



FUNCTIONAL OUTCOMES OF MINIMALLY INVASIVE SURGERY FOR LUMBOSACRAL DEGENERATIVE SPINE DISORDERS: A TERTIARY CARE HOSPITAL EXPERIENCE IN INDIA

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ABSTRACT

Introduction: Minimally invasive spine surgery (MIS) has emerged as an effective alternative to conventional open techniques for managing lumbo-sacral degenerative disorders by minimizing soft tissue injury while achieving adequate decompression and stabilization. However, Indian data evaluating comprehensive clinical, radiological, and paraspinal muscle outcomes following MIS in the lumbo-sacral spine remain limited.

Aim: To evaluate the clinical, radiological, and paraspinal muscle outcomes following minimally invasive surgery in patients with lumbo-sacral spine disorders.

Materials and Methods: This prospective observational study was conducted in the Department of Neurosurgery at a tertiary care center over 18 months. Fifteen patients aged above 18 years with lumbo-sacral degenerative pathology undergoing MIS were included. Clinical outcomes were assessed using Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and Japanese Orthopaedic Association (JOA) score. Radiological parameters including disc height, lumbar lordosis, pelvic parameters, fusion status, and screw placement accuracy were evaluated using X-ray, NCCT, and MRI. Paraspinal muscle degeneration was assessed using Muscle-Fat Index (MFI). Preoperative and postoperative outcomes were compared using appropriate statistical tests.

Results: The mean age of patients was 58.07±3.77 years. Significant improvement was observed in VAS (5.0±1.36 to 1.60±0.63), ODI (47.73±7.0% to 22.67±5.38%), and JOA scores (9.60±2.19 to 13.87±1.99) postoperatively (p<0.001). Disc height and sagittal alignment parameters showed significant improvement. Solid fusion was achieved in 93.3% cases. A significant increase in MFI was noted postoperatively (p<0.001). Complication rate was low (6.7%).

Conclusion: Minimally invasive surgery in the lumbo-sacral spine provides significant clinical and radiological improvement with high fusion rates and minimal complications. Although MIS is muscle-sparing, measurable paraspinal muscle degeneration occurs, highlighting the need for long-term follow-up and rehabilitation strategies.

Keywords: Minimally invasive spine surgery; Lumbo-sacral spine; Lumbar fusion; Muscle-fat index; Degenerative spine disease

INTRODUCTION

Degenerative disorders of the lumbo-sacral spine are a leading cause of chronic low back pain, radiculopathy, and functional disability in adults, particularly in the ageing population [1]. Progressive degeneration of intervertebral discs, facet joints, and ligamentous structures results in clinical conditions such as lumbar canal stenosis, degenerative spondylolisthesis, and segmental instability, often requiring surgical intervention when conservative treatment fails [2].

Conventional open lumbar spine surgery has long been the standard approach for achieving adequate neural decompression and spinal stabilization. However, open procedures are associated with extensive paraspinal muscle dissection, increased intraoperative blood loss, higher postoperative pain, and delayed functional recovery [3,4]. These drawbacks have driven the evolution of minimally invasive spine surgery (MIS) techniques aimed at minimizing approach-related tissue damage while maintaining comparable surgical effectiveness.

Minimally invasive techniques such as minimally invasive transforaminal lumbar interbody fusion (MI-TLIF), oblique lumbar interbody fusion (OLIF), and endoscopic-assisted fusion have gained widespread acceptance for the management of degenerative lumbar spine disorders. Comparative studies have demonstrated that MIS provides clinical outcomes equivalent to open surgery, with additional benefits including reduced blood loss, lower complication rates, and shorter hospital stay [5–7]. Lee et al. reported comparable fusion rates and functional outcomes between open TLIF and MI-TLIF, with significantly reduced morbidity in the minimally invasive cohort [7].

Radiological outcomes are critical indicators of surgical success following lumbar fusion. Restoration of disc height, sagittal alignment, and achievement of solid fusion are essential for long-term clinical improvement. Studies comparing OLIF and MI-TLIF have shown similar pain relief and functional outcomes, with differences in lordosis correction and coronal balance [8,9]. Song et al. demonstrated favorable short- and mid-term outcomes across different minimally invasive fusion techniques in patients with L4–L5 degenerative spondylolisthesis [10].

