Original Article

Minimal invasive transforaminal lumbar interbody fusion versus open transforaminal lumbar interbody fusion

Arvind G Kulkarni, Hussain Bohra, Abhilash Dhruv, Abhishek Sarraf, Anupreet Bassi, Vishwanath M Patil

Abstract

Background: The aim of the present prospective study is to evaluate whether the touted advantages of minimal invasive-transforaminal lumbar interbody fusion (MI-TLIF) translate into superior, equal, or inferior outcomes as compared to open-transforaminal lumbar interbody fusion (O-TLIF). This is the first study from the Indian subcontinent prospectively comparing the outcomes of MI-TLIF and O-TLIF.

Materials and Methods: All consecutive cases of open and MI-TLIF were prospectively followed up. Single-level TLIF procedures for spondylolytic and degenerative conditions (degenerative spondylolisthesis, central disc herniations) operated between January 2011 and January 2013 were included. The pre and postoperative Oswestry Disability Index (ODI) and visual analog scale (VAS) for back pain and leg pain, length of hospital stay, operative time, radiation exposure, quantitative C-reactive protein (QCRP), and blood loss were compared between the two groups. The parameters were statistically analyzed (using IBM® SPSS® Statistics version 17).

Results: 129 patients underwent TLIF procedure during the study period of which, 71 patients (46 MI-TLIF and 25 O-TLIF) fulfilled the inclusion criteria. Of these, a further 10 patients were excluded on account of insufficient data and/or no followup. The mean followup was 36.5 months (range 18-54 months). The duration of hospital stay (O-TLIF 5.84 days + 2.249, MI-TLIF 4.11 days + 1.8, $P < 0.05$) was shorter in MI-TLIF cases. There was less blood loss (open 358.8 ml, MI 111.81 ml, $P < 0.05$) in MI-TLIF cases. The operative time (O-TLIF 2.96 h + 0.57, MI-TLIF 3.40 h + 0.54, $P < 0.05$) was longer in MI group. On an average, 57.77 fluoroscopic exposures were required in MI-TLIF which was significantly higher than in O-TLIF (8.2). There was no statistically significant difference in the improvement in ODI and VAS scores in MI-TLIF and O-TLIF groups. The change in QCRP values preoperative and postoperative was significantly lower ($P < 0.000$) in MI-TLIF group than in O-TLIF group, indicating lesser tissue trauma.

Conclusion: The results in MI TLIF are comparable with O-TLIF in terms of outcomes. The advantages of MI-TLIF are lesser blood loss, shorter hospital stay, lesser tissue trauma, and early mobilization. The challenges of MI-TLIF lie in the steep learning curve and significant radiation exposure. The ultimate success of TLIF lies in the execution of the procedure, and in this respect the ability to achieve similar results using a minimally invasive technique makes MI-TLIF an attractive alternative.

Key words: MI-TLIF, TLIF, spinal fusion, minimally invasive spine surgery, percutaneous pedicle screw
MeSH terms: Spinal column, minimally invasive surgical procedure, bone screws, arthrodesis, lumbar vertebrae

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Introduction

Since its introduction by Harms and Jeszenszky[1] in 1998, transforaminal lumbar interbody fusion (TLIF) has stood the test of time in accomplishing the goal

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of reducing approach-related morbidity in comparison to its predecessors such as posterior lumbar interbody fusion. With a unilateral transforaminal approach, sufficient disc space exposure can be achieved through the resection of a single facet joint. This approach reduces the retraction of the thecal sac and nerve roots, and at the same time preserves the contralateral structures. However, the drawback of open-TLIF (O-TLIF) is in its inherent technique, which involves far lateral dissection, with the stripping of paravertebral muscles to expose the entry point for pedicle screw and disc preparation.[2-10] Advances in the design of percutaneous pedicle screws, combined with the tubular retractor system developed by Foley *et al.*,[3] led to the development of minimally invasive transforaminal lumbar interbody fusion (MI-TLIF). MI-TLIF has the potential advantage of minimizing soft tissue damage and reducing recovery time compared to open procedures. However, critics of the technique have noted that MI-TLIF has a steep learning curve, with longer operative time and exposes patients to increased fluoroscopic radiation.[11,12] Several authors have studied the outcomes of a traditional open TLIF approach to MI-TLIF.[13-21] This study compares the clinical outcomes, length of hospital stay as well as quantifies the tissue trauma in both groups using quantitative C-reactive protein (Q-CRP).

