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Comparison of Minimally Invasive and Open Transforaminal Lumbar Interbody Fusion for Lumbar Disc Herniation: A Retrospective Cohort Study

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Data Interpretation D
Manuscript Preparation E
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Background: This cohort study compared the efficacy and safety of minimally invasive versus open transforaminal lumbar interbody fusion (Mis-TLIF versus Open-TLIF) for lumbar disc herniation with radiculopathy.

Material/Methods: From July 2016 to September 2017, we recruited 37 patients suffering from lumbar disc herniation with radiculopathy. Seventeen patients underwent Mis-TLIF (Mis group) and 20 patients underwent Open-TLIF (Open group). Baseline characteristics were similar between the 2 groups before surgery. We compared postoperative clinical and radiological outcomes between the 2 groups.

Results: Compared to patients in the Open group, patients in the Mis group has significantly less intraoperative hemorrhage, drainage fluid, time to go, and hospital stay after surgery, but had longer operation times ($P<0.05$). These 2 groups had similar postoperative hemoglobin reduction and drain removal time. In addition, the postoperative back and leg pain and intervertebral height reduction at 3 months after surgery in the Mis group were remarkably lower than those in the Open group. There was no significant difference in postoperative Oswestry disability index (ODI) or intervertebral height change immediately after surgery and at 1 month postoperatively between the 2 groups.

Conclusions: Mis-TLIF shows some benefits in lumbar disc herniation compared to Open-TLIF in terms of intraoperative hemorrhage, drainage fluid, time to go, hospital stay after surgery, and postoperative back and leg pain.

MeSH Keywords: **Cohort Studies • Lumbar Disc Herniation • Surgical Procedures, Minimally Invasive • Transforaminal Lumbar Interbody Fusion**

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Background

Transforaminal lumbar interbody fusion (TLIF) has been widely used for degenerative lumbar disease (e.g., lumbar disc herniation and spondylolisthesis), and aims to provide spinal fusion, restore disc height, and maintain the normal lordosis of the lumbar spine [1–3]. TLIF is well known as an effective technique, but extensive paravertebral muscle stripping and retraction is needed to obtain an adequate surgical field [4–6]. This serious soft tissue injury may increase back pain and the atrophy of the paraspinous muscles [7,8].

Minimally invasive TLIF (Mis-TLIF) was first reported by Foley in 2003 [9]. Mis-TLIF has gained great popularity with the advancement of techniques and instruments specialized for minimally invasive spine surgery (e.g., tubular retractors and percutaneous pedicle screw fixation) [6,10–13]. Mis-TLIF results in decreased trauma to back muscles, less intraoperative blood loss, and less damage to bony structures compared to traditional Open-TLIF [14–18]. However, some clinical studies have reported that compared to Open-TLIF patients, patients with Mis-TLIF have comparable intraoperative blood loss and operation time and even longer duration of hospital stay [19–21]. Considering these inconsistent effects, we therefore conducted the present retrospective cohort study to compare the efficacy and safety of Mis-TLIF versus Open-TLIF.

Material and Methods

This study was approved by the Committee of Medical Ethics and the Institutional Review Board of our institution. Patient outcomes were collected independently from patients with informed consent, and data were analyzed blindly.

Patients and selection process

From July 2016 to September 2017, 37 consecutive patients underwent one-level TLIF in our hospital, and all operations were done by a single senior surgeon. Among all the patients, 17 patients underwent Mis-TLIT (Mis group) and 20 patients underwent the traditional Open-TLIF (Open group).

Table 1 shows the demographics and procedure data of patients. The eligibility criteria were: (1) one-level lumbar disk herniation with unilateral radiculopathy, (2) one-level lumbar disk herniation combined with stenosis requiring facetectomy and fusion, and (3) one-level lumbar disk herniation combined with spondylolisthesis or segmental instability requiring fusion. The exclusion criteria were: lumbar fracture, previous spinal surgery, active infection, deformities requiring correction, and any major psychological problems.