Implant-related factors such as screw loosening, cage subsidence, and cage migration have also been evaluated in MIS procedures. Yao et al. reported that lower preoperative bone quality, assessed using CT Hounsfield units, was associated with increased risk of screw loosening and cage subsidence, although these factors did not necessarily correlate with poor clinical outcomes [11]. Similarly, Rickert et al. found that cage migration and subsidence after TLIF were not significantly associated with failure of bony fusion or adverse clinical results [12].

Preservation of paraspinal musculature is considered a major advantage of MIS. Quantitative assessment using muscle-fat index (MFI) has demonstrated significantly less paraspinal muscle degeneration following MIS compared to conventional open surgery [4]. However, biomechanical studies suggest that lumbar fusion, even when performed using minimally invasive techniques, alters load distribution at adjacent segments, potentially contributing to adjacent segment degeneration over time [13].

Despite increasing global evidence supporting MIS, there is a paucity of Indian literature evaluating comprehensive clinical, radiological, and paraspinal muscle outcomes following minimally invasive surgery in the lumbo-sacral spine. Most existing studies focus on isolated outcome measures or specific techniques, with limited integration of functional scores, alignment parameters, fusion status, and muscle degeneration indices.

Therefore, the present prospective observational study was undertaken to evaluate surgical outcomes following minimally invasive surgery in lumbo-sacral spine disorders, with emphasis on clinical improvement, radiological alignment, fusion status, and paraspinal muscle degeneration.

MATERIALS AND METHODS

Study Design and Participants

This prospective observational study was conducted in the Department of Neurosurgery at a tertiary care teaching hospital over a period of 18 months, after obtaining approval from the Institutional Ethics Committee. 15 Adult patients (≥ 18 years) admitted with lumbo-sacral degenerative spine disorders and undergoing minimally invasive spinal surgery were consecutively enrolled.

Patients with previously operated lumbo-sacral spine at the same vertebral level were excluded. Written informed consent was obtained from all participants prior to inclusion in the study.

Surgical Procedure and Outcome Measures

All surgeries were performed using minimally invasive techniques under fluoroscopic guidance by experienced spine surgeons. Intraoperative parameters recorded included duration of surgery, total radiation exposure, and intraoperative complications such as pedicle breach, vascular injury, dural tear, and nerve injury.

Clinical outcomes were assessed preoperatively and postoperatively using the Visual Analog Scale (VAS) for pain, Oswestry Disability Index (ODI), and Japanese Orthopaedic Association (JOA) score. Postoperative neurological status and complications were documented.

Radiological evaluation was performed using plain radiographs, non-contrast computed tomography (NCCT), and magnetic resonance imaging (MRI). Parameters assessed included disc height, lumbar lordosis, segmental lordosis, pelvic incidence, pelvic tilt, coronal tilting angle, Cobb angle, fusion status, and subsidence. Fusion was assessed on dynamic radiographs and CT images, while subsidence was defined as a reduction in disc height of more than 3 mm for single-level and 5 mm for two-level surgeries.

Accuracy of pedicle screw placement was evaluated using the Gertzbein and Robbins grading system. Paraspinal muscle degeneration was assessed using the Muscle-Fat Index (MFI), calculated as the ratio of mean signal intensity of the erector spinae muscle to subcutaneous fat on axial T1/T2-weighted MRI images. MFI was measured preoperatively and postoperatively at the operated level, adjacent levels, and globally from L2–3 to L5–S1. Dural sac cross-sectional area (DSCSA) was measured at the most stenotic level on preoperative and postoperative MRI.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 25. Normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Quantitative variables were expressed as mean $\pm$ standard deviation or median with interquartile range, as appropriate. Preoperative and postoperative comparisons were performed using paired t-test or Wilcoxon signed-rank test. Categorical variables were expressed as frequencies and percentages. A p-value of less than 0.05 was considered statistically significant.