Materials and Methods

All cases of O-TLIF and MI-TLIF were prospectively followed up from January 2011 to January 2013. The inclusion criteria were patients with back and leg pain secondary to degenerative conditions (degenerative and spondylolytic spondylolisthesis, central disc herniations) and failed conservative line of treatment. All patients with spondylodiscitis, failed back surgery syndrome and single-level TLIF with additional level discectomy or decompression and multilevel TLIFs were excluded from this study. All the patients presented with low back pain with radiating pain as their chief complaint and were preoperatively evaluated with radiographs and magnetic resonance imaging (MRI). The patients were given an option to decide between MI-TLIF and O-TLIF, the cost of the procedure was a single major deciding factor. The average additional cost for MI-TLIF was 1.25–1.5 lakhs during the time of study. Back pain and leg pain were quantified by visual analog scores (VASs) collected from patients preoperatively, postoperatively, and at the last followup. The Oswestry Disability Index (ODI) (version 2.0) was similarly recorded. A preoperative Q-CRP just prior to the operation and a postoperative Q-CRP on the morning after the surgery were measured. The demographic details of the patients are summarized in Table 1, and the diagnosis of the patients is summarized in Figure 1.

Table 1: Clinical details of patients

	MI-TLIF group	O-TLIF group
Number of patients	36	25
Mean age (years)	51.55	50.4
Gender (male/female)	10/26	11/14
Body mass index (BMI)	28.22	26.43
Diagnosis (no. of patients)		
Listhesis	30	12
Disc herniation	5	11
Lumbar canal stenosis	1	2
Level involved (no. of patients)		
L2-L3	20	1
L3-L4	16	3
L4-L5		14
L5-S1		7

MI-TLIF=Minimally invasive trans-foraminal lumbar interbody fusion, O-TLIF=Open trans-foraminal lumbar interbody fusion

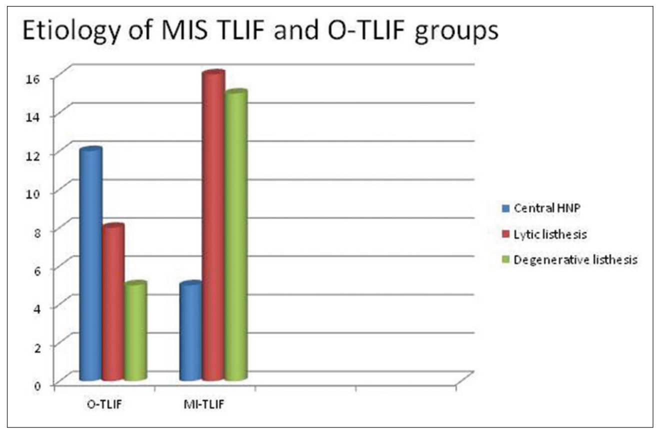

Figure 1: Bar chart depicting the distribution of patients with regards to diagnosis in minimal invasive-transforaminal lumbar interbody fusion, as well as open-transforaminal lumbar interbody fusion

Minimal invasive-transforaminal lumbar interbody fusion technique

The patient was positioned prone on a spinal surgery radiolucent table under general anesthesia. The entire operation was carried out in two critical steps: (a) Decompression, discectomy and cage insertion for interbody fusion, surgical access obtained using a tubular retraction system and (b) percutaneous placement of pedicle screws. The side of the approach was usually based on the location of the preoperative radicular symptoms. Under fluoroscopic guidance, guide wire was advanced, centered over facet joint. Sequential dilators were inserted over the guide wire confirming on fluoroscopy. A 22 mm diameter tubular retractor of appropriate length was used as the working channel. Under microscopic visualization, facetectomy, decompression, discectomy, and endplate preparation was done through the tube. Contralateral decompression was done by wanding technique (tilting the tubular retractor to the opposite side) through the same unilateral incision. Sufficient autologous bone graft obtained from the removed facet was packed in the anterior third of the disc space. A cage of appropriate size was inserted. Screws and rods were placed percutaneously on the both sides and compression applied across the cage. A clinical case is illustrated with pre and postoperative radiographs [Figures 2-4].

Open-transforaminal lumbar interbody fusion technique

After a posterior midline incision, fascia and paraspinal muscles were retracted with the help of self-retaining retractors, for far lateral exposure beyond the facets. The