Surgical technique

The Mis-TLIF procedure was performed with the patient placed in prone position. A para-midline incision approximately 2.5 cm long was made under fluoroscopic guidance to locate the medial border of the facet joint. The erector spinae muscles were retracted, and serial dilators were inserted to dock on the relevant facet joint. Then, a self-retaining retractor was assembled (DePuy Spine, MA, USA).

The surgical techniques of decompression and interbody fusion were similar in the 2 groups. Access to the intervertebral disc was allowed through facetectomy and annulotomy, and then discectomy and preparation of the adjacent vertebral endplates were performed. The disc space was distracted sequentially to the appropriate height, allowing the

Table 1. Demographic data and clinical characteristics.

	Mis group	Open group	P value
Number	17	20	
Age, years	46.12±13.88	52.15±10.5	0.14
Sex, Male/Female	9/8	8/12	0.43
Weight, kg	62.53±10.58	62.93±10.82	0.91
Height, cm	163.76±7.73	162.8±6.01	0.68
Leg pain (left/right)	8/9	10/10	0.86
Symptom duration, months	46.52±62.74	38.95±48.81	0.62
Level fusion			
L2/3	1	0	
L3/4	1	1	
L4/5	7	8	
L5/S1	8	11	

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Table 2. Comparison of clinical outcomes between Mis group and Open group.

	Mis group	Open group	P value
Operation time, min	124.29±21.44	106.8±19.24	0.01
Intraoperative hemorrhage, ml	70.59±25.36	101.5±38.29	0.003
Preoperative hemoglobin, g/L	137.24±14.54	133.45±16.57	0.46
Hemoglobin reduction 1 day after surgery, g/L	16.00±13.52	9.43±9.94	0.18
Drain removal time, day	2.71±0.47	3.10±0.72	0.05
Drainage fluid, ml	106.18±49.42	156.25±63.74	0.0004

insertion of the cage. Final placement of the cage was confirmed fluoroscopically.

The ipsilateral pedicle screws were placed under direct visualization after complete decompression and fusion. On the contralateral side, 1 incision approximately 5 cm long was made on the skin and lumbodorsal fascia between the longissimus and multifidus muscles to expose the facet joint of the corresponding level, and then pedicle screws were placed under direct visualization. Rods of an adequate size were fitted. The wounds were copiously irrigated, drainage catheters were placed, and the wounds were closed layer by layer.

A midline open approach was used for Open-TLIF, and details of the procedures were previously described [15,22].

Outcome measures

We collected data on operation time, intraoperative hemorrhage, hemoglobin, drain removal time, drainage fluid, time to go, and hospital stay after surgery. The drain removal was conducted when the drainage fluid for 24 h was less than 30 ml.

Back and leg pain were evaluated using visual analog scores (VAS) preoperatively and 5 days postoperatively. Intravenous flurbiprofen axetil (50 mg) was used in all patients for 3 days postoperatively, and no patients received painkillers. We used the Oswestry disability index (ODI) version 2.0 before and 5 days after surgery to assess ability to perform activities of daily living. Radiographs were performed to calculate the intervertebral height preoperatively, immediately postoperatively, and 1 month and 3 months postoperatively.

Statistical analysis

Statistical analysis was performed using the *t* test for continuous variables or the chi-square test for dichotomous variables. These 2 tests were used to compare the demographic parameters and perioperative and postoperative parameters between the 2 groups. Statistical significance was defined as P<0.05.

Results

Table 1 demonstrates the baseline characteristics between the Mis group and Open group. There were no significant differences in terms of age, sex, weight, height, leg pain (left/right), and symptom duration between the 2 groups (p>0.05). Seventeen patients were recruited in the Mis group, with 1 case in L2/3, 1 case in L3/4, 7 cases in L4/5, and 8 cases in L5/S1. Twenty patients were recruited in the Open group, with 1 case in L3/4, 8 cases in L4/5, and 11 cases in L5/S1.