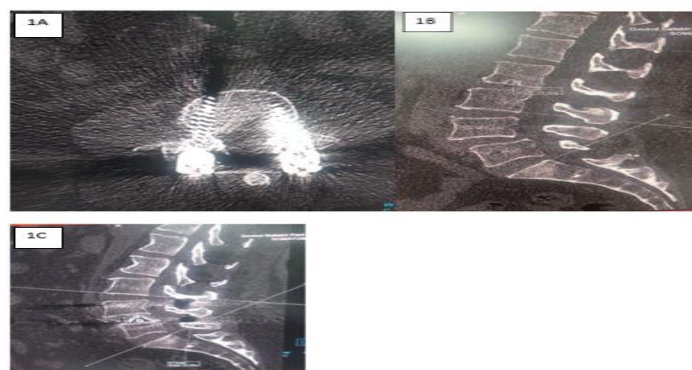


FIG 1: SCREW POSITION (1A)AND SEGMENTAL LORDOTIC ANGLE PREOP(1B)-POST OP(1C) COMPARISION ON NCCT LS SPINE

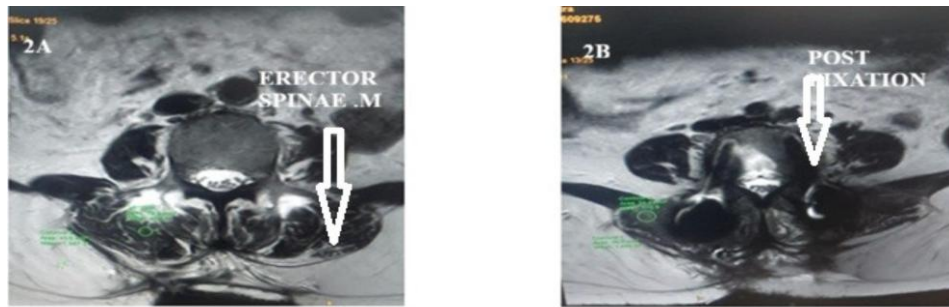


FIG 2: MUSCLE FAT INDEX PRE-OP (2A) AND POST-OP (2B) IN L4-L5 OPERATED LEVEL

RESULTS

A total of 15 patients undergoing minimally invasive surgery for lumbo-sacral degenerative spine disorders were included in the analysis.

Demographic Profile and Operative Characteristics

The mean age of the study population was 58.07 ± 3.77 years. Majority of patients were aged ≥ 55 years. Female patients constituted 53.3% (n=8), while males accounted for 46.7% (n=7).

The mean duration of surgery was 2.80 ± 0.52 hours. Mean total intraoperative radiation exposure was 1373.48 ± 721.49 cGy/cm².

Table 1: Demographic and Operative Characteristics of Study Subjects (n=15)

Variable	Value
Age (years), mean $\pm$ SD	58.07 ± 3.77
Sex (Female : Male)	8 : 7
Body Mass Index (kg/m ²), mean $\pm$ SD	25.6 ± 3.1
Comorbidities	
• Hypertension	6 (40.0%)
• Diabetes mellitus	4 (26.7%)
• Both HTN + DM	2 (13.3%)
• None	3 (20.0%)
Primary diagnosis	
• Degenerative spondylolisthesis	9 (60.0%)
• Lumbar canal stenosis	6 (40.0%)
Level operated	
• Single-level surgery	12 (80.0%)
• Two-level surgery	3 (20.0%)
Type of MIS procedure	
• MIS-TLIF	11 (73.3%)
• Endoscopic / other MIS	4 (26.7%)
Duration of surgery (hours), mean $\pm$ SD	2.80 ± 0.52
Estimated blood loss (mL), mean $\pm$ SD	165 ± 48
Radiation exposure (cGy/cm ²), mean $\pm$ SD	1373.48 ± 721.49
Number of screws used	
• 4 screws	13 (86.7%)
• 6 screws	2 (13.3%)
Intra-operative complications	
• None	14 (93.3%)
• Neurological (EHL weakness)	1 (6.7%)

Clinical Outcome Assessment

There was a statistically significant improvement in all clinical outcome scores postoperatively. Mean VAS score reduced from 5.0 ± 1.36 preoperatively to 1.60 ± 0.63 postoperatively ($p < 0.001$). Mean JOA score increased from 9.60 ± 2.19 to 13.87 ± 1.99 ($p < 0.001$). Mean ODI score improved from $47.73 \pm 7.0\%$ to $22.67 \pm 5.38\%$ ($p < 0.001$) (table 2).

At final follow-up, neurological status improved in 40% of patients, remained unchanged in 53.3%, and worsened in 6.7%.

