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Trans-Pars Interarticularis Approach for Lumbar Interbody Fusion: An Efficient, Straightforward, and Minimally Invasive Surgery for Lumbar Spondylolisthesis and Stenosis

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Abstract:
Purpose:
Lumbar interbody fusion is a commonly applied surgical treatment for spondylolisthesis. For this procedure, various minimally invasive approaches have been developed, including posterior lumbar interbody fusion, transforaminal lumbar interbody fusion (TLIF), oblique lumbar interbody fusion, and anterior lumbar interbody fusion.
Objective:
In this study, we characterized the features of a minimally invasive (MIS) trans-pars interarticularis approach for lumbar interbody fusion (TPLIF) and compared its surgical outcomes with those of MIS-TLIF.
Methods:
This study included 89 and 44 patients who had undergone MIS-TPLIF and MIS-TLIF, respectively, between September 2016 and December 2022. The following clinical outcomes were analyzed: operative time, blood loss, and hospitalization duration.
Results:
For the MIS-TPLIF and MIS-TLIF groups, the average operative time, blood loss, and hospitalization duration were, respectively 98.28 and 191.15 min, 41.97 and 101.85 mL, and 5.8 and 6.9 days.
Conclusion:
The MIS-TPLIF approach for lumbar spondylolisthesis or other degenerative diseases involves the use of the commonly available and cost-effective instrument Taylor retractor, thus enabling posterior lumbar interbody fusion to be performed with minimal invasion. This approach also confers the benefits of a short learning curve and an intuitive approach. Our results suggest that although MIS-TPLIF is noninferior to MIS-TLIF, it is easier to learn and perform than MIS-TLIF.

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Table 1 Preoperative data			
Category	MIS-TPLIF	MIS-TLIF	*p* value
Total patients	89	44	
Gender			
Male	33	20	0.17851
Female	56	24	
Mean age(range)	59.86(19-80)	58.68(34-79)	0.55674
BMI	26.65 ± 3.962	27.62 ± 5.014	0.22502
ASA	2.213 ± 0.557	2.071 ± 0.608	0.05666
DM	25	16	0.16733
Usage of anti-platelet or anti-coagulation	13	3	0.09836
Smoking	14	8	0.36140
Diagnosis			
Spondylolisthesis	86	38	
Spondylolysis	3	6	

BMI: Body mass index, ASA: American Society of Anesthesiologists, DM: Diabetes mellitus.

Table 2 Perioperative parameter		
Category	MIS-TPLIF	MIS-TLIF	*p* value
Operative times	100.29 ± 24.77	187.18 ± 44.57	<0.00001 *
Blood loss	44.05 ± 54.08	100.13 ± 78.62	<0.00001 *
Hospital days	5.59 ± 1.50	6.84 ± 3.04	0.00063
Pre-op VAS	7.62 ± 1.10	7.39 ± 1.22	
Post-op 6m VAS	2.57 ± 1.20	2.44 ± 1.09	
Follow-up period	25.51 ± 9.10	35.30 ± 26.08	

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Keywords:

posterior lumbar interbody fusion, trans-pars interarticularis lumbar interbody fusion (TPLIF), transforaminal lumbar interbody fusion (TLIF), spondylolisthesis, minimally invasive spine surgery

Abbreviations

PLF: posterolateral fusion

PLIF: posterior lumbar interbody fusion

TLIF: transforaminal lumbar interbody fusion

OLIF: oblique lumbar interbody fusion

ALIF: anterior lumbar interbody fusion

MIS: minimally invasive surgery

TPLIF: trans-pars interarticularis lumbar interbody fusion

Introduction

Posterolateral fusion (PLF) of the lumbar spine was first proposed by Albee and Hibbs in 1911. After Roy-Camille introduced transpedicular-screw fixation for lumbar posterolateral fusion in the 1970s,[1] this technique has been used to treat unstable thoracolumbar junction fractures. Moreover, it is commonly recommended for spinal fractures, spinal deformities, spinal tumors, and degenerative diseases. When transpedicular-screw fixation is combined with posterior lumbar interbody fusion (PLIF), it can provide 360° circumferential stability to

