

CLINICAL ARTICLE

Clinical Research and Technique Note of TLIF by Wiltse Approach for the Treatment of Degenerative Lumbar

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Objective: To assess the clinical efficacy and share the technique notes of Wiltse Approach TLIF for the treating single segment degenerative lumbar spinal disease.

Method: In this retrospective controlled study, 780 patients with single segment degenerative lumbar disease who were operated in our hospital from January 2016 to December 2020 were analyzed retrospectively. The patients were randomly assigned to Wiltse approach group (group A, 410 cases) and conventional open approach group (group B, 370 cases). Patient's assessment of pain and disability were evaluated by the visual analogue scale (VAS) and the Oswestry disability index (ODI) before and after surgery. The incision length, operative time, exposure time, intraoperative blood loss, hidden blood loss, time to ambulation, total length of hospitalization, serum creatine kinase, X-rays, CT and MRI were also evaluated.

Results: There were no differences in sex, age, pre-operative ODI score, VAS score between the two groups ($P > 0.05$). The Wiltse approach group had a shorter incision length with 7.69 ± 0.44 cm compared to the conventional group with 11.13 ± 0.36 cm ($P < 0.01$). The average operative time was 119.20 ± 14.64 min with exposure time of 16.20 ± 3.42 min in the Wiltse approach group and 145.65 ± 16.98 min with 29.20 ± 3.42 min in the conventional group ($P < 0.05$, $P < 0.01$). Comparing the intraoperative blood loss, hidden blood loss, serum creatine kinase, time to ambulation, total length of hospitalization, the Wiltse approach group was less than the conventional open approach group ($P < 0.05$). The VAS score of the two groups decreased significantly with time, and the VAS score of the Wiltse group was significantly lower than that of the conventional open approach group ($P < 0.05$). At last investigation after operation, ODI scores of the two groups were significantly decreased compared with that before operation. Wiltse approach group was significantly lower than that of the conventional open approach group ($P < 0.05$). The multifidus of the two groups of patients had a certain degree of atrophy. But the Wiltse approach group multifidus muscle atrophy rate is significantly lower than the conventional open approach group.

Conclusion: The Wiltse approach TLIF significantly reduces the damage to the paravertebral muscles and the postoperative incidence of chronic low back pain.

Key words: Conventional approach; Degenerative lumbar disease; Multifidus muscle; Wiltse Approach

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Introduction

Spinal lumbar fusion surgery is a surgical procedure in the spine surgery. It has wide applications for the management of pain and spinal instability resulting from lumbar disc herniation, lumbar spinal stenosis, lumbar spondylolisthesis and degenerative disc disease. Posterior lumbar interbody fusion (PLIF) was first described by Cloward in the 1950s^{1,2}. The transforaminal lumbar interbody fusion (TLIF) was then proposed by Harms *et al.* in 1982³. However, the conventional open approach technique require a large midline skin incision, extensive detachment and prolonged retraction of back muscles from the spinal processes^{4,5} which may result in the paraspinal muscles being physiologically abnormal due to ischemic necrosis and denervation. The muscle trauma results in post-operative “fusion disease”—radiographically successful fusion with postoperative low back pain^{4,6}.

In 1968, Dr. Wiltse first described a new approach by splitting the muscles between the multifidus and longissimus to retain the integrity of the posterior osseous structure and the ligamentous complex to the maximum (Fig. 1)⁷. This approach protects the para-lumbar muscle soft tissue and provides a true minimally invasive approach technique. He later modified his approach so that it could be applied in other lumbar diseases⁸. Numerous studies have reported the Wiltse approach has advantages in treating degenerative lumbar diseases^{9–11}. Additionally, thoracic disc herniation, spinal tuberculosis and degenerative lumbar scoliosis have also been managed *via* the Wiltse approach¹². Preliminary results suggested that the Wiltse approach is superior to the conventional open approach in terms of reduced intramuscular pressure and paraspinal muscle edema, less blood loss, lower serum creatinine kinase (CK) and less postoperative back pain. But there are still few long-term evaluations of undesirable changes in the multifidus muscle and their potential effects. Besides, the

