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## SPECIALTY SECTION

This article was submitted to Orthopedic Surgery, a section of the journal Frontiers in Surgery

RECEIVED 10 September 2022

ACCEPTED 03 October 2022

PUBLISHED 28 October 2022

## CITATION

Pang D, Yang J, Hai Y, Fan Z, Gao H and Yin P (2022) Changes in paraspinal muscles and facet joints after percutaneous endoscopic transforaminal lumbar interbody fusion for the treatment of lumbar spinal stenosis: A 3-year follow-up.  
Front. Surg. 9:1041105.  
doi: 10.3389/fsurg.2022.1041105

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# Changes in paraspinal muscles and facet joints after percutaneous endoscopic transforaminal lumbar interbody fusion for the treatment of lumbar spinal stenosis: A 3-year follow-up

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**Objectives:** This study investigates the changes in the paraspinal muscles of lumbar spinal stenosis patients after percutaneous endoscopic transforaminal lumbar interbody fusion (PE-TLIF).

**Methods:** Thirty-three patients from Beijing Chaoyang Hospital who had L4/5 segment lumbar spinal stenosis between January, 2017 and January, 2019 were included in this study. Patient-reported outcomes including the visual analog scale scores for back pain and leg pain (VAS-BP and VAS-LP, respectively) and the Oswestry disability index (ODI) scores at pre-operation and 1-week, 3-month, 12-month, and (at least) 3-year follow-up (the final follow-up) were evaluated. Computed tomography (CT) was performed at the 12-month follow-up, 24-month follow-up, and the final follow-up after surgery. Multifidus (MF) muscle functional cross-sectional area (FCSA) and fat infiltration (FI) were evaluated, and the degree of adjacent facet joint degeneration was evaluated using Pathria scores.

**Results:** All patients underwent at least a 3-year follow-up period. The VAS-BP, VAS-LP, and ODI were significantly lower at 1-week, 3-month, 12-month, and 3-year follow-up than at pre-operation ( $P < 0.05$ ). At the 3-year follow-up, no differences were found in FCSA and FI for any patient's MF muscle at the lower third of the vertebral body (L3) above the operation level ( $P > 0.05$ ), and there was no statistical difference in the central plane of the L3/4 and L5/S1 vertebral facet joints at pre-operation, 12-month, 24-month, and 3-month follow-up ( $P > 0.05$ ).

**Conclusions:** PE-TLIF can provide satisfactory clinical outcomes for patients with lumbar spinal stenosis. Furthermore, the technique may also reduce the injury on the paravertebral muscles, especially the MF muscle, as well as on adjacent facet joints.

## Abbreviation

PE-TLIF, percutaneous endoscopic transforaminal lumbar interbody fusion; VAS-LBP, visual analogue scale on lumbar pain; VAS-LP, visual analogue scale on leg pain; ODI, oswestry disability index; CT, computed tomography; MF, multifidus; FCSA, functional cross-sectional area; FI, fat infiltration; LSS, lumbar spinal stenosis; SAP, superior articular process; ROI, regions of interest; ASD, adjacent segment degeneration; USFJ, upper segment facet joints; LSFJ, lower segment facet joints.

## KEYWORDS

transforaminal lumbar interbody fusion, endoscopy, paraspinal muscles atrophy, functional cross-sectional area, spondylolisthesis

## Background

Since the 1990s, traditional open surgery has been widely used to treat Lumbar spinal stenosis (LSS) (1), a condition that affects 47.2% of people worldwide (2). However, paraspinal muscle atrophy, especially the multifidus (MF), and degeneration of the facet joints are frequently observed as a complication of the procedure during follow-up, due to traditional open surgery's lack of protection of the paraspinal muscles and facet joints (3). Paraspinal muscles such as the MF and facet joints play an important role in maintaining the stability of lumbar vertebrae (4), and injuries to these structures can lead to chronic back pain (4–8). Therefore, finding effective treatments for stenosis that reduce the chance of injuries to these structures is of paramount importance.

Clinical trials have shown that minimally invasive interbody fusions are effective at reducing muscle injuries (9). In 2002, Foley and Lefkowitz introduced minimally invasive fusion technology for the first time, and the technique exhibited clear advantages in reduced trauma, wound size, and hospitalization time (10). However, the MIS-TLIF technique uses screws in a similar way to conventional open surgery, and this method can too often lead to the injury of the medial branch of the dorsal ramus, increasing the possibility of MF atrophy. As a result, surgeons have begun to attempt percutaneous screw fixation in lumbar surgery.