Table 2: Comparison of Clinical Outcome Scores Pre- and Post-operatively (n=15)

Parameter	Preoperative	Postoperative	p-value
VAS score	5.0 ± 1.36	1.60 ± 0.63	<0.001
JOA score	9.60 ± 2.19	13.87 ± 1.99	<0.001
ODI (%)	47.73 ± 7.0	22.67 ± 5.38	<0.001

Radiological Outcomes

Postoperative radiological assessment demonstrated a significant increase in disc height from 7.57 ± 0.85 mm to 8.63 ± 1.27 mm ($p < 0.001$). Significant improvements were also observed in sagittal alignment parameters including segmental lumbar lordosis, pelvic incidence, and pelvic tilt ($p < 0.001$ for all).

Solid fusion was achieved in 14 patients (93.3%), while one patient (6.7%) showed incomplete fusion. According to Gertzbein and Robbins grading, Grade A screw placement was observed in 73.3% of patients.

Table 3: Radiological Parameters and Fusion Status (n=15)

Parameter	Preoperative	Postoperative	p-value
Disc height (mm)	7.57 ± 0.85	8.63 ± 1.27	<0.001
Segmental lumbar lordosis (°)	58.13 ± 2.94	50.53 ± 2.20	<0.001
Pelvic incidence (°)	50.40 ± 4.10	44.20 ± 2.98	<0.001
Pelvic tilt (°)	12.47 ± 1.80	9.67 ± 1.75	<0.001
Solid fusion	—	14 (93.3%)	—
G&R Grade A screws	—	11 (73.3%)	—

Paraspinal Muscle Degeneration and Complications

The mean muscle-fat index (MFI) increased significantly from $20.39 \pm 5.19\%$ preoperatively to $37.58 \pm 3.94\%$ postoperatively, with a mean change of $17.19 \pm 5.28\%$ ($p < 0.001$).

Postoperative course was uneventful in 93.3% of patients. One patient (6.7%) developed right extensor hallucis longus (EHL) weakness.

Table 4: Muscle-Fat Index (MFI) Change and Postoperative Complications (n=15)

Variable	Value
Preoperative MFI (%)	20.39 ± 5.19
Postoperative MFI (%)	37.58 ± 3.94
Mean MFI change (%)	17.19 ± 5.28
p-value	<0.001
Uneventful recovery	14 (93.3%)
Neurological complication	1 (6.7%)

Discussion

Minimally invasive spine surgery (MIS) has emerged as an effective alternative to conventional open procedures for the management of lumbo-sacral degenerative disorders. The present prospective observational study evaluated clinical, radiological, and paraspinal muscle outcomes following MIS and demonstrated significant improvement in pain, functional status, sagittal alignment, and fusion rates, with minimal perioperative morbidity.

Clinical and Functional Outcomes

In the present study, there was a statistically significant reduction in pain scores and improvement in functional outcomes, as evidenced by marked improvement in VAS, ODI, and JOA scores postoperatively. These findings are consistent with previous studies reporting comparable or superior clinical outcomes following MIS when compared to open lumbar fusion techniques [5–7,14]. Lee et al. demonstrated equivalent clinical and radiological outcomes between open TLIF and MIS-TLIF, with reduced approach-related morbidity in the minimally invasive group [7]. Song et al. reported favorable short- and mid-term outcomes across different minimally invasive fusion techniques for degenerative spondylolisthesis, with significant improvement in disability scores and low complication rates [10]. Similarly, Hung et al. observed superior early postoperative pain relief and functional recovery in patients undergoing OLIF compared to MIS-TLIF, highlighting the effectiveness of minimally invasive approaches in appropriately selected cases [6]. The improvement in postoperative neurological status observed in the majority of patients in the present study further supports the efficacy of MIS in achieving adequate neural decompression with minimal tissue disruption.[figure 3]