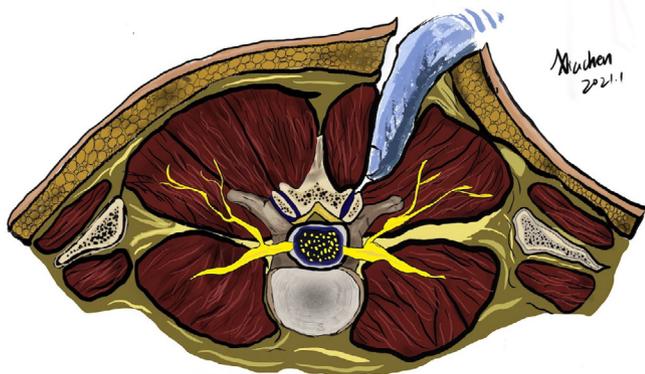


Fig. 1 The drawing depicts shows the location of the intermuscular plane: the multifidus is medially located, the longissimus is lateral.

present papers all focus on the clinical efficacy, and there are few studies sharing the surgical details of the Wiltse approach TLIF^{13,14}.

Our team has performed more than 700 Wiltse approach TLIFs in the past 4 years. In this study, we retrospectively reviewed the clinical results, radiographic parameters, as well as paraspinal muscles in conventional open approach and Wiltse approach TLIF in treating lumbar degenerative diseases. The purpose of this study was: (i) to summarize the technique points of Wiltse approach TLIFs; (ii) to evaluate the clinical results with Wiltse approach TLIF for lumbar disease; and (iii) to investigate the long-term effect on the paraspinal muscle with Wiltse approach TLIF.

Methods

Inclusion and Exclusion Criteria

This study protocol was reviewed and approved by the Ethics Committee of the Zhejiang Provincial People's Hospital. Inclusion criteria: (i) patients have unilateral or bilateral lower extremity and lumbosacral pain and have obvious symptoms and signs of localization; (ii) symptoms are not relieved after 3 months or more of conservative treatment; (iii) diagnosis of lumbar disc herniation, lumbar spinal stenosis, Meyer ding degree I-II lumbar spondylolisthesis or lumbar instability; and (iv) require single-segment fusion surgery. Exclusion criteria: (i) lumbosacral pain and lumbar degeneration caused by other reasons; (ii) requires fusion surgery of more than 2 segments; (iii) Meyer ding degree II or higher lumbar spondylolisthesis; and (iv) a history of lumbar spine surgery.

A total of 780 patients who were treated in our hospital between January 2016 and December 2020 were included in this study. According to different surgical treatments, they were divided into Wiltse approach TLIF group (n = 410) and conventional open group (n = 370). In the Wiltse approach TLIF group, patients were followed up for >1 year (mean 20.5 months, range 12–36 months). In the conventional open group, patients were followed up for >1 year (mean 21.4 months, range 12–36 months). Before surgery all patients provided consent to participate in the study and received preoperative lumbar spine X-rays, dynamic position X-rays, and CT or MRI examinations to definitively confirm their diagnosis and exclude the presence of other spinal diseases. The baseline data of the two groups are shown in Table 1. There are no significant differences between the two groups. All operations were performed by the same surgeon team and all surgical instruments were obtained from Medtronic Inc (Fridley, MN, USA).

Surgical Methods

All surgeries were performed by the same experienced surgeon team in our department. Patients were placed in a prone position under general anesthesia.

TABLE 1 Patients' baseline data

Characteristic	Wiltse TLIF (n = 410)	Conventional open (n = 370)	t/ χ^2	P value
Sex (male/female)	163/247	154/216	0.52	0.41*
Age (years, mean \pm SD)	62.75 \pm 5.44	59.25 \pm 4.43	0.47	0.57**

* Chi-square test for proportions.; ** t test for the differences between means.

TLIF by Wiltse approach

Step 1: patients were placed in a prone position under general anesthesia. The segments were located by C-arm X-rays. Lateral and anteroposterior images were obtained prior to the operation to mark the position of the pedicle of the surgical segment. According to the preoperative MRI, we marked the distance between the muscle space and the spinous process, then the bilateral Wiltse surgical incision was used. Step 2: skin was cut with a scalpel and the subcutaneous tissue was separated from the surface of the lumbodorsal fascia. A longitudinal incision through the lumbodorsal fascia was made in reference to the perforating vessels. The medial multifidus and lateral longissimus muscles were then bluntly separated. Step 3: with the help of inner hook and outer hook pedicle screws and rod were placed under direct vision. The screw and rod system were then locked with slight pressure. The same method was used on the opposite side. Step 4: after the pedicle screw channel was prepared and sealed with bone wax, the multifidus muscle was cut from its attachment point, and then peeled along the spinous process with a bone knife. The expansion sleeve was then placed to the Quadrant channel. Facet joints were removed to reveal the intervertebral disc. The disc tissue and cartilage were gradually removed with an intervertebral reamer. The screw and rod system of the opposite side were used to assist in maintaining intervertebral distraction. The intervertebral space was then implanted with a polyetherketoneketone cage filled with bone particles, followed by locking up with the screw and rod system. Step 5: the inter fixations were located by C arm under X-rays. Fascias were closed with running stitches and the skin was closed with an intradermic suture.