By applying a minimally invasive approach and developing spinal endoscopic techniques, we have developed some novel techniques for performing percutaneous endoscopic transforaminal lumbar interbody fusion. Furthermore, we have developed a guided superior articular process (SAP) resection device that can excise the articular processes precisely and reduce iatrogenic injury (11, 12). Thus, the objective of this study is to evaluate the changes in paraspinal muscles and facet joint degeneration after PE-TLIF and a follow-up period of at least 3 years in order to assess the clinical value of PE-TLIF in the treatment of lumbar spinal stenosis.

## Materials and methods

### Patient population

This retrospective study was performed at Beijing Chaoyang Hospital and included 33 patients who were

diagnosed with lumbar spinal stenosis according to their symptoms, clinical signs, and medical images and subsequently underwent PE-TLIF between January, 2017 and January, 2019. Inclusion criteria were as follows: (1) degenerative instability on the L4/5 level and LSS; (2) receipt of PE-TLIF treatment; and (3) a follow-up period of at least 3 years. Exclusion criteria were: (1) receipt of previous spinal surgery and (2) suffering from infection, trauma, or spondylolisthesis. This study was approved by the Ethics Committee of Beijing Chaoyang Hospital.

### Surgical technique

The specific procedure is detailed in our previous research (12).

### Data collection

In order to examine the changes in paraspinal muscles and facet joints degeneration after PE-TLIF, we obtained MF functional cross-sectional area (FCSA) (13) and fat infiltration (FI) measurements from axial CT axial images at the lower third of the vertebral body (L3) above the operation level (L4/5) before surgery and 12 months, 24 months, and 3 years (or final follow-up if longer than 3 years) after surgery to avoid any artifacts produced by the screws themselves. In addition, to prevent interference from the nearby fat, bony structures, and other soft tissues, we measured the MF FCSA and FI using purpose-built software from GE Healthcare (United States) according to the manufacturer's selection method for muscle regions of interest (ROI) (Figure 1) (14). The FI rate was graded according to the degree to which MF muscle was replaced by adipose tissue: "0" for estimates of normal or no obvious FI within the muscle, "1" for <10% FI, "2" for 10%–50% FI, and "3" for >50% FI. We obtained the total segmental value for FI by summing the left and right values.

The central planes of the L3/4 and L5/S1 vertebral facet joints were qualitatively evaluated using the Pathria grading system in axial scanning CT imaging (15), and once again we obtained the total segmental scores for each level by summing the left and right Pathria scores for that level. Clinical effects, including the visual analog scale scores (VAS) for back pain and leg pain (VAS-LBP and VAS-LP, respectively) and the Oswestry disability index (ODI), were evaluated at



FIGURE 1  
Measurement of the MF FCSA in an atrophied muscle.

pre-operation, and at the 1-week, 3-month, 12-month and final follow-ups.

## Statistical analyses

All data were analyzed using SPSS 21.0 software. We used the Friedman rank-sum test for nominal data and repeated measures analysis of variance for continuous data in order to test MF functional cross-sectional area. For each test, we considered a  $P < 0.05$  to indicate a statistically significant result.

## Results

### Patient demographics

A total of 33 patients were included in this study. There were 13 male and 20 female patients, and the mean age of patients was  $61.0 \pm 8.9$  years (range, 45–82 years). All patients received a follow-up period of at least 3 years, and the average follow-up period was  $41.7 \pm 3.5$  months. The mean body mass index (BMI) was  $23.5 \pm 3.9$  kg/m<sup>2</sup>, and the average operation time was  $208.7 \pm 28.5$  min. Mean blood loss from the operation was  $138.2 \pm 83.5$  ml, and the average postoperative rest time for each patient was  $17.9 \pm 2.2$  days (see [Table 1](#) and [Figure 2](#)).

### Postoperative outcomes

The ODI score decreased from 62% (56,65) at pre-operation to 24% (20,30) at 3-month follow-up, 12% (9.5,16.5) at

TABLE 1 Characteristics of patients.