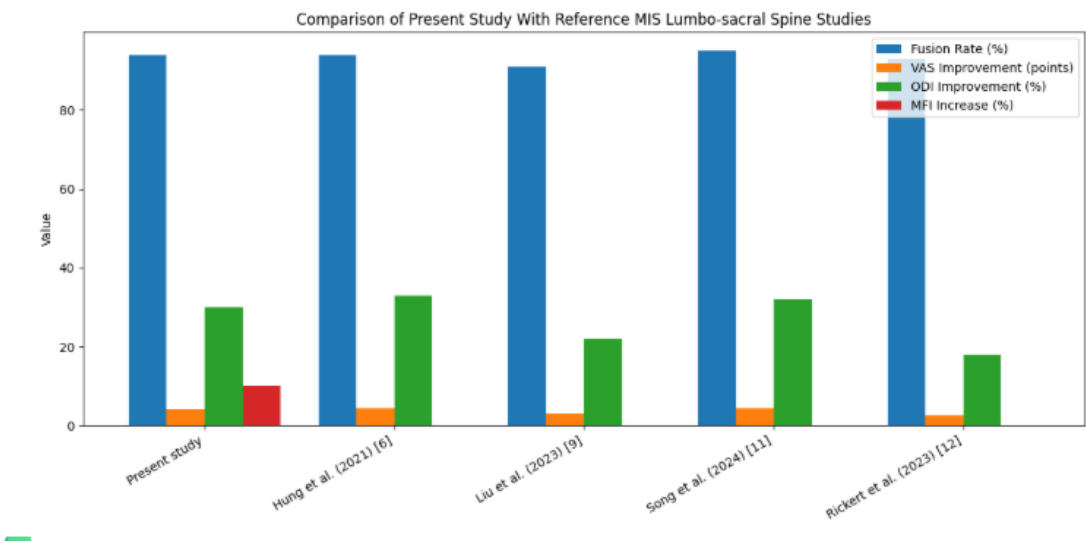


FIG 3 :Comparison of present study with contemporary studies on MIS in LS Spine

Radiological Outcomes and Fusion Status

Radiological assessment in the present study demonstrated significant postoperative improvement in disc height and sagittal alignment parameters, including segmental lumbar lordosis, pelvic incidence, and pelvic tilt. Restoration of disc height and alignment is crucial for maintaining spinal biomechanics and long-term functional outcomes. Similar radiological improvements have been reported in comparative studies evaluating OLIF and MIS-TLIF, with differences in alignment correction attributed to surgical approach and cage positioning [8,9].

A high solid fusion rate of 93.3% was observed in the present study, which is comparable to fusion rates reported in existing literature [5,7,10]. Implant-related complications were minimal. Previous studies have suggested that radiological findings such as screw loosening, cage subsidence, and

migration do not necessarily correlate with poor clinical outcomes. Yao et al. demonstrated that although low bone density increased the risk of screw loosening and cage subsidence, these factors did not adversely affect fusion or functional outcomes in MIS-TLIF [11]. Rickert et al. similarly reported that cage migration and subsidence were not significantly associated with failure of bony fusion [12].

High accuracy of pedicle screw placement observed in this study further reinforces the safety and precision of fluoroscopy-guided MIS techniques.

Paraspinal Muscle Degeneration

Preservation of paraspinal musculature is a major theoretical advantage of MIS. In the present study, a significant postoperative increase in muscle-fat index (MFI) was observed, indicating measurable paraspinal muscle degeneration despite the minimally invasive approach. However, the magnitude of muscle degeneration remains lower than that reported with conventional open surgery.

Fu et al. demonstrated significantly greater paraspinal muscle degeneration following open posterior lumbar surgery compared to MIS, particularly at the caudal adjacent level [4]. These findings suggest that while MIS is muscle-sparing, it does not completely eliminate postoperative muscle changes, which may result from retraction, thermal injury, or ischemia during instrumentation.

Biomechanical studies have highlighted that lumbar fusion alters load transmission across adjacent segments, potentially accelerating adjacent segment degeneration irrespective of surgical approach [13]. Therefore, long-term follow-up is essential to evaluate the functional implications of postoperative muscle degeneration and altered spinal biomechanics.

Complications and Operative Parameters

The overall complication rate in the present study was low, with only one patient developing transient postoperative neurological deficit. This is consistent with systematic reviews and meta-analyses demonstrating lower complication rates, reduced blood loss, and shorter hospital stays with MIS compared to open surgery [3,5,15]. Operative duration and radiation exposure in the present study were within acceptable limits and comparable to previously reported MIS series [6,10].