In conventional open group, a posterior midline skin incision was made, followed by subperiosteal dissection of paravertebral muscles away from the lumbar spine. Decompression (laminectomy and facetectomy) and discectomy were followed by pedicle screw insertion, slip reduction, and interbody cages were used, in the same manner.

Clinical Outcome

Clinical outcome evaluation included incision length, operative time, exposure time, intraoperative blood loss, hidden blood loss, time to ambulation, total length of hospitalization. Serum creatine kinase (a measure of muscle damage) was measured before operation, and 1, 3, and 5 days after operation. Visual analogue scale (VAS) score and Oswestry

Disability Index (ODI) scores, were recorded before operation, at the time of ambulation after surgery, 4 weeks after surgery, and at the last follow-up.

Radiologic Evaluation

Lateral and dynamic X-rays, CT and MRI (1 year after surgery) were routinely performed. The surgery segments were scanned (Somatom Sensation 16 CT; Siemens, Erlangen, Germany) and 3-D reconstruction of the lumbar spine obtained (layer thickness: 0.75mm). A modified Brantigan method was used to evaluate intervertebral fusion¹⁵. Lumbar MRI was performed at preoperation and at the last follow-up to evaluate the degree of multifidus atrophy and fatty infiltration. All the internal fixatives used in our surgeries are MRI-compatible. The cross-sectional area of the multifidus muscles (MCSA) on MRI was measured using digital image processing software (Image J from National Institutes of Health, Bethesda, MD, USA). To determine the MCSA, the region of interest (ROI) was drawn around the muscles of interest on each side of the spine. Fats, bony structures, and other soft tissues nearby should not be included. The rate of multifidus muscle atrophy = (preoperative MCSA — postoperative MCSA) / (preoperative MCSA) \times 100%. Fatty infiltration of the multifidus muscle was visually graded using the standard criteria introduced by Goutallier *et al.*^{16,17} Grade A, normal muscle; Grade B, fat tissue sparsely distributed between muscle fibers; Grade C, fat tissue almost equal to muscle fibers; Grade D, more fat tissue than muscle fibers.

Statistical Analysis

SPSS 20.0 software (SPSS Inc., Chicago, IL, USA) was used to perform statistical analysis. Quantitative data were expressed as mean \pm standard deviation (SD) and were compared using the Student t-test. Categorical variables were compared using the Pearson χ^2 test. The P-value was set <0.05 for significance.

Visual Analogue Scale

VAS is used to assess the degree of pain. The specific method is: draw a 10-cm horizontal line on the paper, one end of the horizontal line is 0, indicating no pain; the other end is 10, indicating severe pain; the middle part indicates varying degrees of pain. A score of 0 means no pain. A score below 3 indicates mild pain and can be tolerated. A score of 4–6 indicates that the patient has pain that affects sleep and is

TABLE 2 General operative indexes for the Wiltse approach group and conventional open group (mean ± SD)

Group	Incision length (cm)	Operation time (min)	Exposure time (min)	Intraoperative blood loss (mL)	Hidden blood loss (mL)
Wiltse TLIF	7.69 ± 0.44	119.20 ± 14.64	16.20 ± 3.42	123.34 ± 14.56	114.34 ± 15.67
Conventional open	11.13 ± 0.36	145.65 ± 16.98	29.20 ± 3.42	246.24 ± 24.67	256.78 ± 31.45
Statistical value	t = 3.45 P < 0.01	t = 2.35 P < 0.05	t = 2.78 P < 0.01	t = 3.45 P < 0.01	t = 2.91 P < 0.01

TABLE 3 Clinical efficacies of the Wiltse approach group and conventional open group (mean ± SD)