Characteristics	<i>n</i>
Gender	
Male	13
Female	20
Age (years)	$59.0 \pm 8.9$
BMI (kg/m <sup>2</sup> )	$23.5 \pm 3.9$
Average incision length (cm)	$8.7 \pm 2.5$
Operation time (min)	$208.7 \pm 28.5$
Intraoperative blood loss (ml)	$138.2 \pm 83.5$
Postoperative rest time (days)	$17.9 \pm 2.2$
Follow-up period (months)	$41.7 \pm 3.5$

12-month follow-up, and 8% (4,15.5) at final follow-up. The VAS-LBP decreased from 7 (7,8) at pre-operation to 3 (2,3) at 1-week follow-up, 1 (1,2) at 3-month follow-up, 1 (0,2) at 12-month follow-up, and 1 (0,1) at final follow-up. Similarly, the VAS-LP decreased from 6 (5,7) at pre-operation to 2 (1,3) at 1-week follow-up, 1 (1,2) at 3-month follow-up, 1 (0,2) at 12-month follow-up, and 0 (0,1) at final follow-up ([Table 2](#)). Compared to the preoperative FCSA of the MF, the postoperative FCSA of the MF for any follow-up stage was not statistically different ( $P > 0.05$ ). Furthermore, the median preoperative MF muscle FI was 2, the median 12-month postoperative MF muscle FI was 3, the median 24-month postoperative MF muscle FI was 3, and the median final follow-up MF muscle FI was 3. None of these differences were statistically different from 0 ( $P > 0.05$ ) ([Table 3](#)).

The postoperative upper segment facet joint scores at 12 months and 24 months were also not statistically different compared to pre-operation ( $P > 0.05$ ), and compared to the preoperative lower segment facet joint score, the postoperative lower segment facet joint scores at 12 months and 24 months were not statistically different either ( $P > 0.05$ ) ([Table 4](#)). Finally, intervertebral fusion was completed in all patients after 12 months, according to the Bridwell criteria (16), Grade I in 13 cases, Grade II in 16 cases, and Grade III in 4 cases.

## Discussion

The focus of our study was on the effects of PE-TLIF for single segment LSS on the MF and facet joints. During the follow-up period for this procedure, we found that use of the PE-TLIF technique provided adequate protection for the MF and adjacent facet joints. Additionally, the PE-TLIF surgery significantly improved the ODI and VAS for all patients, indicating that the clinical symptoms of the patients had been effectively relieved.

The MF is the most important stabilizing muscle of the spine and is located in the deepest part of the spinal column.



**FIGURE 2**  
A 69-year-old female. Preoperative VAS-LBP: 6; Preoperative VAS-LP: 8; Preoperative ODI: 70%. (A, B) A L4/5 spinal stenosis identified in the preoperative MRI. (C, D) A good implantation position shown by x-rays taken a week after the operation. (E) At 12 months after the surgery, a CT scan image revealed a standard lumbar fusion. (F, G) The final x-ray images indicated that the implantation occurred in a good position.

**TABLE 2** Comparison of indicators related to efficacy evaluation before and after PE-TLIF.

n = 33	VAS-LBP	VAS-LP	ODI (%)
Pre-operation	7 (7,8)	6 (5,7)	62 (56,65)
Post-1 w	3 (2,3)*	2 (1,3)*	-
Post-3 m	1 (1,2)*	1 (1,2)*	24 (20,30)*
Post-12 m	1 (0,2)*	1 (0,1)*	12 (9.5,16.5)*
Final follow-up	1 (0,1)*	0 (0,1)*	8 (4,15.5)*

Note. \*Compared to pre-operation,  $P < 0.05$ .

**TABLE 3** Preoperative and postoperative paraspinal muscle parameters.

	Preoperative	Post-12 m	Post-24 m	Final follow-up
FCSA of the MF	(568.09 ± 49.82)	(557.12 ± 51.31)*	(558.55 ± 53.37)*	(537.51 ± 55.11)*
FI of the MF	2 (2,3)	3 (2,3)*	3 (2,3)*	3 (3,3)*

Note. \*Compared to pre-operation,  $P > 0.05$ .

During spinal movement, two-thirds of stabilizing stiffness is provided by the MF. In lumbar surgery, it is necessary to protect paraspinal muscles.

