surgical indication were detected between the open and MIS groups. Similarly, pre-operative medication use did not differ. Intra-operatively, MIS TLIF produced shorter operative times, less blood loss, and fewer complications ($p < 0.05$). Total in-hospitalization morphine equivalent pain medication usage was also lower in the MIS TLIF group. Functional assessment by physical therapy on post-operative day one demonstrated higher function in MIS patients for transfer related tasks, ambulatory ability, and distance walked ($p < 0.05$). This translated into shorter in-patient hospitalizations (mean 6.3 vs. 4.8 days, $p < 0.005$) and an average cost reduction of \$3,885 per MIS patient.

Conclusions: MIS TLIF achieves improved functional mobility, decreased post-operative pain medication usage, and a significant cost reduction compared to open TLIF. To our knowledge, this is the first comparison study analyzing post-operative pain medication usage.

Poster 35. Incidence and Risk Factors for Visual Loss following Spinal Fusion

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Introduction: Visual loss is a rare but devastating complication that may follow spinal surgeries. The incidence of visual loss after spinal fusion is not well characterized over the past decade in the current literature. A population-based database was analyzed to identify incidence, mortality, and risk factors associated with spinal fusions.

POSTER 32 Results					
Modality	Anesthesia (mR/dose)	Technician (mR/dose)	Surgeon (mR/dose)	Patient (mR/dose)	Fold increase in radiation
c-arm	1.44	0.2	54 (tube), 5.7 (detector)	120.3	
XR	2.2	0.7	0.4 (11 ft away)	3435	(28x c-arm)
O-arm	2.7	0.3	0 (not in room)	5220	(43x c-arm)

Methods: Data from the Nationwide Inpatient Sample was obtained for each year from 2002-2009. Patients undergoing spinal fusion (anterior/posterior cervical fusion, anterior/posterior lumbar fusion, and posterior thoracic fusion) for degenerative pathologies were identified. Patient demographics, co-morbidities, length of stay (LOS), costs, and mortality were assessed. SPSS v.20 was used for statistical analysis using Independent-Samples T test for discrete variables and χ^2 test for categorical data. Binomial logistic regression was used to identify independent predictors of visual loss. A p-value of <0.0005 was used to denote significance.

Results: A total of 541,485 spinal fusions were identified in the United States from 2002 to 2009. The overall incidence was 1.5 events per 1,000 cases. The average age of patients suffering vision loss was significantly younger, at 29.8 years, compared to non-affected patients' average age of 52.4 years. Analysis demonstrated that males experienced visual loss more frequently than females, though the data was not statistically significant ($p = 0.03$). Length of stay and hospital costs more than doubled in the patients with visual loss ($p < 0.0005$). Logistic regression analysis demonstrated that independent predictors of visual loss were the presence of a coagulopathy, neurologic disorder, and paralysis ($p < 0.0005$). Factors exerting preventative effects were age ($p < 0.0005$) and large hospital-status ($p = 0.001$).

Conclusions: Our findings demonstrated an overall visual loss incidence of 1.5 events per 1,000 spinal fusions. We demonstrated afflicted patients were more than 20 years younger than non-affected patients. Hospitalization length and costs were doubled in patients who experienced visual loss. Despite being a rare complication following spinal fusion, visual loss is a serious condition that can be prevented with vigilant peri-operative assessment and early recognition of risk factors.

Table 1: Patient Characteristics and Outcomes of Visual Loss following Spinal Fusion Surgery (ACF, PCF, ALF, PLF, Post. Thoracic)			
Comparison Group	No Visual	Visual Loss	p-value
Total (n=count)	541,403	82	
Visual Loss Incidence (per 10,000 cases)	1.5		
Age (Average, years)	52.4	29.8	<0.0005
Age Group (%)			
18-44	29.6	64.6	
45-64	47.7	22.0	
65-74	15.0	9.8	
>75	7.7	3.7	
Gender (% Female)	53.4%	41.5%	0.03
Race			0.15
Caucasian	82.3	75.5	
Black	7.8	4.1	
Hispanic	5.8	14.3	
Asian	1.2	2.0	
Native American	0.4	0.0	
Other	2.5	4.1	
Charlson Co-morbidity Index Score	2.27	2.71	0.03
LOS (days)	4.1	9.6	<0.0005
Costs (US dollars)	\$22,697	\$55,614	<0.0005
Mortality (per 1,000 cases)	3.0	0.0	0.62