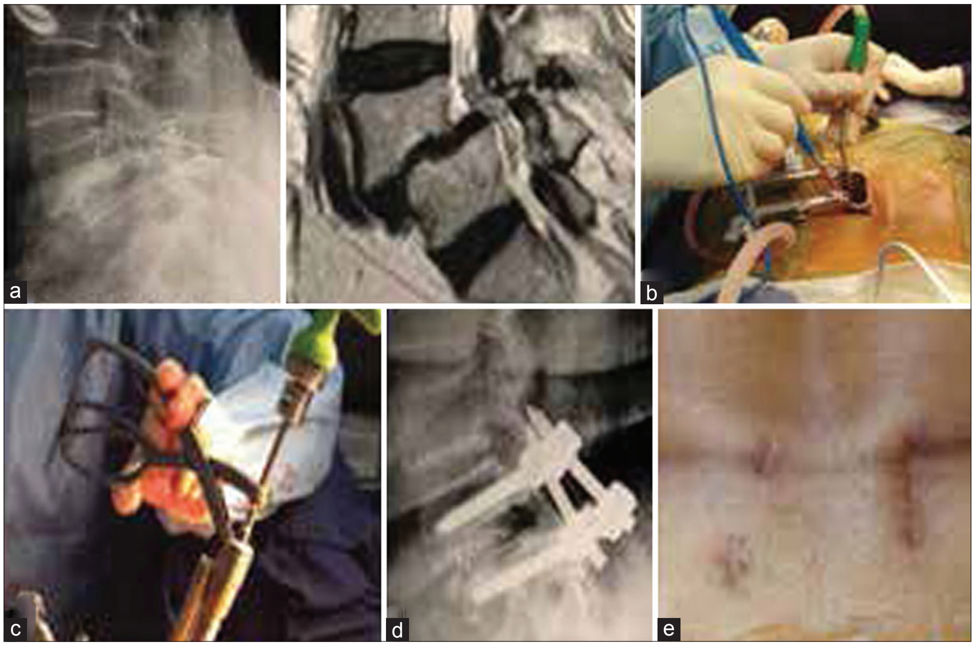

Figure 2: Clinical case demonstration: Minimal invasive-transforaminal lumbar interbody fusion in spondylolytic spondylolisthesis. (a) Preoperative radiograph lumbosacral spine and T2W sagittal MRI showing spondylolisthesis L4L5 vertebral body (b) Intra operative photograph showing decompression tubular retractor. (c) Intraoperative photograph showing manipulation (d) Postoperative radiograph showing implant and cage *in situ* (e) Postoperative photograph showing scar mark

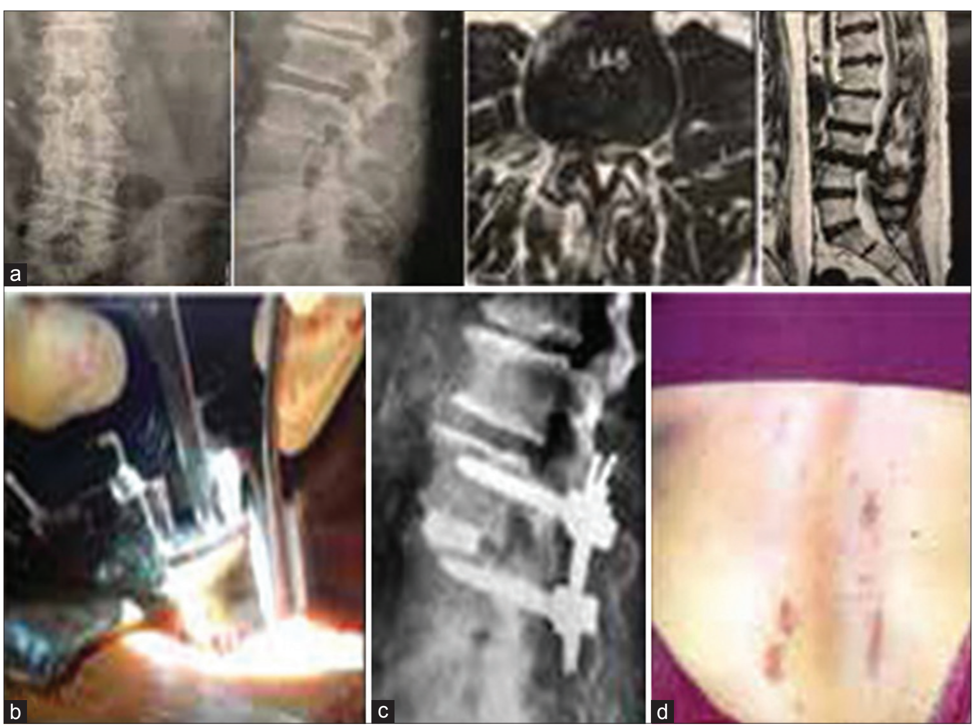

Figure 3: Clinical case demonstration: Minimal invasive-transforaminal lumbar interbody fusion in degenerative stenosis with scoliosis. (a) Preoperative anteroposterior and lateral radiograph; T2W axial and sagittal MRI of LS spine showing degenerative sterosis with scoliosis (b) Intraoperative photograph showing decompression (c) Postoperative photograph showing pedicle screws and cage *in situ* (d) Postoperative photograph showing scar mark

Figure 4: Clinical photograph showing postoperative scar in minimal invasive-transforaminal lumbar interbody fusion patient with good cosmesis