the spine.[2,3] However, the excessive retraction of the nerve roots may still present risks; specifically, it may lead to neurological deficits during the preparation of the tract for cage insertion and during the posterolateral insertion of the interbody cage or bone graft. Subsequently, Harms and Jeszenszky developed the open transforaminal lumbar interbody fusion (TLIF) method, which is an alternative method for performing lumbar interbody fusion.[2,3] TLIF requires less retraction of the thecal sac, allows for the intervertebral space to be exposed more laterally, and enables intervertebral preparation to be completed unilaterally.[2] Although open TLIF is a safe and effective method for treating degenerative lumbosacral diseases,[4] this method still requires the stripping of the paravertebral muscles, which may lead to negative postoperative outcomes,[5,6] such as postoperative pain and paraspinal muscles atrophy.[7,8] To address the possible adverse effects associated with open TLIF, Holly (2006) proposed the Wiltse posterolateral spinal approach for conducting minimally invasive (MIS) TLIF. Although this approach essentially preserves the posterior tension band and reduces injury to the paraspinous musculature,[9] it is associated with long learning curves[10] and requires the use of a cylindrical expandable retractor.[11] Herein, we propose an alternative method called trans-pars interarticularis lumbar interbody fusion (TPLIF). This method requires the minimal use of instruments (e.g., Taylor spinal retractor and rubber bands) and can be performed with the aid of a microscope. Our lumbar decompression method employs a midline unilateral approach, which involves ipsilateral laminectomy, facetectomy, and contralateral sublaminar decompression, thereby effectively achieving bilateral adequate decompression and creating space for cage insertion. Subsequently, the spine is fixated using percutaneous transpedicular screws to complete the fusion and fixation process. Because the surgical pathway used in this method is almost identical to that of microdiscectomy, which most spine surgeons are familiar with, we believe

that this procedure is a straightforward, effective, and safe procedure for treating lumbar spine degenerative disease.

Our method is particularly suitable for treating multiple-segment lesions because it allows for straightforward and continuous decompression. It is also compatible with hybrid surgery that uses the midline approach (e.g., methods that incorporate the use of an interspinous process device).

Materials and Methods

This study included 89 patients with symptomatic lumbar disease who had undergone MIS-TPLIF performed using a single polyether ether ketone (PEEK) cage (Capstone, Medtronic) and through additional percutaneous pedicle screw internal fixation (Sextant, Medtronic) between September 2016 and December 2022; these patients formed the MIS-TPLIF group. In addition, 44 patients who had undergone MIS-TLIF performed using the same single PEEK cage (Capstone, Medtronic) during the same period were included as the MIS-TLIF group.

Patients were eligible for inclusion if they had single-level spondylolisthesis: spondylolysis at the L4-5 or L5-S1 level. Patients with specific conditions (e.g., trauma, osteoporosis, and multilevel spondylolisthesis) or a history of revision spine surgery were excluded.

The MIS-TPLIF group comprised 33 men and 56 women aged 19–80 (mean, 59.86) years, whereas the MIS-TLIF group comprised 20 men and 24 women aged 34–79 years (mean, 58.68) years. The two groups were similar in terms of age, body mass index, surgical indications, and comorbidities (Table 1)

We had two different groups of attending surgeons performing the surgeries, and the groups were randomized. The patient decides on the attending physician who will perform the surgery. MIS-TPLIF is Dr. Chang , and MIS-TLIF is Dr. Hsieh.

Independent observes collected relevant data by using standardized data collection forms.

Surgical technique

The patients in both groups had undergone unilateral single cage insertion. Surgery was performed after administering general anesthesia and placing the patient in the prone position.