Poster 36. Plain Radiography Fusion Assessment In Lateral Lumbar Interbody Fusion

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Introduction: Lateral Lumbar Interbody Fusion (LLIF) is increasingly utilized for a broad spectrum of fusion indications. A theoretical advantage of this minimally-invasive technique is increased fusion rates due to the large graft chambers of the commercially available implant devices and the structurally unique location of implantation that utilizes the dense apophyseal ring for cage position. In all arthrodesis operations, it is a challenge to assess fusion from plain radiography, and often surgeons must rely on computed tomography (CT) which is radiation-intensive. The purpose of this study was to investigate the accuracy of plain radiography in postoperative fusion assessment after LLIF for limitation of radiation-intensive computed tomography (CT) in the postoperative setting. We hypothesize that given the unique location of the implant in the anterior spine above the iliac wing, plain radiography is an accurate tool for the assessment of fusion in LLIF.

Methods: The sensitivity and specificity of plain radiography for postoperative fusion assessment after LLIF was determined by two independent fellowship-trained spine surgeons based on definition of fusion status by CT in 101 LLIF segments among 49 patients from a single institution. Twenty-five LLIF segments in 17 patients remained after applying a refining algorithm, namely excluding those without a true lateral view on plain radiographs, a coronal angulation >5°, a subsidence >4mm, or the level at or below the iliac wing. The ability of X-ray for fusion assessment with and without the refining algorithm was analyzed.

Results: The overall sensitivity/specificity of lateral X-ray was 96.23/64.29% and 94.34/85.71% for the two readers, respectively, to correctly detect fusion on X-ray as pre-defined by CT. The fusion analysis limited to patients with a true lateral view on plain radiography indicated sensitivity/specificity values of 100/50% and 92.1/100% for both readers, respectively. After adoption of the refining algorithm (n=25, 24.8%) the sensitivity/specificity values became 100/100% and 91.67/100%, respectively.

Conclusions: Surgeons can forgo obtaining CT scans for fusion assessment in LLIF by use of plain X-ray in approximately 25% of cases when radiographic inclusion criteria (a true lateral view, a coronal angulation <5°, a subsidence <4mm, level not at or below the iliac wing) are met.

Poster 37. Medical Marijuana Use Characteristics In The Spinal Surgery Patient

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Introduction: The use of marijuana for medical purposes was legalized in the state of Colorado in 2000 and there are currently over 115,000 patients registered to receive marijuana from over 800 dispensaries. Over 94% of marijuana recommendations are issued for the treatment of pain. There has been a paucity of research examining the use of marijuana for pain control and there have been no studies examining marijuana use in the spine surgery patient. We seek to describe patterns of marijuana usage in patients presenting to a tertiary spine center in the state of Colorado.

Methods: After IRB approval, all adult patients presenting for

evaluation at the University of Colorado Spine Center were asked to participate. Informed consent was obtained in all participating patients and a brief survey was administered. Responses were stored in a secured, de-identified file.

Results: One hundred eighty four patients agreed to participate while 16 declined enrollment. Of the 184 participants, 35 patients (19.0%) admitted to marijuana use: four patients reported taking marijuana recreationally, while 31 reported using marijuana only for medical purposes. Marijuana users were younger than non-users (44 vs 54, $p < 0.05$), but had similar educational and employment characteristics.

Rates of use were higher in Hispanic patients (28.6%) than White or African-American patients (18.4% and 12.5% respectively), although this difference did not reach statistical significance. Of patients who did admit to marijuana use, 45.5% had a prescription and 73% of these had that prescription primarily for back pain. Eighty three percent of users also take other pain medications, especially narcotic pain medications. Eight nine percent of users felt that marijuana "moderately" or "greatly" relieved their pain. Users typically used marijuana less than 1-2 times a day. Fourteen endorsed negative side effects, including depressed mood 5.7%, difficulty concentrating 20%, memory problems 8.6%, weight gain 25.7%, and paranoia 11.4%. However, only 43% (6 of 14) of these patients felt the side effects were significant. Users trended towards reporting higher VAS and ODI scores.

