Objective: The aim of this study was to investigate whether treatment with minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF) causes patients suffering from lumbar spinal stenosis (LSS) to experience less anxiety and better clinical efficacy than open transforaminal lumbar interbody fusion (TLIF).

Methods: In this retrospective cohort study, we analyzed 86 patients, including 46 male patients and 41 female patients, who suffered from single-segmental lumbar spinal stenosis in our department between January 2016 and January 2018. They were divided into two groups: a control group (n = 46), for patients who underwent open TLIF surgery, and an experimental group (n = 40), for patients who underwent Mis-TLIF surgery. All patients were evaluated based on operation time, intraoperative blood loss, hospital stay, visual analogue scale (VAS), Oswestry disability index (ODI), hospital anxiety depression scale (HADS), fusion rate, and complications (screw misplacement and loosening, cerebrospinal fluid leakage, infection, and delayed wound healing). Patient characteristics were compared within and between groups.

Results: The average incision length was 3.64 ± 0.476 cm in the experimental group, which was smaller than that (8.11 ± 2.406 cm) in the control group (P < 0.05). The operation time of the experimental group was a little longer than that of the control group. The intraoperative blood loss and hospital stay in the experimental group were less than those in the control group.

The mean preoperative low back pain VAS score was 7.525 ± 1.432 in the experimental group and 7.087 ± 1.799 in the control group (P > 0.05). The low back pain VAS scores on postoperative day 3 and at 3, 6, and 12 months postoperatively were 5.000 ± 0.987, 4.075 ± 0.997, 2.150 ± 0.834, and 1.450 ± 0.639 in the experimental group, respectively; these scores were lower than those in the control group (6.870 ± 1.572, P < 0.05; 4.630 ± 1.103, P < 0.05; 2.630 ± 1.103, P < 0.05; and 2.326 ± 1.034, P < 0.05, respectively). There was no obvious difference in the leg pain VAS scores between the two groups at all follow-up points.

The mean preoperative ODI score was 58.700 ± 19.703% in the experimental group and 61.696 ± 17.583% in the control group (P > 0.05). The ODI scores at postoperative months 3, 6, and 12 were 25.225 ± 5.554%, 20.150 ± 7.698%, and 16.125 ± 9.565% in the experimental group; these scores were lower than those in the control group (49.130 ± 14.805%, 30.444 ± 15.148%, 20.150 ± 7.698%, and 16.125 ± 9.565%, P < 0.05, respectively).

Address for correspondence Desheng Wu, PhD, Department of Spine Surgery, Shanghai East Hospital, Tongji University School of Medicine, 150 Jimo Road, Shanghai, China 200120 Tel: 86-02138804518-12025; Fax: +86-38804518(2025); Email: wdsphine2012@163.com; Weidong Zhao, MD, Department of Spine Surgery, Shanghai East Hospital, Tongji University School of Medicine, 150 Jimo Road, Shanghai, China 200120 Tel: 86-13801649394; Fax: +86-38804518(2025); Email: spinetan@163.com

Disclosure: All the authors declare that they have no conflict of interest.

These authors have contributed equally to this work.

Received 28 June 2020; accepted 17 February 2021
The mean preoperative HADS score was 14.475 ± 3.113 in the experimental group and 13.391 ± 2.824 in the control group (P > 0.05). However, the mean HADS scores on postoperative day 3 in the experimental group was 8.500 ± 2.000, decreasing obviously compared to the preoperative scores (P < 0.05). The mean postoperative HADS score on postoperative day 3 in the control group was 12.734 ± 1.949, which had not decreased significantly compared to the preoperative score (P > 0.05). The HADS scores in the experimental group was lower than that in the control group on postoperative day 3 (P < 0.05).

In the correlation analysis, the incision length was correlated to the HADS scores on postoperative day 3 (r = 0.527, P < 0.05). The HADS scores on postoperative day 3 were positively correlated with the low back pain VAS scores on the same day (r = 0.388, P < 0.05). The HADS scores on postoperative day 3 were positively correlated with the ODI scores at 3-month (r = 0.460, P < 0.05), 6-month (r = 0.429, P < 0.05), and 12-month follow up (r = 0.349, P < 0.05).