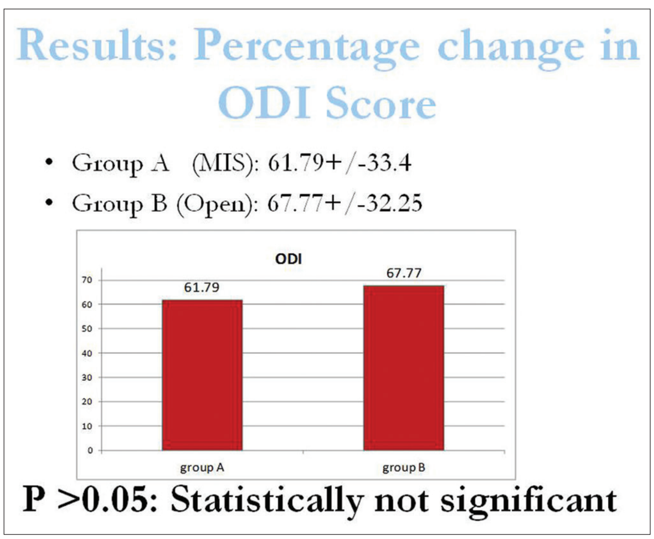

Figure 6: Bar chart showing the percentage change in Oswestry Disability Index score in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion

pedicle screws were inserted using the freehand technique. A unilateral facetectomy at the level of fusion was done. A standard decompression was carried out in the respective cases requiring decompression. A thorough discectomy and end plate preparation was performed, followed by the placement of interbody cage with autograft.

Statistical analysis

Statistical analyses were performed using SPSS-IBM software 17.0. Data were shown as mean ± standard deviation. Student's *t*-test was used for the comparison of continuous variables. *P* values below 0.05 were accepted for significance.

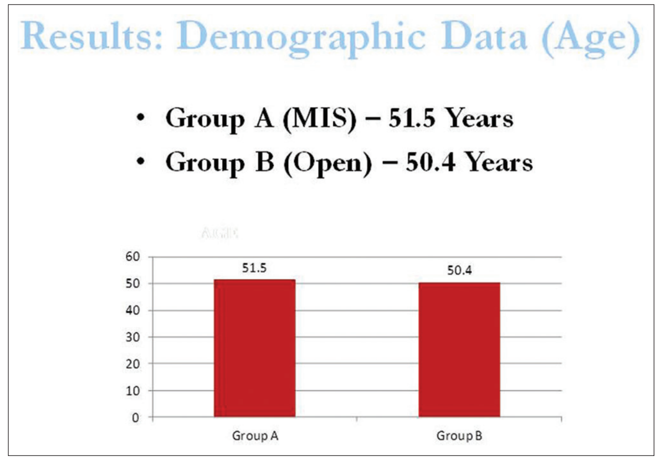

Figure 5: Bar chart showing the demographic data of minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion

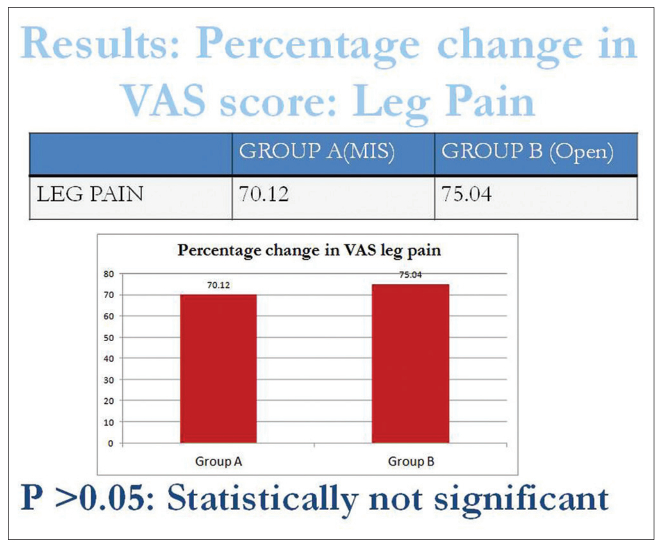

Figure 7: Bar chart showing the percentage change in visual analog scale score-leg pain in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion

Results

A total of 129 patients underwent TLIF during the study period for various indications. Seventy-one of these fulfilled the inclusion criteria; of these, 10 patients were excluded in view of insufficient data or loss to followup. Finally, there were 61 subjects (MI-TLIF [n = 36] and O-TLIF [n = 25]). In MI-TLIF group, female:male ratio was 2.6:1 with the mean age of 51.55 years (26 females, 10 males). The mean followup was 36.5 months (range 18–54 months). The average percent change in ODI was 61.79 ± 33.4. The average percent change in VAS score for leg pain was 70.12 + 39.19 and that of back pain was 50.17 ± 38.39. There was one case of transient foot drop which resolved with conservative management. The possible cause was that the pedicle screw at L5 on the affected side had breached medially, which was corrected intraoperatively. There was one more case of bowel and bladder incontinence, which resolved in due course of time. Postoperative MRI did not reveal any obvious compression. None of the cases in MI-TLIF group needed to be converted to O-TLIF technique. The mean change in Q-CRP value was 2.4 ± 1.30. In the O-TLIF group, female: male ratio was 1.27:1 (14 females, 11 males) with the mean age of 50.4 years [Figure 5]. The mean followup was 40.2 months (range 18–56 months). The average percent change in ODI was 67.77 + 32.25 [Figure 6]. The average percent change in VAS score for leg pain was7.54 ±3.57 [Figure 7] and for back pain was 45.79 + 41.89 [Figure 8]. No complications were encountered in this group. The mean change in Q-CRP value was 5.33 ± 2.02 [Figure 9]. The duration of hospital stay (O-TLIF 5.84 days + 2.249, MI-TLIF 4.11 days + 1.8, $P < 0.05$) was shorter in MI-TLIF cases [Figure 10]. There was less blood loss (open 358.8 ml, MI 111.81 ml, $P < 0.05$) in MI-TLIF cases [Figure 11]. The blood loss was measured from suction collection pump, gauze pieces, and cotton pattinoids. The operative time (O-TLIF 2.96 h + 0.57, MI-TLIF 3.40 h ± 0.54, $P < 0.05$) was longer in MI group [Figure 12]. On an average, 57.77 (range 44–96) fluoroscopic shoots were required in MI-TLIF, which was significantly higher than in O-TLIF (average 8.2 shoots; range 5-18 shoots) [Figure 13]. Both MI-TLIF and O-TLIF groups showed significant improvement in ODI scores, VAS scores for back pain and leg pain postoperatively and at recent followup however, there was no statistically significant difference between the two groups. The change in Q-CRP values pre and postoperative was significantly

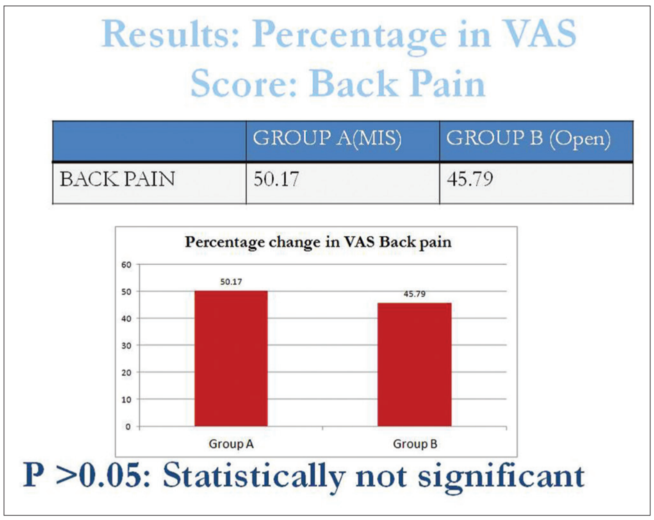

Figure 8: Bar chart showing the percentage change in visual analog scale score-back pain in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion

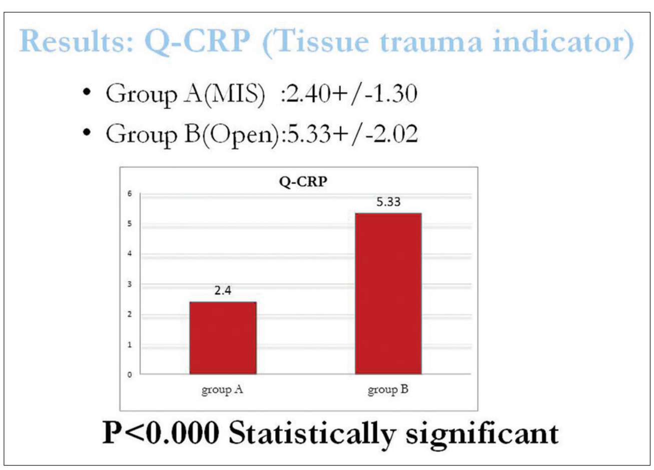

Figure 9: Bar chart showing the average quantitative C-reactive protein levels in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion

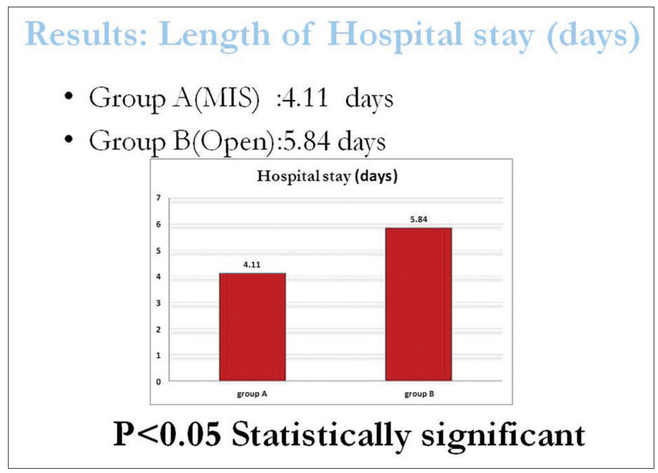

Figure 10: Bar chart showing the average hospital stay in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion groups