Conclusion: Marijuana use is frequent in the spine patient population. While marijuana users tend to be younger than non-users, other demographic factors surveyed were comparable. Most patients using marijuana report significant alleviation of painful symptoms with tolerable side effects. More research is needed to ascertain whether marijuana use is truly efficacious in this population and to determine whether it may have any effect on surgical results.

Poster 38. The Impact Of The Cage Height, Diameter And Positioning On Clinical And Radiographic Outcome Of The Extreme Lateral Inter-body Fusion

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Introduction: Extreme lateral interbody fusion (ELIF) is a novel technique for anterior spinal fixation and indirect decompression of neural elements.

Methods: Retrospective analysis of 145 ELIFs in 90 patients. Lumbar lordosis, cage position, foraminal and intervertebral disc height were determined on pre-operative, post-operative, and the latest follow-up studies. Clinical outcomes were evaluated by Oswestry Disability Index and Visual Analogue Scale.

Results: We used cages measuring 8 – 14 mm in height. Immediate postoperative radiographs suggested a tendency towards positive correlation between cage height and restoration of foraminal height. However, at the time of last follow-up restoration of foraminal height was best maintained with medium height cages (9 – 11 mm). Approximately one half of our patients received 18 mm spacers and the other 22 mm grafts. 18 mm spacers allowed for a 2.1 mm increase of foraminal height while 22 mm spacers lead to an increase by 4.0 mm on postoperative radiographs. Importantly this difference remained significant at the time of last follow-up. One third of patients received lordotic spacers. Both, lordotic and non-lordotic cages allowed for increased lumbar lordosis on post-operative imaging (6.0 degrees, 4.7 degrees, respectively). Lordotic cages lead to significantly greater restoration of foraminal height on postoperative imaging compared to non-lordotic spacers (4.3 mm vs. 2.5 mm, $P < 0.01$). Moreover, there was a tendency towards greater restoration of foraminal height with a more posterior position of the graft. Clinical evaluation revealed a mean ODI, VAS back, buttock and leg pain improvements of 21.1 %, 3.7, 3.6 and 3.7 points, respectively.

Conclusion: Restoration of foraminal height by ELIF may be optimized by grafting large-diameter lordotic cages into the posterior aspect of the disc space.

Poster 39. In vivo Biomechanical Range of Motion Evaluation of a Unilateral Facet Replacement System

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Globus Medical

Introduction. Patients with degenerative arthritis of the facet, or hypertrophic facets, experience pain but may have healthy intervertebral discs. The goal of facet replacement systems is maintain pre-operative motion limits, while allowing decompression. The range of motion (ROM) of a facet replacement device under physiological load limits is evaluated on a cadaveric model.

Methods. Seven L3-S1 fresh human cadaver specimens (5M, 6F; age 56.6 ± 9.4) were tested. A pure moment of ± 7.5 Nm was applied at a rate of 1.5o/sec in flexion-extension, lateral bending, and axial rotation using a six degree of freedom machine. The testing order was 1) intact; 2) L4-L5 right side unilateral facetectomy (UF); 3) L4-L5 right side unilateral facet replacement (UFR). ACADIA® (Globus Medical Inc.; Audubon, PA) was used for the facet replacement device. ROM was measured at L4-L5 and significant differences ($p \leq 0.05$) were determined using a repeated measures ANOVA followed by a Tukeys post hoc analysis.

Results. Compared to intact, UF increased ROM to $107 \pm 3\%$, $108 \pm 6\%$, and $130 \pm 14\%$ in flexion-extension, lateral bending, and axial rotation respectively (Figure 1). The increase in motion was significantly more than intact in lateral bending and axial rotation ($p \leq 0.05$). Compared to intact, UFR restabilized the spine to a mean value of $101 \pm 8\%$, $107 \pm 8\%$, and $108 \pm 10\%$ in flexion-extension, lateral bending, and axial rotation, respectively. The net increase in motion was not significantly greater than intact ($p \geq 0.05$). In axial rotation, the facet replacement system significantly reduced motion compared to the UF injury ($p \leq 0.05$).

Conclusion. A unilateral facetectomy at L4-L5 significantly increases motion compared to intact in lateral bending and axial rotation. In axial rotation, the addition of the unilateral facet replacement device significantly reduced the 30% increase in motion due to the facetectomy. In all modes, the motion of the facet replacement system was comparable to intact. It appears that instrumentation may be necessary in the lower lumbar spine following a decompressive facetectomy.