Fusion rates were not significantly different between the two groups. There was no screw misplacement and loosening, infection, or delayed wound healing in either group. The cerebrospinal fluid leakage rate in the control group was higher than that in the experimental group.

**Conclusion:** Patients undergoing Mis-TLIF experience less anxiety and have better outcomes than those who undergo open TLIF. The lower level of anxiety experienced by patients undergoing Mis-TLIF is positively correlated with postoperative VAS and ODI scores.

**Key words:** Anxiety; Lumbar stenosis; Minimally invasive surgery; Spinal fusion; VAS

**Introduction**

Lumbar spinal stenosis (LSS) is a common type of degenerative lumbar disease, especially in the elderly. The prevalence of LSS is estimated to be 9% in the general population and is as high as 47% in people over 60 years of age. Patients with LSS experience pain in the buttocks or lower extremities, with or without back pain. For patients in whom conservative treatment is ineffective, open transfatorial lumbar interbody fusion (TLIF) and minimally invasive transforminal lumbar interbody fusion (Mis-TLIF) are treatment options.

Introduced by Harms in 1982, open TLIF has become a popular and established technology. With the development of minimally invasive spine technology and instruments, Mis-TLIF has gained popularity since being introduced by Foley and Lefkowitz in the early 2000s. Both operations are widely used in clinical practice.

The purpose of treatment for LSS is to provide pain control and improve function and mobility and, thus, enhance the quality of life. Both Mis-TLIF and open TLIF can significantly improve the symptoms of patients. Advantages of the TLIF approach include relatively easier access to the posterior structures, including the lamina, ligamentum flavum, and facet joints. However, Mis-TLIF has demonstrated that it results in less intraoperative blood loss, shorter hospital stay and recovery time, fewer complications, and less need for postoperative narcotic use, with similar clinical outcomes and fusion rates compared with open TLIF.

Mis-TLIF remains one of the most popular surgical procedures because of surgeons’ familiarity with the posterior approach anatomy. Good surgical outcomes depend on both surgeons’ skill and patients’ good mental health. Previous studies have indicated that emotional status is associated with the quality of life of patients with lumbar spinal stenos

**Materials and Methods**

**Inclusion Criteria and Exclusion Criteria**

The inclusion criteria were: (i) patients had been diagnosed with single-level lumbar spinal stenosis; (ii) patients had clinical signs of neurogenic claudication or severe low back pain and unilateral leg pain; (iii) there was radiographic evidence of dural sac or nerve root compression due to degenerative changes; (iv) patients were refractory to conservative treatment; (v) patients did not have congenital spinal diseases, previous surgical history, or chronic anxiety disorders; (vi) patients underwent Mis-TLIF or open TLIF; and (vii) this study was a retrospective cohort study.

The exclusion criteria were: (i) previous spinal fusion; (ii) mental impairment; (iii) systemic or neuromuscular diseases; and (iv) any subject who had previously undergone cognitive-behavioral therapy.

**Patients**

For this retrospective cohort study, we initially enrolled 86 patients with LSS who underwent single-segmental surgeries from January 2016 to January 2018. According to the kind of surgery, patients were divided into two groups: a control group (n = 46), for patients who underwent open TLIF surgery, and an and experimental group (n = 40), for patients who underwent Mis-TLIF surgery.
patients who underwent Mis-TLIF surgery. We accomplished Mis-TLIF with a mini-open incision.

**Minimally Invasive Transforaminal Lumbar Interbody Fusion Surgical Procedure**

After general anesthesia, the patients were placed in the prone position. The incision length was approximately 3.0 cm (Fig. 1A). Instead of using tubular retractors, we used a single lamina retractor for the whole surgical procedure. Using the single lamina retractor, we elevated and dissected the paravertebral muscles. We then removed the corresponding articular process and part of the lamina with an osteotome. After clearing the intervertebral disc, we implanted decompressed bone particles and inserted a single suitably-sized interbody fusion cage (Fig. 2A–D).
We then inserted appropriate pedicle screws and rods (Fig. 3A,B and Fig. 4A,B). Finally, we confirmed using C-arm fluoroscopy that the internal fixation and cage were in good positions (Fig. 4C,D). The final incision for the Mis-TLIF was approximately 3.0 cm (Fig. 5A).