Significant differences were found in operating time (124.29±21.44 min in Mis group versus 106.8±19.24 in Open group) between the 2 groups (p=0.01). Intraoperative hemorrhage was significantly less for Mis group (70.59±25.36 ml) than in the Open group (101.5±38.29 ml, p=0.003). However, there was no substantial difference in preoperative hemoglobin, hemoglobin reduction 1 day after surgery, and drain removal time between these 2 groups. Drainage fluid after the surgery was significantly less in the Mis group (106.18±49.42 ml) compared to the Open group (156.25±63.74 ml, P=0.0004, Table 2).

Furthermore, patients in the Mis group had shorter time to go (2.35±0.49 days versus 3.15±0.99 days) and hospital stay (3.82±0.73 days versus 4.90±1.07 days) after surgery compared to patients in the Open group (P<0.05, Figure 1). None of the patients in the 2 groups require blood transfusions.

Preoperative back VAS was higher in the Mis group than in the Open group (7.06±0.75 versus 6.55±0.76, P=0.04). No significant difference was found in terms of preoperative leg VAS between the 2 groups (P>0.05). However, on postoperative 3 day, Mis-TLIF patients had significantly lower back pain VAS (2.88±0.33 versus 3.45±0.69, P=0.001) and leg pain VAS (2.06±0.66 versus 2.65±0.88, P=0.02) compared to the Open-TLIF patients. No significant difference was found in preoperative and postoperative ODI between the 2 groups (P>0.05, Table 3).

Patients in the 2 groups had similar preoperative intervertebral heights (9.34±0.94 cm in Mis group and 9.54±1.39 cm in Open group, P=0.60). After the TLIF surgery, intervertebral

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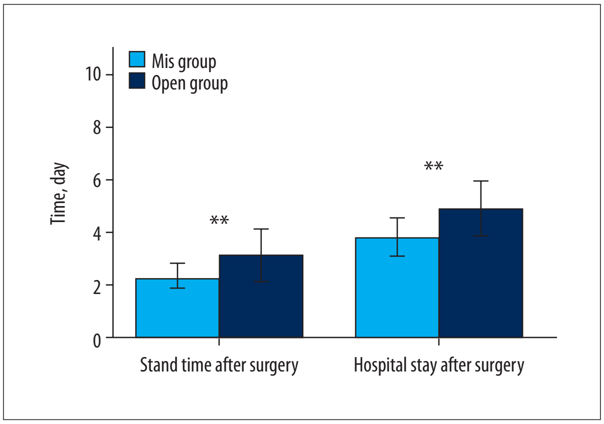

Figure 1. Comparison of time to go after surgery and hospital stay after surgery between Mis group and Open group. ** represents P<0.01.

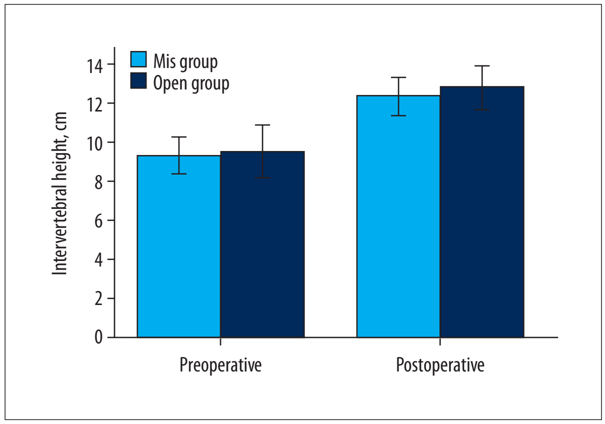

Figure 2. Comparison of preoperative and postoperative intervertebral height between Mis group and Open group. P>0.05.

Table 3. Comparison of pain and ODI between Mis group and Open group.