Poster 40. Epidemiological Trends in Kyphoplasties between 2004-2009

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Introduction: Kyphoplasty was introduced as a minimally invasive procedure to treat vertebral compression fractures with deformity. The purpose of this study was to analyze a population-based database to describe national trends of kyphoplasty procedures in the United States.

Methods: Data from the Nationwide Inpatient Sample database was obtained from 2004-2009. Patients undergoing kyphoplasty for the diagnosis of pathologic fractures of the thoracolumbar spine were identified. Demographics (gender, age, and race), Charlson Co-morbidity Index (CCI), costs (adjusted for inflation), and mortality were assessed. Statistical analysis was performed using Pearson's correlation to identify trends. Logistic regression was performed to identify predictors of mortality.

Results: The total number of patients undergoing kyphoplasty increased from 44,459 in 2004-2005 to 85,530 in 2006-2007 and then decreased to 76,583 in 2008-2009. The mean pre-operative CCI increased from 4.59 in 2004 to 5.06 in 2009 ($p<0.0005$) (Table 1). Mean in-hospital costs significantly increased from \$12,815 in 2004 to \$16,853 in 2009 ($p=0.006$). Mortality did not change across this time period ($p=0.32$). Predictors of mortality in patients undergoing kyphoplasty were metastatic cancer, fluid/electrolyte disorders, congestive heart failure, pulmonary circulation disorders, renal failure, and weight loss.

Discussion: Our study demonstrates that kyphoplasty procedures have increased in incidence from 2004-2009. We identified a trend of older patients with increasing co-morbidities undergoing kyphoplasty. Mortality has not changed despite the increasing co-morbidity of patients. This patient population also incurred increasing hospitalization days and costs which may be due to increasing chronic illnesses. Patients with mortality risk factors indicative of chronic illness should be carefully followed for complications in the peri-operative period after kyphoplasty procedures.

	2004	2005	2006	2007	2008	2009	P-value	Correlation (R)
US Total Population	293,655,404	296,410,404	299,398,484	301,621,157	304,059,724	307,006,550		
Count (Total-weighted)	7,049	57,410	39,861	45,849	42,320	34,263	0.21	
% of US Population undergoing kyphoplasty surgery	2.4×10^{-6}	12.6×10^{-6}	13.3×10^{-6}	15.2×10^{-6}	13.9×10^{-6}	11.1×10^{-6}	0.24	
Age (years)	75.2	75.9	76.5	76.4	76.3	76.3	0.10	
Female (%)	71.9	73.3	73.8	73.4	73.1	72.2	0.95	
LOS (days)	3.9	4.5	4.5	4.7	5.4	5.9	0.002	0.96
CCI Score	4.59	4.72	4.83	4.87	5.02	5.06	<0.0005	0.99
Costs adjusted (unadjusted)	\$12,815 (\$11,377)	\$13,719 (\$12,594)	\$13,754 (\$12,941)	\$13,947 (\$13,490)	\$16,012 (\$16,076)	\$16,853 (\$16,853)	0.006	0.94
Race (% Caucasian)	93.0	92.3	89.9	90.6	88.7	87.0	0.002	-0.96
Mortality (Count)	7	42	43	52	63	37	0.32	

Poster 41. Incidence and Mortality of Surgical Site Infections after Lumbar Spine Surgery

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Introduction: Surgical site infections (SSI) are a common complication after orthopaedic procedures. The incidence of SSI in lumbar spine surgery has not been reported in large patient populations. In order to characterize the national burden of SSI, a population-based database was analyzed to identify incidence, mortality, and costs associated with lumbar decompressions (LD) and lumbar fusions (LF).

Methods: Data from the Nationwide Inpatient Sample database was obtained from 2002-2009. Patients undergoing LD or LF for the diagnosis of lumbar radiculopathy, herniated nucleus pulposus, degenerative disc disorder, and spinal stenosis were included. Incidences of SSI were identified and calculated. Co-morbidities were calculated using a modified Charlson Co-morbidity Index (CCI). Mortality associated with SSI was also assessed. Statistical analysis was performed using Student T-test for discrete variables, and χ^2 -test for categorical data. Logistic regression was used to identify independent predictors of SSI. A p-value of <0.0005 was used to denote significance.