It truly was difficult to accomplish the surgery with the tiny incision. To ensure our surgeries were completed successfully, we performed a decompression before inserting the pedicle screws, which allowed enough space for surgeons to operate. The loupe also played an important role in ensuring sufficient views. After repeated practice, we finally mastered the technique.

**Open Transforaminal Lumbar Interbody Fusion Surgical Procedure**

After general anesthesia, the patients were placed in the prone position. An approximately 8.0 cm longitudinal incision was made (Fig. 1B), and the paravertebral muscles were elevated and dissected. Under the exposure by two re retractors, bilateral pedicle screws were inserted (Fig. 2E–H). Then, laminotomy and unilateral facet resection were performed. Disc tissues were cleared and endplates were prepared using conventional methods. We then implanted decompressed bone particles and inserted a single suitably-sized interbody fusion cage (Fig. 3C,D). Finally, we inserted bilateral rods to connect the pedicle screws and made sure, using fluoroscopy, that the internal fixation and cage were in good positions (Fig. 4E–G). The final incision for the open TLIF was approximately 8.0 cm (Fig. 5B).

**Assessment Index**

The clinical outcomes were based on the size of the incision, operation time, intraoperative blood loss, visual analogue...
scale (VAS), the Oswestry disability index (ODI), hospital stay, fusion rate, and complications (screw misplacement and loosening, cerebrospinal fluid leakage, infection, and delayed wound healing). The psychological outcomes were based on the hospital anxiety and depression scale (HADS).
Visual Analogue Scale
The VAS score system was used to assess low back pain and leg pain before surgery, on day 3 postoperatively, and at 3, 6 and 12 months after surgery. Subjects were asked to choose the scores that best matched their pain, from 0 (no pain) to 10 (unbearable pain). Clinical improvement was defined as preoperative and postoperative changes in VAS.

Oswestry Disability Index
The ODI was used to assess the daily activities of people with disabilities before surgery and at 3, 6, and 12 months after surgery. In the present study, nine of the ODI items were included, which assess pain intensity, personal care, weight lifting, walking, sitting, standing, sleep, social life, and travel, with the exception of sexual activity. There are six levels of dysfunction, and subjects were asked to choose the degree closest to their experience. Clinical improvement was defined as preoperative and postoperative changes in ODI, and the correlations between these values were analyzed.

![Fig. 6 Incision lengths were positively correlated with the hospital anxiety depression scale (HADS) scores on postoperative day 3.](image)

**TABLE 1 Comparison between Mis-TLIF and open TLIF (mean ± standard deviation)**

| Parameters                  | Mis-TLIF        | Open TLIF       | P-value |
|-----------------------------|-----------------|-----------------|---------|
| Age (years)                 | 59.1 ± 12.475   | 55.6 ± 9.853    | 0.115   |
| Gender                      |                 |                 |         |
| Male                        | 19 (47.5%)      | 26 (56.5%)      | 0.286   |
| Female                      | 21 (52.5%)      | 20 (43.5%)      |         |
| Operated level              |                 |                 |         |
| L4–5                        | 23 (57.5%)      | 27 (58.7%)      | 0.911   |
| L5–S1                       | 17 (42.5%)      | 19 (41.3%)      |         |
| Operation time (min)        | 129.00 ± 30.89  | 103.74 ± 36.19  | 0.001*  |
| Blood loss (mL)             | 120.38 ± 43.57  | 230.33 ± 74.48  | 0.000*  |
| Hospital stay (days)        | 4.00 ± 1.50     | 7.74 ± 2.70     | 0.000*  |
| Incision length (cm)        | 3.64 ± 0.476    | 8.11 ± 2.406    | 0.000*  |
| Low back pain VAS           |                 |                 |         |
| Preoperation                | 7.525 ± 1.432   | 7.087 ± 1.799   | 0.220   |
| 3 days postoperation        | 5.000 ± 0.987   | 6.870 ± 1.572   | 0.000*  |
| 3 months postoperation      | 4.075 ± 0.997   | 4.630 ± 1.103   | 0.017*  |
| 6 months postoperation      | 2.150 ± 0.834   | 2.630 ± 1.103   | 0.027*  |
| 12 months postoperation     | 1.450 ± 0.639   | 2.326 ± 1.034   | 0.000*  |
| Leg pain VAS                |                 |                 |         |
| Preoperation                | 8.150 ± 1.145   | 8.000 ± 1.366   | 0.586   |
| 3 days postoperation        | 1.900 ± 0.632   | 1.848 ± 0.729   | 0.726   |
| 3 months postoperation      | 1.802 ± 0.112   | 1.817 ± 0.9733  | 0.504   |
| 6 months postoperation      | 1.475 ± 0.506   | 1.500 ± 0.506   | 0.820   |
| 12 months postoperation     | 1.325 ± 0.474   | 1.304 ± 0.465   | 0.839   |
| ODI                         |                 |                 |         |
| Preoperation                | 58.700 ± 19.703 | 61.696 ± 17.583 | 0.457   |
| 3 months postoperation      | 25.225 ± 5.554  | 49.130 ± 14.805 | 0.000*  |
| 6 months postoperation      | 20.150 ± 7.698  | 34.044 ± 15.148 | 0.000*  |
| 12 months postoperation     | 16.125 ± 9.565  | 29.282 ± 13.567 | 0.000*  |