	Mis group	Open group	P value
Preoperative back VAS	7.06±0.75	6.55±0.76	0.04
Postoperative back VAS	2.88±0.33	3.45±0.69	0.001
Preoperative leg VAS	7.88±0.86	7.65±0.75	0.39
Postoperative leg VAS	2.06±0.66	2.65±0.88	0.02
Preoperative ODI	59.47±6.26	58.8±6.83	0.76
Postoperative ODI	32.41±2.87	34.45±3.8	0.06

ODI – Oswestry disability index; VAS – visual analog scale.

Table 4. Intervertebral height change between Mis group and Open group.

	Mis group	Open group	P value
IH Increase after surgery, cm	3.04±0.82	3.30±1.08	0.41
IH Reduction 1 month after surgery, cm	0.64±0.49	0.81±0.59	0.53

IH –intervertebral height.

height was significantly improved, with no significant difference between the 2 groups (12.38±0.85 cm versus 12.84±1.06 cm, P=0.14, Figure 2). Patients in the 2 groups had comparable intervertebral height postoperatively (3.04±0.82 cm versus 3.30±1.08 cm) and 1 month after surgery (0.64±0.49 cm versus 0.81±0.59 cm (P>0.05, Table 4). At 3 months after the surgery, patients in the Mis group had less reduction in intervertebral height (0.72±0.51 cm versus 2.15±0.31 cm, P<0.05) than those in the Open group.

Complications

Two patients had constipation (1 in each group). In the Open group, 1 patient had cerebral infarction and 1 patient had hepatic dysfunction, and both recovered after standard treatments. There were no dural tears, wound infections, device-related complications (e.g., hardware loosening and cage migration), or neurological injuries in the 2 groups. The total complication rate was 5.9% in the Mis-TLIF group and 15% in the Open-TLIF group.

Discussion

Minimally invasive fusion procedures can significantly reduce iatrogenic tissue trauma, and Mis-TLIF surgery is able to preserve the contralateral ligament and paraspinal muscles through the tubular retraction system [23–26]. Minimal muscle dissection and bone removal is associated with decreases in intraoperative bleeding and tissue fluid accumulation, which subsequently reduces incidence of adverse events (e.g., wound

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infection) [27–30]. Many methods have been developed to reduce the risk of wound infection. For instance, in a study comparing the effects of various lavage techniques for posterior lumbar interbody fusion, pulse lavage and closed drainage had much better postoperative infection prevention than traditional saline lavage [31]. Open-TLIF procedures require extensive dissection of paraspinal muscles, which increases intraoperative blood loss, tissue injury, and the risk of complications (e.g., dural tear, infection, and hematomas) [32–34]. Our results also confirm that patients with Mis-TLIF have less intraoperative hemorrhage compared to those with Open-TLIF (P=0.003). The methods of TLIF show no substantial influence on postoperative hemoglobin reduction (P=0.18).

However, the operation time in the Mis group was longer than in the Open group (P=0.01), possibly because the only surgeon in our study just learned to perform Mis-TLIF a short time before, and was in the initial stage of the learning curve. Mis-TLIF procedures are conducted under limited surgical vision and working space, and a relatively long learning curve may be required. A retrospective study revealed that the operative time decreases as the series progressed in 86 patients with degenerative lumbar disease, and an asymptote is reached after 30 cases [35]. Mis-TLIF may be safe and effective after traversing the initial learning curve, and the surgeon experience is remarkably associated with operation time, intraoperative blood loss, and complication rates [36,37].

Decreased intraoperative blood loss and tissue trauma have important benefits for recovery after surgery. The present study found that time to go and hospital stay after surgery were significantly shorter in the Mis group compared to the Open group (P<0.05). Subsequently, Mis-TLIF may reduce costs to patients. Mis-TLIF is reported to reduce the mean hospital cost compared to Open-TLIF [38]. In addition, our study demonstrates that, compared with Open-TLIF, Mis-TLIF results in decreased drainage fluid, but has no influence on the drain removal time.