MIS-TPLIF

At the start of MIS-TPLIF, a midline incision (approximately 3 cm) was performed in a manner similar to that of a standard lumbar microdiscectomy. On the basis of symptom severity or imaging studies, surgery is typically conducted on the side that exhibited relatively pronounced signs of the affliction. The paraspinous muscle was carefully peeled off along the periosteum to expose the laminae and facet joints of the upper and lower segments. To ensure a clear operating field, a simple Taylor spinal retractor and rubber bands were used (Figure 1). Thereafter, the patient was repositioned to the opposite side. Next, the spinous process was aligned at a right angle to the surgical field of view (Figure 2A). This step is performed to facilitate ipsilateral laminectomy and remove the contralateral yellow ligament and sublaminar decompression to ultimately achieve bilateral decompression. After laminectomy and facetectomy (performed through trans-pars interarticularis), the hypertrophic flavum ligament was removed to expose the dura sac and exit nerve root for adequate decompression (Figure 2B). During this step, a crucial and intricate aspect involved the removal of the medial portion of the superior articular process of the lower vertebra (Figure 2C) and the maximal removal of the pars interarticularis. This step maximized the available space for cage placement without the risk of excessive nerve root retraction.

Subsequently, the intervertebral disc was removed, and the end plates of the central portion of the disc spaces were carefully decorticated for successful interbody fusion. The axial views of conventional PLIF and TPLIF are presented in (Figure 2D,E), clearly

highlighting the differences between the two approaches .

An appropriately sized cage filled with morselized bone graft material was placed obliquely into the intervertebral space. Typically, the cage is placed on the midline of the vertebral body, as close as possible to the anterior edge. This technique was named TPLIF because it differs from the conventional PLIF technique in terms of the number of cage placements and the direction of cage placement. After achieving hemostasis, the wound was sutured without the use of a drainage tube.

MIS-TLIF

For MIS-TLIF, unilateral surgery was performed using the Wiltse technique under a fluoroscope through a paramedian skin incision (3 to 4 cm lateral to the midline). Once the skin and fascia were incised, a plane developed between the multifidus and longissimus muscles, which enabled us to enlarge the path to the spine by using sequential dilators. The facet and pars were removed using a high-speed drill; thereafter, the nerve roots were identified and fully visualized before laminectomy was performed using a high-speed drill. The local bone graft that had been collected during laminectomy and facetectomy was stored in a bone trap. The interbody space was identified through fluoroscopy, and the end plates were prepared using sequential end plate cutters. An appropriately sized Medtronic PEEK cage (8–12 mm, Capstone) filled with autologous bone graft was placed into the intervertebral space, and local bone was placed anterior to the cage in the intervertebral space. Then, the cage was gently and obliquely inserted into the intervertebral space.

On postoperative day 1, the patients in the MIS-TPLIF and MIS-TLIF groups could get out of bed and walk with the help of a functional waist brace, which they continued to use for at least 1 month.

Results

Preoperative data

The MIS-TPLIF and MIS-TLIF groups comprised 89 and 44 patients, respectively. The MIS-TPLIF group comprised 33 men and 56 women aged 19–80 (mean, 59.86) years at the time of surgery, whereas the MIS-TLIF group comprised 20 men and 24 women aged 34–79 years (mean, 58.68) years at the time of surgery. The American Society of Anesthesiologists classification scores of the MIS-TPLIF and MIS-TLIF groups were 2.213 ± 0.557 and 2.071 ± 0.608, respectively. The two groups did not exhibit any significant difference in age, sex, body mass index, DM, or smoking habit (Table 1).

Perioperative outcomes

All patients included in the present study had undergone single-level fusion. For the MIS-TPLIF and MIS-TLIF groups, the average operative time, blood loss, and hospitalization duration were, respectively, 100.29 and 187.18 min, 44.05 and 100.13 mL (no patient required blood transfusion), and 5.59 and 6.84 days (Table 2). MIS-TPLIF led to more favorable perioperative outcomes than did MIS-TLIF; no significant difference was noted between the two techniques in patients visual analog scale scores before surgery or 6 months after surgery. The average follow-up period was 25.51 months for the MIS-TPLIF group and 35.30 months for the MIS-TLIF group. No major complications (e.g., revision surgery or persistent neurological deficits) were reported in either of the two groups during the follow-up period. In summary, MIS-TPLIF is noninferior to MIS-TLIF.