Results: A total 578,457 lumbar procedures were identified from 2002-2009 in the United States (Table 1). Incidences (per 1,000 cases) of SSI were 7.4 and 8.4 for the LD and LF groups respectively. Patients with SSI demonstrated increased co-morbidity scores, hospitalizations, and costs ($p<0.0005$). SSI's were associated with increased incidences of in-hospital mortality of 18.9 and 16.4 for the LD and LF groups respectively ($p<0.0005$). Comparison of SSI patients across the surgical groups demonstrated an increased rate of SSI, increased hospitalizations and costs in the LF group ($p<0.0005$). Logistic regression identified the most significant predictors of SSI are anemia, drug abuse, liver disease, fluid/electrolyte disorders, and weight loss.

Discussion: Our study demonstrates a national incidence of 0.8% for SSI in patients undergoing lumbar spine surgery. SSI's in both surgical groups resulted in increased hospitalization, costs, and mortality. The incidence of infection is significantly higher after LF compared with LD. We conclude that patients undergoing lumbar surgery with particular co-morbidities (anemia, drug abuse, liver disease, fluid/electrolyte disorders and weight loss) are at an increased risk for SSI. Peri-operative antibiotic protocols and pre-operative risk factors should be identified to decrease incidence of SSI in patients at greatest risk of infection.

	Lumbar Decompression (LD)			Lumbar Fusion (LF)			LD and LF		
Total (n=Count)	290,007	2,170	P-value	283,884	2,396	P-value	2,170	2,396	P-value
Comparison Group	No SSI	SSI		No SSI	SSI		SSI	SSI	
Age (years)	55.0	59.3	<0.0005	55.2	58.0	<0.0005	59.3	58.0	0.003
Age Group (%)									
0-44	29.6	16.6		25.7	18.4		16.6	18.4	
45-64	37.4	44.2		45.0	46.8		44.2	46.8	
65-75	18.2	21.4		18.9	21.2		21.4	21.2	
>75	14.8	17.8		10.4	13.6		17.8	13.6	
Charlson Comorbidity Index	2.43	3.62	<0.0005	2.46	3.33	<0.0005	3.62	3.33	<0.0005
SSI Incidence (per 1000 cases)	7.4			8.4			7.4	8.4	<0.0005
Mortality (per 1000 cases)	0.7	18.9	<0.0005	1.4	16.4	<0.0005	18.9	16.4	0.508
LOS (days)	2.4	14.8	<0.0005	4.3	17.9	<0.0005	14.8	17.9	<0.0005
Costs (US dollars)	\$7,045	\$28,013	<0.0005	\$25,603	\$57,290	<0.0005	\$28,013	\$57,290	<0.0005

Poster 42. Open vs. Percutaneous Fixation for Thoracolumbar Flexion Distraction Injuries in Poly-Trauma Patients: Perioperative Outcomes

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Background: Unstable flexion distraction fractures (FDI) of the thoracolumbar (TL) spine are typically treated with conventional open fixation and arthrodesis. At times these procedures are associated with prolonged operative times and increased blood loss. This is problematic in the polytrauma patients where the morbidity may be magnified. Minimally invasive techniques for spine fixation have evolved and have been used more extensively in spine trauma in an attempt to minimize these complications and improve outcomes.

The objective of this study is to examine the perioperative outcomes for patients with thoracolumbar FDI treated purely posterior either with percutaneous minimally invasive transpedicular screws (MIS) or open stand-alone posterior fixation (OSPF) in a cohort of consecutive patients at a level I trauma center.

Materials and Methods: A cohort of 21 consecutive polytrauma patients from a prospective Early Appropriate Care (EAC) protocol with a flexion distraction TL injury were included in the study. The EAC protocol calls for definitive fixation of operative spine injuries within 36 hours of injury if the patient is appropriately resuscitated. Objective parameters of resuscitation are pH<7.25, lactate<4.5 and base excess>-5. Fourteen patients had been treated conventionally with OSPF and seven patients received MIS transpedicular screws fixation. The injury severity score for the OSPF group was average 26.7±10.0 while 24.1±6.1 for the MIS group. Minimum follow-up was 6 months for the entire cohort. Variables analyzed included intraoperative blood loss, operative time, complications, ICU stay, and length of hospital stay.