* P-value < 0.05; Mis-TLIF, minimally invasive transforminal lumbar interbody fusion; ODI, Oswestry disability index; open TLIF, open transforminal lumbar interbody fusion; VAS, visual analogue scale.
**Hospital Anxiety Depression Scale**

The HADS is an indicator of perioperative anxiety and depression. The HADS is a patient-oriented survey that assesses anxiety and depression on a 0–3-point scale using seven items for anxiety and seven items for depression. The total scores for anxiety and depression are summed and interpreted as follows: 0–7 points, asymptomatic; 8–10 points, suspicious; and 11–21 points, definitely present. Both suspicious and symptomatic patients are considered positive for anxiety and depression.

**Fusion Rate**

Postoperative CT scans were obtained for all patients in the study to assess fusion status at 12 months postoperatively. Fusion was defined as evidence of bony bridges from endplate to endplate within the cage as well as bony bridges lateral to the cage.

**Subgroup Analyses**

In the Mis-TLIF group, subgroup analyses were undertaken for different genders. The comparative indexes included the operation time, intraoperative blood loss, hospital stay, low back pain VAS score, leg pain VAS score, ODI score, and HADS score.
Statistical Analysis
Patients’ characteristics were summarized using means and standard deviations (SD) for continuous variables. These values were compared within and between groups. Statistical analyses, including the independent sample \( t \)-test, the \( \chi^2 \)-test, the paired sample \( t \)-test, and Pearson correlation analysis, were performed using IBM SPSS version 20 (IBM, Armonk, NY, USA). Statistical significance was accepted at \( P \)-value <0.05.

Results

Demographic and Clinical Characteristics
All patients were operated on by the same operating group in our department from January 2016 to January 2018. All patients were followed up for 12 months after surgery. In the control group, 46 patients were treated with open TLIF, including 26 men and 20 women, aged 55.6 ± 9.853 years; there were 27 patients with L4–5 lumbar stenosis and 19 patients with L5–S1 lumbar stenosis. In the experimental group, 40 patients underwent Mis-TLIF surgery, including 19 men and 21 women, aged 59.1 ± 12.475 years; there were 23 patients with L4–5 lumbar stenosis and 17 patients with L5–S1 lumbar stenosis. There was no meaningful difference in the gender, age, and operated level between the two groups (\( P > 0.05 \) (Table 1)).

General Results
The operation time in the experimental group was 129.00 ± 30.89 (min), which was longer than that in the control group (103.74 ± 36.19, \( P = 0.001 \)). However, the intraoperative blood loss was 120.38 ± 43.57 (mL) in the experimental group, which was less than that in the control group (230.33 ± 74.48, \( P = 0.000 \)). The hospital stay after surgery in the experimental group was 4.00 ± 1.50 (days), which was shorter than that in the control group (7.74 ± 2.70, \( P = 0.000 \)) (Table 1).

Incision Length
The average incision length was 3.64 ± 0.476 cm in the experimental group, which was smaller than that (8.11 ± 2.406 cm) in the control group (\( P = 0.000 \)) (Table 1). In the correlation analysis, the length of the incision was positively correlated with the postoperative HADS score on postoperative day 3 (\( r = 0.527, P = 0.000 \)) (Table 3 and Fig. 6).