Minimized tissue trauma and reduced paraspinal muscle dissection are associated with postoperative back pain and ODI scores in Mis-TLIF surgery. Mis-TLIF results in 0.4 points lower for VAS scores of back pain and 2.2 points lower for ODI scores than Open-TLIF [39]. In addition, a study compared unilateral pedicle screw (UPS) and bilateral pedicle screw (BPS) instrumented TLIF in patients with degenerative lumbar disorders, showing similar clinical outcomes between UPS fixation and BPS procedure, and concluding that the UPS technique is superior to BPS procedure in terms of operative time and blood loss, but results in lower fusion rate [40].

Our results reveal that, compared to patients undergoing Open-TLIF, patients undergoing Mis-TLIF had less postoperative back and leg pain (P<0.05), and demonstrate comparable postoperative ODI. The lower leg pain in the Mis group may be due to less traction of nerve roots during the decompression. In contrast, pain intensity was reported to be worse in patients undergoing Mis-TLIF compared to those receiving Open-TLIF [11]. Better VAS and ODI outcomes result from shorter durations of intramuscular pressures and less tissue injury caused by a more experienced surgeon, but long operation time is associated with poor VAS and ODI scores when surgery is performed by surgeons in the early stage of the learning curve [41]. Our study also reveals that Mis-TLIF can provide sufficient recovery and maintenance of intervertebral height postoperatively and at 1 month after surgery compared Open-TLIF, and Mis-TLIF may have better maintenance of intervertebral height at 3 months postoperatively, which may be associated with reduced trauma to paraspinal muscles.

Some clinical trials have reported that Open-TLIF surgery increases the possibility of adjacent-level revision surgery, and Mis-TLIF surgery can preserve the bony structure and soft tissues for the better spine stabilization [16]. A recent meta-analysis suggests that Mis-TLIF surgery entails more in radiation exposure, possibly affecting its efficacy and safety [39]. However, in the present study, we only found 1 additional radiation exposure was needed to accurately mark the facet joints of the corresponding level preoperatively compared to conventional Open-TLIF.

Limitations

Our study has several limitations. Firstly, the number of enrolled patients is small and overestimation of the treatment effect is more likely in smaller trials compared with larger samples. Secondly, this study mainly focused on the short-term parameters that aim to promote the enhanced recovery after surgery, and longer follow-up time is needed to assess the long-term clinical outcomes between the Mis group and Open group. Thirdly, all operations were performed by a single surgeon who was in the early stage of the learning curve, and the results may be different if many surgeons with varying degrees of experience perform the Mis-TLIF procedures.

Conclusions

Mis-TLIF may provide additional benefits to patients with lumbar disk herniation compared to traditional Open-TLIF.

Conflicts of interest

None.

References:

1. Giorgi H, Prebet R, Delhaye M et al: Minimally invasive posterior transforaminal lumbar interbody fusion: One-year postoperative morbidity, clinical and radiological results of a prospective multicenter study of 182 cases. Orthop Traumatol Surg Res, 2015; 101 (6 Suppl.): S241–45
2. Fan G, Wu X, Yu S et al: Clinical outcomes of posterior lumbar interbody fusion versus minimally invasive transforaminal lumbar interbody fusion in three-level degenerative lumbar spinal stenosis. Biomed Res Int, 2016; 2016: 9540298
3. Hu W, Tang J, Wu X et al: Minimally invasive versus open transforaminal lumbar fusion: A systematic review of complications. Int Orthop, 2016; 40: 1883–90
4. Salehi SA, Tawk R, Ganju A et al: Transforaminal lumbar interbody fusion: Surgical technique and results in 24 patients. Neurosurgery, 2004; 54: 368–74; discussion 374
5. Potter BK, Freedman BA, Verwiebe EG et al: Transforaminal lumbar interbody fusion: Clinical and radiographic results and complications in 100 consecutive patients. J Spin Disord Tech, 2005; 18: 337–46
6. Goldstein CL, Phillips FM, Rampersaud YR: Comparative effectiveness and economic evaluations of open versus minimally invasive posterior or transforaminal lumbar interbody fusion: A systematic review. Spine, 2016; 41(Suppl. 8): S74–89
7. Liang Y, Shi W, Jiang C et al: Clinical outcomes and sagittal alignment of single-level unilateral instrumented transforaminal lumbar interbody fusion with a 4 to 5-year follow-up. Eur Spine J, 2015; 24: 2560–66
8. Kim CW, Doerr TM, Luna IY et al: Minimally invasive transforaminal lumbar interbody fusion using expandable technology: A clinical and radiographic analysis of 50 patients. World Neurosur, 2016; 90: 228–35
9. Foley KT, Gupta SK: Percutaneous pedicle screw fixation of the lumbar spine: Preliminary clinical results. J Neurosurg, 2002; 97: 7–12
10. Fan S, Hu Z, Zhao F et al: Multifidus muscle changes and clinical effects of one-level posterior lumbar interbody fusion: Minimally invasive procedure versus conventional open approach. Eur Spine J, 2010; 19: 316–24
11. Dhall SS, Wang MY, Mummaneni PV: Clinical and radiographic comparison of mini-open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up. J Neurosurg Spine, 2008; 9: 560–65
12. Seng C, Siddiqui MA, Wong KP et al: Five-year outcomes of minimally invasive versus open transforaminal lumbar interbody fusion: A matched-pair comparison study. Spine, 2013; 38: 2049–55
13. Brodano GB, Martikos K, Lolli F et al: Transforaminal lumbar interbody fusion in degenerative disk disease and spondylolisthesis grade I: Minimally invasive versus open surgery. J Spinal Disord Tech, 2015; 28(10): E559–64
14. Lee KH, Yue WM, Yeo W et al: Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion. Eur Spine J, 2012; 21: 2265–70
15. Peng CW, Yue WM, Poh SY et al: Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion. Spine, 2009; 34: 1385–89
16. Wong AP, Smith ZA, Stadler JA et al: Minimally invasive transforaminal lumbar interbody fusion (MI-TLIF): Surgical technique, long-term 4-year prospective outcomes, and complications compared with an open TLIF cohort. Neurosurg Clin N Am, 2014; 25: 279–304
17. Chen C, Cao X, Zou L et al: Minimally invasive unilateral versus bilateral technique in performing single-segment pedicle screw fixation and lumbar interbody fusion. J Orthop Surg Res, 2015; 10: 112
18. Emami A, Faloon M, Issa K et al: Minimally invasive transforaminal lumbar interbody fusion in the outpatient setting. Orthopedics, 2016; 39: e1218–e22
19. Sulaiman WA, Singh M: Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis grades 1-2: patient-reported clinical outcomes and cost-utility analysis. Ochsner J, 2014; 14: 32–37
20. Cheng JS, Park P, Le H et al: Short-term and long-term outcomes of minimally invasive and open transforaminal lumbar interbody fusions: Is there a difference? Neurosurg Focus, 2013; 35: E6
21. Archavlis E, Carvi y Nievas M: Comparison of minimally invasive fusion and instrumentation versus open surgery for severe stenotic spondylolisthesis with high-grade facet joint osteoarthritis. Eur Spine J. 2013; 22: 1731–40