CONCLUSION

Minimally invasive surgery for lumbo-sacral degenerative spine disorders resulted in significant improvement in pain relief, functional outcomes, and radiological alignment with a high fusion rate and minimal complications. The procedure demonstrated acceptable operative duration, controlled radiation exposure, and high accuracy of instrumentation. Although minimally invasive techniques are associated with reduced soft-tissue disruption, measurable paraspinal muscle degeneration was observed, emphasizing the need for structured postoperative rehabilitation and long-term follow-up. Overall, minimally invasive spine surgery represents a safe and effective surgical option for appropriately selected patients with lumbo-sacral spine pathology.

References

1. Vialle EN, Vialle LRG, Simões CE, Menegaz PS. Clinical-radiographic correlation of degenerative changes of the spine: a systematic review. *Coluna/Columna*. 2016;15(4):325–9.
2. Skovrlj B, Gilligan J, Cutler HS, Qureshi SA. Minimally invasive procedures on the lumbar spine. *World J Clin Cases*. 2015;3(1):1–9.
3. Pokorny G, Amaral R, Marcelino F, Moriguchi R, Barreira I, Yozo M, et al. Minimally invasive versus open surgery for degenerative lumbar pathologies: a systematic review and meta-analysis. *Eur Spine J*. 2022;31(10):2502–26.

4. Fu CJ, Chen WC, Lu ML, Cheng CH, Niu CC. Comparison of paraspinal muscle degeneration and decompression effect between conventional open and minimally invasive approaches for posterior lumbar spine surgery. *Sci Rep.* 2020;10(1):14635.
5. Sousa JM, Ribeiro H, Silva JL, Nogueira P, Consciência JG. Clinical outcomes, complications and fusion rates in endoscopic assisted intraforaminal lumbar interbody fusion versus minimally invasive transforaminal lumbar interbody fusion: a systematic review and meta-analysis. *Sci Rep.* 2022;12(1):2101.
6. Hung SF, Liao JC, Tsai TT, Li YD, Chiu PY, Hsieh MK, et al. Comparison of outcomes between indirect decompression of oblique lumbar interbody fusion and MIS-TLIF in single-level lumbar spondylosis. *Sci Rep.* 2021;11(1):12783.
7. Lee KH, Yue WM, Yeo W, Soeharno H, Tan SB. Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion. *Eur Spine J.* 2012;21(11):2265–70.
8. Liu L, Xue H, Han Z, Jiang L, Chen L, Wang D. Comparison between OLIF and MIS-TLIF in degenerative lumbar stenosis: an age-, sex-, and segment-matched cohort study. *Sci Rep.* 2023;13(1):13188.
9. Hung SF, Liao JC, Tsai TT, Li YD, Chiu PY, Hsieh MK, et al. Radiological and clinical outcomes of OLIF versus MIS-TLIF in lumbar degenerative disease. *Sci Rep.* 2021;11(1):12783.
10. Song Z, Zhang Z, Zheng J, Zhang K, Wang F, Ran M et al. Short-term and mid-term evaluation of three types of minimally invasive lumbar fusion surgery for treatment of L4/L5 degenerative spondylolisthesis. *Sci Rep.* 2024;14(1):4320.
11. Yao YC, Chao H, Kao KY, Chen WC, Lee YC, Tu YK, et al. CT Hounsfield unit is a reliable parameter for screw loosening or cage subsidence in minimally invasive transforaminal lumbar interbody fusion. *Sci Rep.* 2023;13(1):1620.
12. Rickert M, Fennema P, Wehner D, Rahim T, Hölper B, Eichler M, et al. Postoperative cage migration and subsidence following TLIF surgery is not associated with bony fusion. *Sci Rep.* 2023;13(1):12597.
13. Ebrahimkhani M, Arjmand N, Shirazi-Adl A. Biomechanical effects of lumbar fusion surgery on adjacent segments using musculoskeletal models of the intact, degenerated and fused spine. *Sci Rep.* 2021;11(1):17892.
14. Phan K, Mobbs RJ. Minimally invasive versus open lumbar fusion: a systematic review and meta-analysis. *World Neurosurg.* 2016;87:498–506.
15. Wang MY, Cummock MD, Yu Y, Trivedi RA. An analysis of the differences in the outcomes between open and minimally invasive lumbar spine fusion. *Neurosurgery.* 2010;66(3):489–95.