Visual Analogue Scale
Before surgery, the mean low back pain VAS scores were 7.525 ± 1.432 in the experimental group and 7.087 ± 1.799 in the control group (\( P = 0.220 \)). However, there was a noticeable difference between these two groups at all follow-up points. The low back pain VAS scores on day 3 postsurgery and at 3, 6, and 12 months after surgery were 5.000 ± 0.987, 4.075 ± 0.997, 2.150 ± 0.834, and 1.450 ± 0.639, respectively, in the experimental group; these scores were lower than those in the control group (6.870 ± 1.572, \( P = 0.000 \); 4.630 ± 1.103, \( P = 0.017 \); 2.630 ± 1.103, \( P = 0.027 \); and 2.326 ± 1.034, \( P = 0.000 \), respectively).

The mean preoperative leg pain VAS score was 8.150 ± 1.145 in the experimental group and 8.000 ± 1.366 in the control group (\( P = 0.586 \)). There was no significant difference between the two groups. The leg pain VAS scores on postoperative day 3 and at 3, 6, and 12 months postoperatively were 1.900 ± 0.632, 1.802 ± 0.112, 1.475 ± 0.506, and 1.325 ± 0.474, respectively, in the experimental group; these scores were lower than those in the control group (1.848 ± 0.532, \( P = 0.000 \)).

The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative Oswestry disability index (ODI) scores at 6-month follow up.

Fig. 9 The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative Oswestry disability index (ODI) scores at 6-month follow up.

Fig. 10 The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative Oswestry disability index (ODI) scores at 12-month follow up.

The hospital anxiety depression scale (HADS) scores on postoperative day 3 were positively correlated with postoperative Oswestry disability index (ODI) scores at 12-month follow up.
In the control group was 13.391, the mean HADS score in the experimental group was 12.734 (P = 0.000). The mean preoperative HADS scores on 3 days postoperatively were 8.500, which did not decrease obviously compared to the mean preoperative score (P = 0.094). The mean HADS score in the experimental group was lower than that in the control group on postoperative day 3 (P = 0.000) (Table 2).

**Correlation between Visual Analogue Scale and Hospital Anxiety Depression Scale**

In the correlation analysis, the HADS scores on postoperative day 3 were positively correlated with the low back pain VAS scores on the same day (P = 0.000) (Fig. 7). However, there were no obvious correlations with the postoperative low back pain VAS scores at 3-month (r = 0.150, P = 0.168), 6-month (r = 0.145, P = 0.181), and 12-month follow up (r = 0.261, P = 0.015) (Table 3).

**Correlation between Oswestry Disability Index and Hospital Anxiety Depression Scale**

The mean HADS score on postoperative day 3 was positively correlated with the ODI scores at 3-month (r = 0.460, P = 0.000), 6-month (r = 0.429, P = 0.000), and 12-month follow up (r = 0.349, P = 0.001) (Table 3, Figs 8, 9, and 10).

**Subgroup Analyses**

In the Mis-TLIF group, there were no differences between different genders in the operation time, intraoperative blood loss, hospital stay, low back pain VAS score, leg pain VAS score, ODI score, and HADS score (P > 0.05) (Table 4).
Fusion Rate and Complications
The fusion rates of both groups were 100% at 12 months postoperatively. The cerebrospinal fluid leakage rate in the experimental group was 1/40 (2.5%), while the cerebrospinal fluid leakage rate in the control group was 3/46 (6.5%). There was no significant difference between the two groups ($P = 0.377$). There was no case of infection or delayed wound healing in either group. No screw misplacement or loosening occurred in the two groups.

Typical Cases
Three patients with typical single-level lumbar spinal stenosis underwent the Mis-TLIF surgery and achieved satisfactory recovery in our department (Figs 11, 12 and 13). Noting that a 1-yuan coin has a diameter of 2.5 cm, it is evident our mini-open incision length was only 3.0 cm (Figs 11 and 13).

Discussion
With the shift in the medical model from a biological to a biopsychosocial approach, the influence of psychological factors, especially anxiety, can no longer be ignored in modern therapeutics. To the best of our knowledge, this is the first study to assess the correlation between anxiety and Mis-TLIF surgery.