Group	Time to ambulation	VAS when ambulation	Total length of hospitalization
Wiltse TLIF	1.29 ± 0.54	3.39 ± 0.54	7.21 ± 1.32
Conventional open	4.69 ± 2.16	5.65 ± 1.18	13.46 ± 3.52
Statistical value	t = 1.75 P < 0.05	t = 1.82 P < 0.05	t = 3.78 P < 0.05

TABLE 4 Comparison of VAS and ODI scores between the Wiltse TLIF group and conventional open group (mean ± SD)

Group	Pre-op VAS	Post-op (day 28) VAS	Last follow-up VAS	Pre-op ODI	Post-op (day 28) ODI	Last follow-up ODI	interbody fusion rate(%)
Wiltse TLIF	7.89 ± 1.14	2.20 ± 0.94	0.91 ± 0.32	68.12 ± 15.21	31.98 ± 8.12	15.38 ± 6.12	81.23 ± 8.64
Conventional open	7.59 ± 1.46	4.65 ± 1.28	1.76 ± 0.52	67.89 ± 15.7	47.39 ± 11.45	14.39 ± 7.45	81.23 ± 8.64
Statistical value	t = 3.75 P = 0.29	t = 2.42 P < 0.05	t = 0.78 P < 0.05	t = 1.45 P = 0.681	t = 1.91 P < 0.05	t = 0.78 P < 0.05	χ = 0.39 P > 0.05

There was no significant difference in the preoperative serum creatine kinase level between the two groups ($P > 0.05$). The level of serum creatine kinase in the conventional open group was significantly higher than that in the Wiltse approach group on day 1 and 3 postoperatively ($P < 0.05$, Fig. 2), but these differences disappeared on day 5 postoperatively.

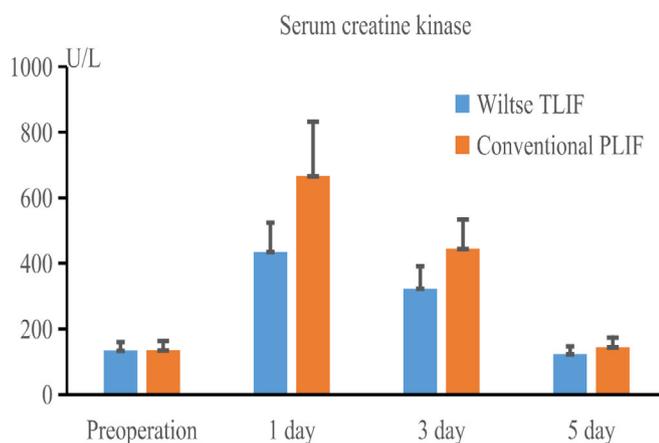


Fig. 2 Comparison of pre- and post-operative serum creatine kinase in the two groups.

bearable. A score of 7–10 indicates that the patient has increasingly intense pain, which is unbearable, affecting appetite and sleep. The lower the score is, the lighter the pain.

Oswestry Disability Index

ODI is a scale commonly used to evaluate low back pain and dysfunction in the world. The ODI score questionnaire contains 10 items, including lumbar and leg pain, self-care ability of daily living, lifting, walking, standing, sitting, sexual behavior, sleeping, social life, and traveling. Each observation item is divided into six levels according to its degree, with 0 indicating normal and 5 indicating limited function. The calculation formula = (total score / (questions × 5)) × 100%. Mild dysfunction (0%–20%); moderate dysfunction (21%–40%); severe dysfunction (41%–60%); disability (61%–80%), and either long-term bedridden, or exaggerating the impact of pain on his or her life (81%–100%).

Results

General Operative Indexes for the Wiltse TLIF group and Conventional Open Group

For the Wiltse approach, the incision length was 7.69 ± 0.44 cm, operation time 119.20 ± 14.64 min, exposure time 16.20 ± 3.42 min, intraoperative blood loss 123.34 ± 14.56 mL and hidden blood loss 114.34 ± 15.67 mL. For the

TABLE 5 Multifidus muscle evaluation: atrophy and fatty infiltration

Group	Preoperative MCSA	Last follow-up MCSA	The rate of atrophy(%)
Wiltse TLIF	1012.32 ± 276.12	893.23 ± 253.67	11.67 ± 6.74
Conventional open	1045.67 ± 223.67	653.23 ± 213.23	37.53 ± 11.34
Statistical value	t = 12.65 P = 0.45	t = 8.35 P < 0.05	t = 2.78 P < 0.05

conventional open group, the incision length was 11.13 ± 0.36 cm; operation time 145.65 ± 16.98 min; exposure time 29.20 ± 3.42 min, intraoperative blood loss 246.24 ± 24.67 mL and hidden blood loss 256.78 ± 31.45 mL. The incision length, operation time, blood loss and exposure time were all significantly less in the Wiltse TLIF group than those in the conventional open group (all $P < 0.05$; Table 2). The exposure time and blood loss in the Wiltse TLIF group were nearly half of those in the conventional open group.