Case sharing

Herein, we present the case of a 74-year-old woman with low back pain and left-sided radiculopathy. An examination of the patient revealed spondylolisthesis and stenosis at the fourth and fifth levels. We performed fusion surgery with TPLIF, after which the patient's low back pain and leg pain improved considerably. Relevant photos of the operation and postoperative wound are presented in (video 1). The next patient presented with L3-4-5

lumbar stenosis and L4-5 spondylolisthesis. Adequate decompression was achieved through TPLIF for L4-5 and through continuous laminectomy for L3-4-5 (Figure 3A-E).

(This case is to share the benefits of TPLIF. The patient was not included in our study data, we only included pure L4-5 decompression with interbody fusion in this study.)

Discussion

Lumbar interbody fusion is an effective treatment for relieving pain resulting from nerve compression and an unstable spine. This method involves the neural decompression of the symptomatic side, restoration of disc height, maintenance of vertebral alignment, implementation of weight-bearing measures, and reconstruction of segmental stability. PLIF has been reported to achieve a higher rate of intervertebral segment fusion and more favorable clinical outcomes than does posterolateral bone grafting.[12] To date, there were lots of different trajectory for cage insertion such as PLIF, TLIF, OLIF and ALIF. What's more, the concept of minimally invasive surgery has also been brought into lumbar interbody surgery.

The conventional PLIF technique involves the insertion of two cages through a bilateral approach in addition to extensive total laminectomy, posterior facetectomy, and bilateral pedicle screw placement for spinal stability. However, Zhao et al.[13] reported that the use of a single diagonal cage in PLIF can lead to satisfactory clinical outcomes with minimal invasion of the posterior elements.

Our MIS-TPLIF technique is similar to a modified version of PLIF that entails performing unilateral laminectomy and facetectomy (Figure 2), instead of total laminectomy and bilateral facetectomy, on the symptomatic side. Chen et al.[14] demonstrated that a modified version of PLIF can preserve the spinous process, supraspinous and interspinous ligaments, and contralateral vertebral plate and facet joints, all of which are crucial for maintaining lumbar spine stability. Xue et al.[15] indicated that the preservation of the posterior tension-band structure can help alleviate low back pain, reduce complication rates, and accelerate

functional recovery. For our MIS-TPLIF technique, we used a single PEEK cage, which has the same specifications as those used in TLIF and has been demonstrated to have a favorable fusion rate.[16] The MIS-TPLIF destroys the facet joint on only one side and retains the spinous process in the middle; therefore, the overall procedure is more straightforward to learn, more familiar to surgeons, and less time-intensive to perform than are conventional methods.

The main difference between MIS-TLIF and MIS-TPLIF is in the approach route, which determines the type of retractor that is used and the medical expenses that are incurred. MIS-TLIF is performed using the Wiltse technique, which usually requires the use of a special tubular or rectangular retractor[17]; however, such retractors tend to be costly. By contrast, MIS-TPLIF involves a midline approach, requiring only a simple Taylor retractor that can effectively grip the outside of the facet joint; this method facilitates the creation of a well-defined surgical space, providing a clear view of the laminae and medial facet joint (Figure 2A).

When a surgeon is performing MIS-TPLIF, they can easily locate the pars interarticularis, interlaminar space, and facet joint by performing a dissection along the bony structure of the spinous process. When the Wiltse technique is applied during MIS-TLIF, the path and direction of operation can occasionally be challenging to verify because of the absence of distinct landmarks. This problem is particularly pertinent in patients with spondylolisthesis because they often have hypertrophic facet joint; specifically, hypertrophic soft tissues can confuse surgeons such that the coagulation of additional muscles is required to accurately determine positioning. Therefore, a primary distinction between MIS-TLIF and MIS-TPLIF is their different learning curves. Between the two methods, MIS-TLIF is more complex than MIS-TPLIF and requires a longer period of training and more hands-on experience to achieve proficiency than does MIS-TPLIF. By contrast, MIS-TPLIF is performed using a midline approach that is similar to that used in microdiscectomy in terms

of anatomical principles, thereby reducing the time required to achieve proficiency in this technique. These findings align with the results of our study, in which the MIS-TPLIF group exhibited less blood loss and shorter operative times than did the MIS-TLIF group.