Incision Length
With the development of minimally invasive technology, smaller incisions are being made in patients for surgery, which appeals to patients. However, Mis-TLIF are usually performed using tubular retractors. In addition, the expensive equipment that is required and the long learning curve have limited its general development to some extent$^{19}$. Our small incision surgery is based on the conventional surgical approach, which is more familiar to most surgeons$^{20,21}$. Thus, we accomplished Mis-TLIF with a mini-open incision, which could preserve medical resources and reduce the learning curve. There are many differences between these two kinds of surgeries, including the incision length, operation time, blood loss, and length of hospital stay$^{22,23}$. Our Mis-TLIF resulted in less blood loss and shorter hospital stay, reducing patient costs. From an economic perspective, most patients would prefer Mis-TLIF with a mini-open incision, to save money.
Visual Analogue Scale, Oswestry Disability Index, and Hospital Anxiety Depression Scale

In terms of low back pain VAS and ODI, our study showed that Mis-TLIF surgery resulted in better outcomes for patients than open TLIF. The minimal damage for Mis-TLIF could explain why the average low back pain VAS scores in the experimental group were lower than those for open TLIF after surgery. However, there was no significant difference in the leg pain VAS scores between the two groups, which indicated that both Mis-TLIF and open TLIF could alleviate patients’ leg pain. Mis-TLIF could also assist in decompressing the nerve roots. HADS scores on postoperative day 3 in the experimental group decreased obviously compared to the preoperative scores. In addition, patients who underwent Mis-TLIF did experience less anxiety than those who underwent open TLIF after knowing their incision lengths on postoperative day 3. Postoperative HADS were positively correlated with postoperative low back pain VAS at 3 days, which demonstrated that a reduction in anxiety could alleviate patients’ pain to some degree. We found that postoperative HADS were positively correlated with postoperative ODI, which means that patients with lower levels of anxiety could return to their normal lives earlier. There may be several potential explanations for this phenomenon. First, with Mis-TLIF surgery, incisions are smaller, and patients experience less anxiety compared to those undergoing open TLIF. In our correlation analysis, the incision lengths were positively correlated with the postoperative HADS scores, which indicates that the smaller the incision is, the less anxious the patient feels after surgery. Second, anxiety itself actually affects patients’ physiological recovery.

Fig. 12 A 60-year-old female patient with low back pain and right leg pain. (A) Sagittal T1-weighted, (B) sagittal, and (C) axial T2-weighted MRI of a patient with severe L4–5 lumbar stenosis. (D, E) X-ray films after surgery. (F) The incision used to accomplish minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF).
process. Anxiety reduces patients’ confidence and performance of active exercises, which means the more anxious the patient is, the slower the recovery process will be.

**Influence of Anxiety**

Relieving pain is an important therapeutic goal in patients with degenerative lumbar diseases, and pain should be viewed as a psychosomatic factor that bridges physical and psychological domains. Daubs et al. proposed that mental illness affects the outcomes of chronic low back pain treatment. Another study showed that increased preoperative anxiety was associated with increased postoperative pain, increased postoperative analgesia requirements, and prolonged rehabilitation and length of hospital stay for patients undergoing lumbar spine surgery (including those with lumbar spinal stenosis). Anxiety has a profound impact on patients and is often accompanied with a poor prognosis. Dobran et al. demonstrated that anxiety was associated with a poorer clinical outcome. Lee et al. and Dobran et al. both found that preoperative anxiety may be related to improvement in subjective disability after surgery. In our research, it was evident that patients with LSS feel anxious before surgery. How anxiety can be relieved in patients with LSS is worth considering. Burgess et al. suggested that preoperative education could play a positive role in such diseases. Besides preoperative education, what else can we do to alleviate patients’ anxiety? The present study demonstrated that patients undergoing Mis-TLIF with a mini-open incision...
experienced less anxiety, and the lower level of anxiety had a positive impact on pain relief in the short term and on the daily activities of patients within 12 months postsurgery.

**Fusion Rate and Complications**

The fusion rates of both groups were 100% at 12 months postoperatively. With small incisions, there can be difficulties with screw and cage placement. However, there were no such issues in the present study. In addition, the success of Mis-TLIF depended on proficient skill and repetitive practice.