Clinical Indexes for the Wiltse Approach Group and Conventional Open Group

Short-term clinical outcome after surgery was evaluated by time to ambulation, total length of hospitalization and VAS score. Wiltse TLIF group had shorter time to ambulation and total length of hospitalization and lower VAS score when ambulation after operation than conventional open group ($P < 0.05$; Table 3).

The average follow-up duration was 20.5 ± 4.5 and 21.4 ± 6.7 months in the Wiltse TLIF group and conventional open group, respectively. Postoperative ODI score, VAS score for low back pain and leg pain were significantly improved after surgery in both groups. The VAS and ODI scores improvement at the post-operation were greater in the Wiltse TLIF group than those in the conventional open group ($P < 0.05$; Table 4). However, there was no significant difference in the interbody fusion rate between the two groups.

Radiographic evaluation for the multifidus muscle

In the Wiltse approach group, the rate of multifidus atrophy is only $11.67\% \pm 6.74\%$ between pre-op and the last follow-up MRI. However, in the conventional posterior open approach group, the rate of multifidus atrophy is $37.53\% \pm 11.34\%$ at final follow-up MRI. Multifidus CSA at final follow-up MRI was significantly less than in the Wiltse group ($P < 0.05$; Table 5). Typical case pictures are shown in the Fig. 3.

The grade of fatty infiltration in the multifidus muscle was evaluated bilaterally. In the Wiltse group, fatty infiltration was Grade A in 50, B in 102, and C in 46 cases preoperatively; and Grade B in 118, C in 56, and D in 26 cases postoperatively. In the conventional posterior open group, fatty infiltration was Grade A in 58, B in 103, and C in 22 cases preoperatively; and Grade C in 66, and D in 117 cases postoperatively (Table 6).

Discussion

Advantages of Mini-invasive TLIF via the Wiltse Approach

As we all know, the concept of “minimally invasive” means not only short incisions, but also less extensive soft tissue injury and maximum therapeutic result. The Wiltse approach can dramatically reduce the muscle injury and approach related morbidity.

Less Bleeding and clear operative field

Reduction of intraoperative bleeding is critical in obtaining a clear surgical field and saving operation time. Our study illuminated that Wiltse approach TLIF has significantly shortened surgical and exposure time compared to the conventional group. This is partially because there is no obvious cross-vessel between the multifidus muscle and the longissimus muscle. Thus, the Wiltse approach through the gap between multifidus muscle and the longissimus muscle can greatly reduce intraoperative bleeding, which reduces the time taken to stop bleeding and achieves a better surgical site exposure for the operation. Besides, blood loss with the Wiltse approach primarily originates from bone surface bleeding after osteotomy and bleeding associated with the spinal venous plexus, which are controllable and preventable.

Protection of Multifidus Muscle and Low Incidence of Postoperative LBP

The multifidus muscles play an important role in maintaining the stability of the lower back¹⁸⁻²⁰. Wilke *et al.*²¹ found multifidus contributed to two-thirds of the increased stiffness imparted by the simulated contraction of back muscles. Therefore, atrophy of this muscle would be expected to weaken lumbar segmental stability and lead to further damage. Many documents have highlighted that the atrophy and fatty infiltration of the multifidus muscles are directly related to postoperative low back pain. The conventional open approach requires extensive dissection of the multifidus, with irreparable damages to its blood supply and nerves, leading to postoperative multifidus degeneration and denervation manifested as muscle atrophy, fibrosis and fat deposition. In addition, during the conventional approach surgery, the extensive distraction of the paravertebral muscles also results in irreversible ischemic degeneration and contractile dysfunction of the paraspinal muscles. As a result, the incidence of postoperative chronic low back pain increases.