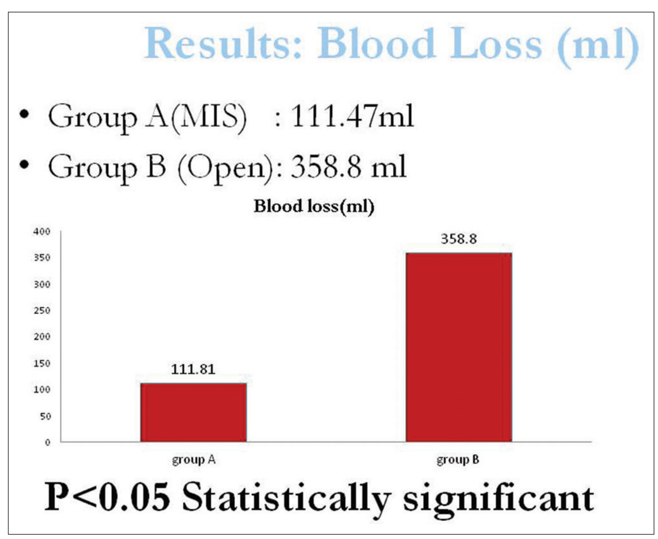

Figure 11: Bar chart showing the average blood loss in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion groups

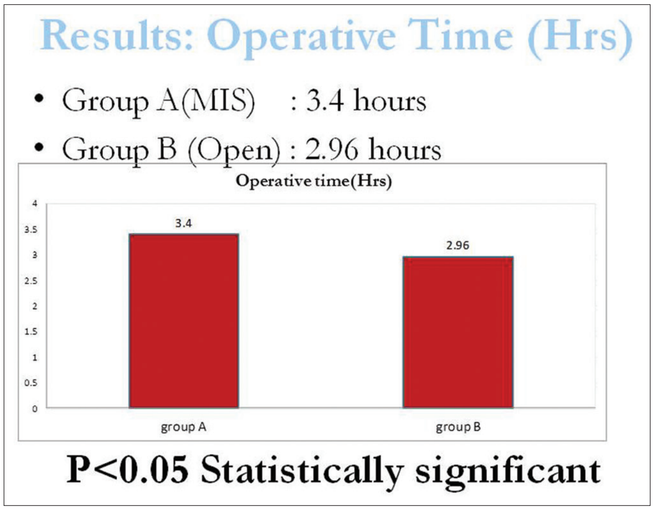

Figure 12: Bar chart showing the average operative time in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion

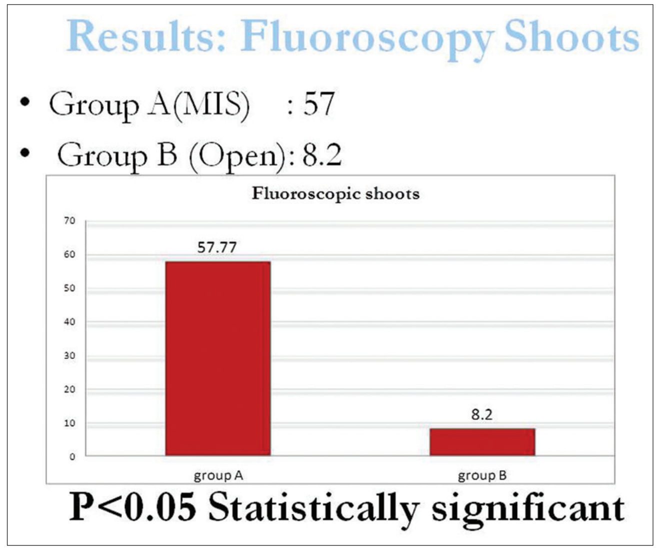

Figure 13: Bar chart showing the average fluoroscopic shoots in minimal invasive-transforaminal lumbar interbody fusion and open-transforaminal lumbar interbody fusion

lower ($P < 0.000$) in MI-TLIF group than in O-TLIF group, indicating lesser tissue trauma. All patients in the study were mobilized the following day; MI TLIF patients were discharged earlier compared to O-TLIF group (MI-TLIF: 3 ± 2; open 5 ± 2 days). The fusion in each of the groups was seen and confirmed on dynamic radiographs at the end of 1-year followup. There were no cases of instability at the end of followup.