22. Yucesoy K, Yuksel KZ, Baek S et al: Biomechanics of unilateral compared with bilateral lumbar pedicle screw fixation for stabilization of unilateral vertebral disease. J Neurosurg Spine, 2008; 8: 44–51
23. Choi WS, Kim JS, Ryu KS et al: Minimally invasive transforaminal lumbar interbody fusion at L5–S1 through a unilateral approach: Technical feasibility and outcomes. Biomed Res Int, 2016; 2016: 2518394
24. Ahn J, Tabaraee E, Singh K: Minimally invasive transforaminal lumbar interbody fusion. J Spin Disord Tech, 2015; 28: 222–25
25. Adogwa O, Carr K, Thompson P et al: A prospective, multi-institutional comparative effectiveness study of lumbar spine surgery in morbidly obese patients: Does minimally invasive transforaminal lumbar interbody fusion result in superior outcomes? World Neurosurg, 2015; 83: 860–66
26. Tay KS, Bassi A, Yeo W, Yue WM: Intraoperative reduction does not result in better outcomes in low-grade lumbar spondylolisthesis with neurogenic symptoms after minimally invasive transforaminal lumbar interbody fusion-a 5-year follow-up study. Spine J, 2016; 16: 182–90
27. Lo WL, Lin CM, Yeh YS et al: Comparing miniopen and minimally invasive transforaminal interbody fusion in single-level lumbar degeneration. Biomed Res Int, 2015; 2015: 168384
28. Guan J, Bisson EF, Dailey AT et al: Comparison of clinical outcomes in the national neurosurgery quality and outcomes database for open versus minimally invasive transforaminal lumbar interbody fusion. Spine, 2016; 41: E416–21
29. Keorochana G, Setrkraising K, Woratanarat P et al: Clinical outcomes after minimally invasive transforaminal lumbar interbody fusion and lateral lumbar interbody fusion for treatment of degenerative lumbar disease: A systematic review and meta-analysis. Neurosurg Rev, 2018; 41(3): 755–70
30. Lee WC, Park JY, Kim KH et al: Minimally invasive transforaminal lumbar interbody fusion in multilevel: Comparison with conventional transforaminal interbody fusion. World Neurosurg, 2016; 85: 236–43
31. Fei J, Gu J: Comparison of lavage techniques for preventing incision infection following posterior lumbar interbody fusion. Med Sci Monit, 2017; 23: 3010–18
32. Lin Y, Chen W, Chen A, Li F: Comparison between minimally invasive and open transforaminal lumbar interbody fusion: A meta-analysis of clinical results and safety outcomes. J Neurol Surg A Cent Eur Neurosurg, 2016; 77(1): 2–10
33. Kim CH, Lee CH, Kim KP: How high are radiation-related risks in minimally invasive transforaminal lumbar interbody fusion compared with traditional open surgery?: A meta-analysis and dose estimates of ionizing radiation. Clin Spine Surg, 2016; 29: 52–59
34. Hey HW, Hee HT: Open and minimally invasive transforaminal lumbar interbody fusion: Comparison of intermediate results and complications. Asian Spine J, 2015; 9: 185–93
35. Lee JC, Jang HD, Shin BJ: Learning curve and clinical outcomes of minimally invasive transforaminal lumbar interbody fusion: Our experience in 86 consecutive cases. Spine, 2012; 37: 1548–57
36. Mannion RJ, Guilfoyle MR, Efendy J et al: Minimally invasive lumbar decompression: Long-term outcome, morbidity, and the learning curve from the first 50 cases. J Spinal Disord Tech, 2012; 25: 47–51
37. Lau D, Lee JG, Han SJ et al: Complications and perioperative factors associated with learning the technique of minimally invasive transforaminal lumbar interbody fusion (TLIF). J Clin Neurosci, 2011; 18: 624–27
38. Parker SL, Mendenhall SK, Shau DN et al: Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis: Comparative effectiveness and cost-utility analysis. World Neurosurg, 2014; 82: 230–38
39. Phan K, Rao PJ, Kam AC, Mobbs RJ: Minimally invasive versus open transforaminal lumbar interbody fusion for treatment of degenerative lumbar disease: Systematic review and meta-analysis. Eur Spine J, 2015; 24: 1017–30
40. Liu X, Li G, Wang J, Zhang H: Minimally invasive unilateral *vs.* bilateral pedicle screw fixation and lumbar interbody fusion in treatment of multi-segment lumbar degenerative disorders. Med Sci Monit, 2015; 21: 3652–57
41. Datta G, Gnanalingham KK, Peterson D et al: Back pain and disability after lumbar laminectomy: Is there a relationship to muscle retraction? Neurosurgery, 2004; 54: 1413–20; discussion 1420

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