There was no significant difference in the cerebrospinal fluid leakage rate between the two groups. Surgeons may be concerned that cerebrospinal fluid leakage can occur when small incisions are used. The small incision did not cause this problem in the present study. On the one hand, the surgeon would be more careful when using small incisions. On the other hand, small incision surgery was performed with a microscope or a loupe, which improved the visibility of the operation area and prevented errors. There were no cases of infection or delayed wound healing in either group. Although the operation time was longer than for open TLIF, Mis-TLIF did not cause delayed incision healing or infection after surgery. In our experience, intermittently relaxing the muscle may avoid delayed wound healing after surgery. No screw misplacement or loosening occurred in either group.

**Advantages of Minimally Invasive Transforaminal Lumbar Interbody Fusion**

Open TLIF and Mis-TLIF are two common types of surgery for LSS. Lv et al., found that Mis-TLIF was superior to open TLIF in terms of postoperative outcomes and could prevent paraspinal muscle atrophy during the follow-up period. In our experience, although the operation time of Mis-TLIF surgery is a little longer, patients with small incisions had significant improvements in terms of the intraoperative blood loss, hospital stay, and postoperative pain relief. In addition, there is less likelihood of injury to the posterior ligament complex of the lumbar spine, which helps to maintain the stability of the lumbar spine and promote patient recovery. Early rehabilitation also has a positive effect through alleviating the anxiety of patients and their families, and leads to a higher degree of satisfaction.

**Limitations**

There are several limitations of this study. First, the sample size of this study was too small. We are planning to perform further prospective research with large samples. Second, the longest follow-up time was 1 year, which should be extended in future research. Third, the patients that we enrolled did not suffer from chronic anxiety disorders. As their rehabilitation progressed, the patients’ levels of anxiety gradually returned to normal. Therefore, we did not explore the relationship between long-term anxiety and patient recovery. To explore the influence of anxiety on the long-term prognosis of patients with lumbar spinal stenosis, patients with anxiety disorders as well as with lumbar spinal stenosis should be enrolled. Psychologists should be called upon to make more precise judgments.

**Conclusion**

Patients undergoing Mis-TLIF experience less anxiety, less low back pain, and better functional recovery than those undergoing open TLIF. The reduced anxiety as a result of Mis-TLIF is positively correlated with VAS and ODI scores. Anxiety has a profound effect on patients’ recovery process and can impact their prognosis to a certain extent.

**Acknowledgments**

This work was financially supported by the National Natural Science Foundation of China (No. 81672199), the National Natural Science Foundation of China (No. 81972106), and the Key Discipline Construction Project of Pudong Health Bureau of Shanghai (PWZxk2017-08).