Discussion

Conventional lumbar fusion technique is associated with significant morbidity in view of the extensive dissection[2,3] required and its deleterious effects have been well documented in literature.[4-10] The goal of minimally invasive spine surgery is to achieve the same objective as conventional procedures but through a less traumatic approach. Since the MI-TLIF procedure is done through a unilateral paraspinal approach, it spares the posterior tension band. The contralateral musculature is left completely intact. There is minimal injury to the ipsilateral paraspinal muscles due to the introduction of serial dilators to dilate the tract, thus splitting the muscle fibers prior to docking the tubular retractor system. This is unlike the O-TLIF procedure, wherein the approach itself involves a certain degree of soft tissue trauma. Hence, lesser tissue trauma in MI-TLIF accounts for the faster recovery and lesser postoperative pain.[21] The pedicle screws and rods are inserted percutaneously which adds to soft tissue preservation, by obviating far lateral stripping of paraspinal musculature. The outcomes of the various studies comparing MI-TLIF versus O-TLIF are summarized in Table 2. Dhal *et al*.[19] in their retrospective study of 42 patients found significantly reduced total blood loss and length of hospital stay in MI-TLIF group. However, they found a higher incidence of implant-associated complications with MI-TLIF group. Wang *et al*.[18] in their prospective randomized clinical study of 79 patients found increased intraoperative fluoroscopy time in MI-TLIF group and increased postoperative drainage volume as well as prolonged postoperative recovery time in O-TLIF group. They also found that MI-TLIF can effectively reduce sacrospinalis muscle injury compared with O-TLIF surgery, which is conducive to early functional recovery. They concluded that in short term MI-TLIF is superior to O-TLIF but in the long term there is no significant difference between the two procedures. Peng *et al*.[17] in their prospective study of 58 patients reported decreased fluoroscopy time and operative time in the open group whereas less blood loss, less morphine use, and shorter hospital stay were reported in the MI-TLIF group. Both the groups showed significant improvement in ODI score, back pain and lower limb symptoms (VAS), and quality of life (short form-36 [SF-36]) at 6 months and 2 years, but there was no significant difference between the two groups. Lee *et al*.[16] in their prospective observational study of 144 patients showed longer fluoroscopic time, less intraoperative blood loss and no postoperative drainage, less morphine usage, early mobilization, and shorter hospital stay in MI-TLIF group. However, the operative time was comparable with O-TLIF group. Improvement in terms of VAS, ODI, SF-36, and return to full function was similar in both the groups. Wang *et al*.[15] in their prospective study of 85 patients reported significantly lesser blood loss, lesser need for transfusion, lesser postoperative back pain, and shorter length of hospital stay in MI-TLIF group. Radiation time was significantly longer in MI-TLIF group. Villavicencio *et al*.[14] in their prospective study of 139 patients reported less blood loss and shorter hospital stay in MI-TLIF group. Mean change in VAS scores postoperatively, MacNab's criteria

Table 2: Summary of various studies comparing MI-TLIF vs O-TLIF

Name Year	Number of patients		Mean f/u (months)		Mean Back pain VAS improvement		Mean leg pain VAS improvement		Mean ODI improvement		Mean hospital stay (days)		Mean operative time (mins)		Total blood loss (ml)		Complications
	M	O	M	O	M	O	M	O	M	O	M	O	M	O	M	O	
Schizas[13] (2009)	18	18	22	24	4.2	2.2	NR	NR	22	27	6.1	8.2	348	312	551	1438	M-Dural tear (1), brachial plexus palsy due to arm positioning (1), L5 root paresis (1) O-L3 root pain (1), cage rupture (1)
Villavicencio[14] (2010)	76	63	24	24	4.1	5.2	NR	NR	NR	NR	3	4.2	222.5	214.9	163	366.8	M-Allograft malposition (3), screw malposition (4), CSF leak (1), infection (1), neurological deficit (5) O-Allograft malposition (2), screw malposition (2), CSF leak (7), infection (1), neurological deficit (1)
Wang J[15] (2010)	42	43	26.3	26.3	6.28	6.3	NR	NR	30.4	26.3	10.6	14.6	156	145	303	831	M-radiculopathy (2)& dural tear (1), non-union (1) O- screw malposition (1) , dural tear (2), non-union (1)
Lee[16] (2012)	72	72	24	24	4	3.9	4.2	4.2	26.7	23.7	3.2	6.8	166	181	50.6	975	O-MI (1), pneumonia (1), anaemia and wound abscess (1), asymptomatic cage migration (6) M-screw malposition (1), dural tear (1), pneumonia (1), asymptomatic cage migration (4)
Peng[17] (2009)	29	29	24	24	NR	NR	NR	NR	29	30.2	4	6.7	170	216	150	681	M-bone graft site infection (2) O-UTI (2), wound infection (1) and atelectasis (1)
Hongli[18] (2011)	41	38	24	24	NR	NR	NR	NR	NR	NR	6.4	8.7	168.7	145	322.3	525.5	M-Transient L5 nerve root palsy (1), Superficial wound infection (1), pulmonary infection (1) O-wound infection (2), pulmonary infection (2), Fat Liquefaction (1)
Dhall[19] (2008)	21	21	24	34	NR	NR	NR	NR	NR	NR	3	5.5	199	237	194	505	M-Transient L5 sensory loss (2), screw malposition (1) , cage migration (1), pseudarthrosis (1) O-dural tear (1), Radiculitis (1) screw malposition (1)
Adogwa[20] (2011)	15	15	24	24	2.9	4.7	3	4.7	21.2	17.2	3	5.5	300	210	200	295	
Wang[21] (2014)	42	39	NR	NR	5	4.5	NR	NR	22.9	22.8	NR	NR	127	168	326	835	M- Dural tear (2), Superficial wound infection (2), Non-union (1) O- Dural tear (3), Superficial wound infection (4), Non-union (1)
Our study (2016)	25	36	25.41	25.24	3.42	3.2	5.72	6.76	35.65	40.14	4.1	5.8	3.4	2.9	111	358	M-transient foot drop (1) and bowel bladder incontinence (1)