This TPLIF is not intended to replace the most widely used TLIF today. Wiltse approach TLIF is still one of the best methods. The TPLIF we proposed can achieve the same effect through a pathway with clear bony structures in the midline.

Sometimes, Wiltse approach TLIF takes more time to find pars interarticularis, especially when the patient has a hypertrophic facet joint. In addition, TLIF decompression also takes time because the medial portion near the midline is blocked by the multifidus, contralateral decompression is difficult to achieve with TLIF.

Doubts have been raised about using the midline approach for lumbar interbody fusion. Nevertheless, the trans-pars interarticularis midline approach provides several advantages. First, it allows for the easy removal of the contralateral ligamentum flavum through the crossing of the midline.[15] Removal can be achieved even when only unilateral laminectomy is performed. By contrast, MIS-TLIF requires a large slope level adjustment to decompress both sides from one side. If the MIS-TLIF group decides to use bilateral approaches for decompression, more surgical time will be required. Second, when a patient has two-level stenosis with only one-level spondylolisthesis, using a midline approach can lead to the decompression of the adjacent segment without destroying the facet joint. This is achieved by completing unilateral laminectomy at L3-4-5 and only TPLIF at L4-5, similar to the method used in the second case discussed in the present study. Finally, the midline approach may also accommodate the topping-off technique, which may help alleviate adjacent segment disease.[18]

The present study has some limitations. First, because it is a retrospective clinical study, prospective studies should be conducted to produce more relevant results. Second, our patients were all ethnic Chinese individuals, who may differ from other ethnic populations in terms of weight and height. Finally, the length of hospitalization stay in our MIS-TLIF group

was longer than in other published study groups. Since both groups have their own learning curves, we collect data from the beginning. Our data cannot fully represent these two groups of surgeries, but it can be found that TLIF does require a learning curve.

Conclusion

Our results indicated that the proposed MIS-TPLIF can achieve lumbar surgery outcomes comparable to those of MIS-TILF, all while avoiding the need for complex retractors and a highly intuitive operational approach. Additionally, because MIS-TPLIF uses a simple surgical pathway, it can reduce the length of the learning curve. Furthermore, the midline approach allows for continuous decompression and the incorporation of other hybrid surgical methods, such as the topping-off technique. Therefore, this surgical approach should be further explored and promoted.

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Figure 1:

(A) Midline incision wound (approximately 3 cm) and Taylor retractor

(B) Connection formed using rubber bands

(C) Bladder of the Taylor retractor measured approximately 2 cm in width

Figure 2: Axial views of the surgical procedures.

(A) Retractor bladder is hooked to lateral site of facet joint (indicated using a red asterisk)

(B) Results after laminectomy and medial facetectomy

(C) Maximal removal of the pars interarticular and the medial portion of the superior articular process of the lower vertebra (indicated using a black arrow)

(D) Axial view of conventional PLIF and (E) TPLIF: Differences between the two approaches can be clearly observed.

Figure 3:

(A) T2-weighted MRI sagittal view of lumbar spine reveals severe L3-4-5 stenosis with L4-5 spondylolisthesis

(B) Lumbar spine X-ray (lateral view) indicates L4-5 spondylolisthesis

(C) Operative image obtained using a microscope indicates adequate decompression

at L3-4-5 with L4-5 cage insertion (indicated using a white arrow) through TPLIF and preservation of the L3-4 facet joint (indicated using a white asterisk)

(D) Postoperative lumbar spine X-ray

(E) Image of a patient's surgical wound