Results: The average operation time, ICU stay and total length of hospital stay were not statistically different between the two groups. The intraoperative blood loss was significantly less in the MIS group (average 31 ml ± 13.4) when compared to the open group (average 579 ml ± 379.1). Wound infection and total complications including the ICU complications were greater in the open group as compared to the MIS group (14% versus 0% and 43% versus 0% respectively).

Conclusion: Minimally-invasive posterior fixation can be a good treatment option for poly trauma patients with flexion distraction TL injury by reducing surgical morbidity and simplifying the immediate postoperative recovery.

Table 1. Operative and Postoperative Course

	Open	Percutaneous	p-value*
Total Levels Operated	4.9 ± 1.7	2.9 ± 0.7	0.007*
Duration of Operation (min)	215.7 ± 113.0	220.0 ± 80.5	0.8
Blood loss (ml)	578.6 ± 379.1	30.7 ± 13.4	0.001*
ICU Duration (days)	8.1 ± 10.3	7.4 ± 9.7	0.9
Total Length of Stay (days)	11.4 ± 9.1	11.3 ± 7.1	0.99
ARDS	4	2	0.99
	29%	29%	
Wound Infection	2	0	0.5
	14%	0%	
Total Complications	6	0	0.06
	43%	0%	
Spinal Fusion	9	7	0.1
	64%	100%	
Total Follow up (months)	6.8 ± 3.9	5.6 ± 4.4	0.5

mean ± standard deviation for continuous variables, count and percent for categorical variables

* statistically significant p<0.05

T1-test for continuous variables, Fisher's Exact for categorical variables

Poster 43. The Clinical Use Of Stem Cells And Bone Marrow Cells For Spinal Fusion. A Systematic Review Of The Literature

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Introduction: Autologous iliac crest bone graft (ICBG) is the gold standard for thoracolumbar spinal fusion. However, it is associated with high complications rate. Alternative grafts options that combine stem cells (SC) and bone marrow cells (BMC) with synthetic or allograft scaffolds have been recently used in several animal and clinical studies.

Methods This systematic review of the literature addresses the following key questions (KQs): 1) Does the use of SCM or BMC combined with synthetic or allograft materials contribute for thoracolumbar fusion rates that are comparable to those achieved iliac crest graft or local bone graft (LBG)?, 2) Is the supplementation of ICBG or LBG by SC or BMC contributes for better thoracolumbar fusion rates? 3) Are the cervical spine fusion outcomes achieved by the use of SCM or BMC with synthetics or allograft comparable to the ICBG or LBG outcomes? 4) Is there any difference in the fusion rates when MSC were used as compared to BMC? The figure below demonstrates the detailed strategy

Results : Using a systematic strategy, 396 unique potential articles were found. For KQ1, seven articles were included, one study for KQ 2 and none met the inclusion criteria for KQ 3, 4. For KQ1, four level II, III studies used of ICBG as control. In one study, BMC was combined with calcium sulfur and resulted in significantly lower fusion rates than the control group. In other report, BMC combined with allograft led to comparable fusion outcome as compared ICBG. In the third study ICBG was used for all inter-body fusion. Postero-laterally a similar fusion rates were found using ICBG and demineralized collagen. The fourth was a case-control study that used collagen-hydroxyapatite matrix with BMC and showed comparable posterolateral fusion rates and lower inter-body fusion rates by the study group. Three, level II,III studies, used LBG as control. Similar fusion rates were demonstrated when BMA was combined with calcium phosphate in two studies. In the third study, both LBG alone and BMC with collagen scaffold performed similarly and superiorly to BMC carried by allograft. For KQ2, one level III study compared ICBG use to DBM with BM and ICBG with BM. No significant difference was found in the fusion rates.

Conclusion: The currently available evidence is insufficient to support the use of SC or BMA combined with synthetic or allograft materials as a substitute or supplementary graft to ICBG or LBG

Poster 44. DISK: A Novel Classification System of Lumbar Spine Adjacent Segment Pathology

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Background: Adjacent Segment Degeneration (ASD), also referred to as adjacent segment disease, junctional stenosis, transfer lesion, or adjacent Segment Pathology is a broad term that actually encompasses multiple distinct pathologic entities. Currently, there are no validated classification systems of adjacent segment pathology in the lumbar spine. The goal of this study was to validate and test a comprehensive radiographic classification system of adjacent segment pathology of the lumbar spine.