f/u=Follow up, NR=Not reported, M=MI-TLIF, O=O- TLIF, ODI= Oswestry Disability Index, VAS= Visual analog scale Figures in round brackets in complication column denotes the number of patients score, and overall patient satisfaction and total operative time were comparable in both the groups. They concluded that MI-TLIF technique may provide equivalent long term clinical outcomes compared to O-TLIF. The potential benefit of minimized tissue disruption, reduced blood loss, and length of hospitalization must be weighed against the increased rate of neural injury-related complications associated with a learning curve. Schizas *et al*.[13] in their study of 36 patients reported no difference in operative time between the two groups. MI-TLIF group had less blood loss and shorter hospital stay. No difference was noted in postoperative pain, initial analgesia consumption, VAS, or ODI between the two groups. The results from our study are very much in agreement with the aforementioned studies.

O-TLIF is associated with significant amount of blood loss intraoperatively.[22-26] The average blood loss in our series was 111 ml in MI-TLIF group as compared to 358 ml in O-TLIF group. Less wound related issues, shorter hospital stay, and less postoperative pain requiring less analgesia all adds to the decreased cost.[26] The length of hospital stay in our study in MI-TLIF group was significantly shorter than in O-TLIF group. There was significant improvement in ODI scores, VAS scores for back pain and leg pain postoperatively in both MI-TLIF and O-TLIF groups, but there was no statistically significant difference between the two groups.

Several studies have attempted to correlate various biochemical parameters as markers of tissue trauma. Various markers include CRP, Creatinine phosphokinase-MM, and interleukins.[27,28] These studies have been conducted in relation to micro-endoscopic discectomy. They have concluded that micro-endoscopic discectomy causes less local damage than micro-discectomy, in the treatment of symptomatic disc herniations. In our study, we did a preoperative Q-CRP level in all patients undergoing a TLIF procedure, whether open or by minimal access. The postoperative Q-CRP levels were determined on the 1st postoperative day. The change in the Q-CRP levels was calculated in both the groups and the unpaired *t*-test was used for analysis of the significance. There was a significant change in Q-CRP levels in between the groups. The MI-TLIF group showed a significantly smaller rise in Q-CRP levels as compared to the O-TLIF group. The authors emphasize that this is an indicator of lesser tissue damage in the MI-TLIF procedure. This is the first time that Q-CRP has been used for a comparative study in relation to implant-related minimal access procedures.

MI-TLIF has its own share of problems. It is a technically challenging procedure as the decompression and fusion are achieved through a limited available area. It requires familiarity with the use of longer and bayoneted surgical instruments through a narrow channel under magnification. As it is a recently introduced technique, it has a steep learning curve which must be surpassed before technical proficiency can be achieved. This is associated with a longer operative time. In our study, the operative time was significantly higher in MI-TLIF group than in O-TLIF group. In addition, the amount of radiation exposure is significantly higher in MI-TLIF as compared to O-TLIF, which echoes with the finding in our study. Apart from the hazards of radiation, a significant factor is the cost of implants in MI-TLIF procedures. The implants are expensive as compared to conventional screws. This remains a prohibitive factor in a large number of patients in developing countries.

This study has its limitations. First, it is a nonrandomized study as the patients were given an option to choose the procedure. A randomized study will provide more convincing, evidence-based results. The MI-TLIF group had two neurological complications which are resolved with conservative management. These complications were in the early days of using tubular retractor for MI-TLIF (steep learning curve).

Conclusion

MI-TLIF patients do as well as O-TLIF patients in terms of outcomes. Due to less tissue trauma and surgical exposure, the minimally invasive technique may reduce the amount of iatrogenic injury with less blood loss, shorter hospital stay, and fewer complications while still safely accomplishing the goals of O-TLIF. The challenges of MI-TLIF lie in the steep learning curve (longer operative time), with possible complications in early days and significant radiation exposure. Use of robotic-assisted spine surgery, two-dimensional/three-dimensional navigation, and low-dose radiation are some of the current options that help in reducing the amount of radiation exposure.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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