**References**

1. Tomkins-Lane C, Melloh M, Lurie J, et al. ISSLS prize winner; consensus on the clinical diagnosis of lumbar spinal stenosis: results of an International Delphi Study. Spine (Philad Pa 1976), 2016, 41: 1239–1246.
2. Patel J, Osburn I, Wanaselja A, Nobles R. Optimal treatment for lumbar spinal stenosis: an update. Curr Opin Anaesthesiol, 2017, 30: 588–603.
3. Harris J. A one-stage procedural operation in the treatmet of spondylolistheses: dorsal traction-reposition and anterior fusion (author’s trans.). Z Orthop Ihre Grenzgeb., 1982, 120: 343–347.
4. Lv Y, Chen J, Chen J, et al. Three-year postoperative outcomes between MIS and conventional TLIF in 1-segment lumbar disc herniation. Minim Invasive Ther Allied Technol, 2017, 26: 168–176.
5. Foley KT, Lefkowitz MA. Advances in minimally invasive spine surgery. Clin Neurosurg, 2002, 49: 499–517.
6. Ozdemir E, Paker N, Bugdayci D, Tekdos DS. Quality of life and related factors in degenerative lumbar spinal stenosis: a controlled study. J Back Musculoskeletal Rehabil, 2015, 28: 749–753.
7. Mobbs RJ, Phan K, Maltham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg, 2015, 1: 2–18.
8. Lener S, Wipplinger C, Hernandez RN, et al. Defining the MIS-TLIF: a systematic review of techniques and technologies used by surgeons worldwide. Global Spine J, 2020, 10: 151S–167S.
9. Tan JH, Liu G, Ng R, Kumar N, Wong HK, Liu G. Is MIS-TLIF superior to open TLIF in obese patients?: a systematic review and meta-analysis. Eur Spine J, 2018, 27: 1877–1886.
10. Hammad A, Winnes A, Ardehshi A, Nikiforov O, Geiger F. Open versus minimally invasive TLIF: literature review and meta-analysis. J Orthop Surg Res, 2019, 14: 229.
11. Khan NR, Clark AJ, Liao LS, et al. Surgical outcomes for minimally invasive vs open transforminal lumbar interbody fusion: an updated systematic review and meta-analysis. Neurosurgery, 2015, 77: 847–874.
12. Adogwa O, Parker SL, Bydon A, Cheng J, McIntyre MJ. Comparative effectiveness of minimally invasive versus open transforminal lumbar interbody fusion: 2-year assessment of narcotic use, return to work, disability, and quality of life. J Spinal Disord Tech, 2011, 24: 479–484.
13. Urban-Baeza A, Zárate-Kalfopulos B, Romero-Vargas S, et al. Influence of depression symptoms on patient expectations and clinical outcomes in the surgical management of spinal stenosis. J Neurosurg Spine, 2015, 22: 75–79.
14. Celestin J, Edwards RR, Jamison RN. Pretreatment psychosocial variables as predictors of outcomes following lumbar surgery and spinal cord stimulation: a systematic review and literature synthesis. Pain Med, 2009, 10: 639–653.
15. Heller GZ, Manuguerra M, Chow R. How to analyze the visual analogue scale: myths, truths and clinical relevance. Scand J Pain, 2016, 13: 67–75.
16. Fairbank JC. Oswestry disability index. J Neurosurg Spine, 2014, 20: 239–241.
17. Theologis AA, Tabaraee E, Toogood P, et al. Anterior corpectomy via the mini-open, extreme lateral, transpsoas approach combined with short-segment posterior fixation for single-level traumatic lumbar burst fractures: analysis of health-related quality of life outcomes and patient satisfaction. J Neurosurg Spine, 2016, 24: 60–68.

18. Lee J, Kim HS, Shim KD, Park YS. The effect of anxiety, depression, and optimism on postoperative satisfaction and clinical outcomes in lumbar spinal stenosis and degenerative spondylolisthesis patients: cohort study. Clin Orthop Surg, 2017, 9: 177–183.

19. Kim YB, Hyun SJ. Clinical applications of the tubular retractor on spinal disorders. J Korean Neurosurg Soc, 2007, 42: 245–250.

20. Eckman WW, Hester L, McMillen M. Same-day discharge after minimally invasive transforaminal lumbar interbody fusion: a series of 808 cases. Clin Orthop Relat Res, 2014, 472: 1806–1812.

21. Singh K, Nandyala SV, Marquez-Lara A, et al. A perioperative cost analysis comparing single-level minimally invasive and open transforaminal lumbar interbody fusion. Spine J, 2014, 14: 1694–1701.

22. 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: 236–243.

23. Goldstein CL, Macwan K, Sundararajan K, Rampersaud YR. Perioperative outcomes and adverse events of minimally invasive versus open posterior lumbar fusion: meta-analysis and systematic review. J Neurosurg Spine, 2016, 24: 416–427.

24. Du Bois M, Donceel P. A screening questionnaire to predict no return to work within 3 months for low back pain claimants. Eur Spine J, 2008, 17: 380–385.

25. Daubs MD, Norvell DC, McGuire R, et al. Fusion versus nonoperative care for chronic low back pain: do psychological factors affect outcomes. Spine (Phila Pa 1976), 2011, 36: S96–S109.

26. de Groot KI, Boeke S, van den Berge HJ, Duivenvoorden HJ, Bonke B, Passchier J. The influence of psychological variables on postoperative anxiety and physical complaints in patients undergoing lumbar surgery. Pain, 1997, 69: 19–25.

27. Dobran M, Nasi D, Giadi M, et al. Clinical and psychological outcome after surgery for lumbar spinal stenosis: a prospective observational study with analysis of prognostic factors. Neurrol Neurochir Pol, 2018, 52: 70–74.

28. Burgess LC, Arundel J, Wainwright TW. The effect of preoperative education on psychological, clinical and economic outcomes in elective spinal surgery: a systematic review. Healthcare (Basel), 2019, 7: 48.