The traditional posterior surgery has great trauma, which causes direct damage to the paraspinal muscles in the process of muscle stripping. In addition, Tsutsumimoto et al. (17) believe that the continuous stretch of the paraspinal muscle caused by the retractor increases the pressure of the paraspinal muscle and affects the blood perfusion of the capillaries of the paraspinal muscle in traditional open surgery. This ischemic change of paraspinal muscles will eventually lead to functional changes of paraspinal muscles and muscle atrophy. The PE-TLIF technology we have developed has the advantages of smaller incision size and reduced paravertebral muscle dissection, which reduces the direct injury to the paraspinal

**TABLE 4** Preoperative and postoperative scores of the segment facet joints.

	Preoperative	Post-12 m	Post-24 m	Final follow-up
USFJ	5 (4,6)	5 (4,6)*	5 (4,5)*	5 (4,6)*
LSFJ	5 (4,6)	5 (4,5)*	5 (4,6)*	5 (4,7)*

Note. \*Compared to pre-operation,  $P > 0.05$ .

muscle and the influence on the blood circulation of the paraspinal muscle. Moreover, through the analysis of the morphological changes of the multifidus in MRI after the injury of the the medial branch of the dorsal ramus after operation, it is considered that the muscle atrophy after lumbar surgery is related to the iatrogenic injury of the medial branch of the dorsal ramus (18–21). According to anatomy, it was found that the MF was innervated only by the medial branch. Traditional posterior open surgery increases the probability of injury of this nerve and the possibility of denervated atrophy of MF. In order to reduce the risk of the nerve injury, different from the traditional posterior lumbar interbody fusion and minimally invasive fusion technique, we chose to use the percutaneous method. According to Regev et al. (22), percutaneous screw placement can reduce the incidence of indirect injury to the medial branch nerve from 84% to 20%.

In order to evaluate the changes of MF after PE-TLIF, we compared the FCSA and FI rate of MF at pre-operation, 12-month follow-up, 24-month follow-up, and at final follow-up. Some studies have shown that the decrease of muscle volume and the increase of fat deposition are the main characteristics of paraspinal muscle degeneration (23, 24). Kang et al. confirmed by MRI that the degree of paraspinal muscle degeneration can be reflected by the decrease of paraspinal muscle FCSA and FI (25). In our study, we used FCSA and FI to assess the degree of MF atrophy by CT axial images. FCSA assessed by CT has high intraclass correlation with MRI according to Hu et al. (26). Due to interference from the metal artifacts, however, the MF had to

be measured in selected axial images (27). The results showed that the FI rate of the MF muscles did not change significantly at 12 months, 24 months, or the final follow-up after surgery. Some studies have reported that the function of the MF can be affected after operation (28, 29), but in this study we found no difference in the FCSA of the MF at 12 months, 24 months, or the final follow-up after PE-TLIF.

In order to help us perform this novel procedure, we have invented a cannula with a hook-shaped front. This tool can effectively remove part of the articular process and protect local tissue. By reducing intraoperative trauma, the impact on adjacent segments can be reduced. The adjacent segmental facet joint scores of the 33 patients in this study were not statistically different from their preoperative scores. In our study, all the patients achieved satisfactory clinical results, and their postoperative lumbar pain was significantly reduced. No obvious degeneration of adjacent facet joint was found at least 3 years after operation, but for long-term results, it is necessary to analyze the effects of degeneration and operation on adjacent segments, so as to evaluate the results of PE-TLIF. However, this study has several limitations. First, the study was retrospective and single-center in design, and it was neither randomized nor controlled. Second, the sample size was small. Finally, we couldn't estimate the effects of our procedure on the muscles at the fusion level due to the interference from the metal artifacts.

## Conclusion

Our novel PE-TLIF can provide satisfactory clinical outcomes for patients with lumbar spinal stenosis. By the avoiding direct injury to the paraspinal muscle and the traction of the paraspinal muscle, and reducing the injury probability of the medial dorsal branch, Our PE-TLIF can adequately protect the MF and reduce the degeneration of the adjacent facet joints.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author/s.

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## Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Beijing Chaoyang Hospital. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

## Author contributions

PY, JY, YH, and DP contributed to the design and operation of the study. HG and ZF were in charge of data collection. DP and HG collected follow-up information specifically. DP contributed to the graphics and statistical analysis. All authors contributed to the article and approved the submitted version.

## Acknowledgments

The authors thank AiMi Academic Services (www.aimieditor.com) for English language editing and review services.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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