Methods: The database of a single surgeon in an academic-associated private practice was reviewed in order to identify a retrospective consecutive case series of 31 patients over 2 years who underwent revision elective lumbar spinal surgery after a previous lumbar spinal fusion. Approval was obtained from the Institutional Review Board.

The revision imaging at presentation for each subject was reviewed, consisting of a midline sagittal cut, an axial image through each disc level, and standing lateral x-ray when clinically indicated and available. These were reviewed by three fellowship trained spine surgeons and three orthopaedic residents who independently scored each spinal level (on a scale of 0-2) from L2-L3 to L5-S1 using the proposed DISK classification system, (D = Disc Degeneration, I = Instability, S= Stenosis, K = Kyphosis) giving a composite DISK score from 0-8. Data was used to calculate mean values at each spinal level for each class of degeneration.

Overall inter-observer variability and inter-observer variability among staff surgeons were calculated using Cohen's kappa coefficient and Kendall's coefficient of concordance. A comparison of staff and residents was also performed.

Results: The validation analysis consisted of 75 spinal levels evaluated in each component of the DISK system for a total of 300 spinal levels evaluated. In the staff surgeons, Kendall's coefficient showed substantial agreement for disc degeneration (0.70), instability (0.73), and kyphosis (0.64). Moderate agreement was seen for stenosis (0.57). Cohen's kappa showed fair agreement for disc degeneration (0.28) and instability (0.38) and slight agreement for stenosis (0.19) and kyphosis (0.14). The level immediately above the fusion had the highest overall composite DISK value (2.54) and the most significant component of ASD was stenosis at this level (1.08).

Conclusions: The DISK classification system provides the first known comprehensive classification system for adjacent segment degeneration in the lumbar spine. It provides a framework to specifically evaluate each component of degeneration at specific spinal levels, and was reproducible among the fellowship trained spine surgeons in this study.

Poster 45. High Resolution Imaging of Disc Degeneration via Equilibrium Partitioning of an Ionic Contrast Agent - micro computed tomography (EPIC-microCT)

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Introduction: Animal models are critical to our understanding of disc degeneration. MRI is often used in characterization of the disc, but this method fails to achieve a resolution high enough to be conducive to quantitative imaging in rodent models of disc pathology. Recently, the technique of equilibrium partitioning of ionic contrast agent – micro computed tomography (EPIC-microCT) has been

developed to facilitate high resolution imaging of articular cartilage. Our group has since applied this imaging technique to imaging of the rabbit intervertebral disc.

Materials and Methods: New Zealand White rabbits were randomized to undergo an open posterolateral approach to the lumbar spine. Upon adequate exposure, each disc was randomized to receive either disc puncture, or a complete aspiration of the nucleus. Three or six weeks after the procedure, spines were harvested and immediately immersed in ionic contrast agent. Discs were then imaged by EPIC-microCT and transferred to a solution to desorb the contrast agent from the tissue. After 48 hours of desorption, specimens were transferred to 10% buffered formalin to assess the effect of tissue fixation on imaging. To confirm results of EPIC-microCT, decalcified histologic specimens were stained with Safranin-O/Fast green to evaluate proteoglycan content.

Results: EPIC-microCT imaging provided high resolution imaging of proteoglycan content throughout the disc. Formalin fixation had an effect on signal attenuation, suggesting that higher contrast agent concentration, or contrast agent incubation time may be needed in future studies involving formalin-fixed tissue. Proteoglycan content varied significantly between damaged and healthy disc tissue at 3 and 6 weeks, which correlated with decalcified histology. EPIC-microCT was effective in determining endplate changes associated with the degenerative process.

Discussion: High resolution imaging of disc degeneration in smaller preclinical models is a significant challenge associated with basic science research. EPIC-microCT is a high-throughput method of imaging the three dimensional distribution throughout the intervertebral disc. With the current protocol, EPIC-microCT was able to differentiate distinct processes associated with the process of disc degeneration.

Conclusion: EPIC-microCT is a promising new, high resolution imaging technique that can be applied to the preclinical study of disc degeneration and disc regeneration.

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