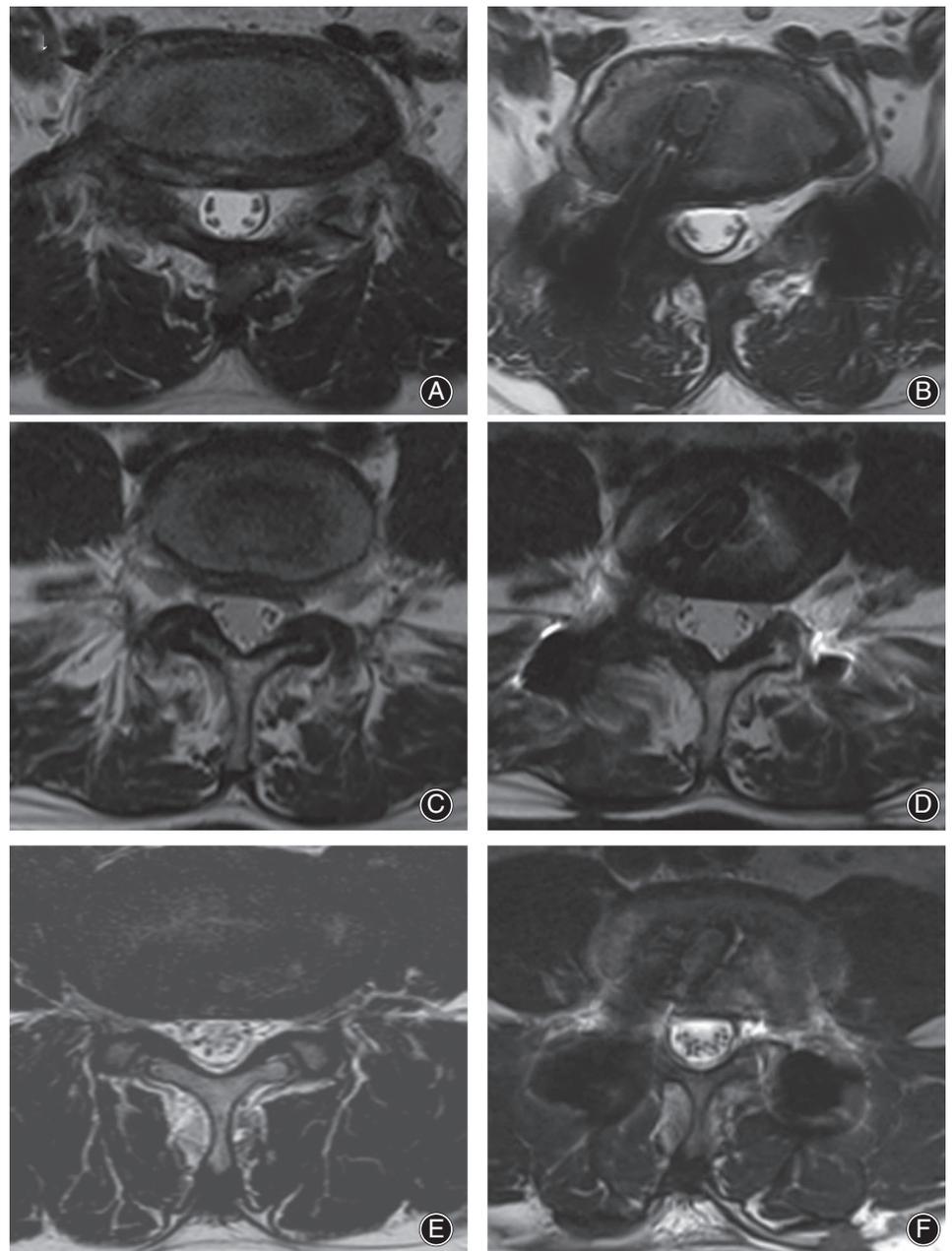


Fig. 3 The 3 typical cases of the Wiltse Approach TLIF. (A, B) Spondylolytic spondylolisthesis (L5/S1) in a 56-year-old man. Pre-operative T2WI MR image showing mild multifidus atrophy. One year postoperative T2WI MR image showing the appearance of the multifidus does not differ significantly from its pre-operative appearance. (C, D) Degenerative spondylolisthesis (L4/L5) in a 60-year-old woman. Pre-operative T2WI MR image showing moderate multifidus atrophy. One year postoperative T2WI MR image showing the appearance of the multifidus does not differ significantly from its pre-operative appearance. (E, F) Degenerative spondylolisthesis (L4/L5) in a 65-year-old man. Pre-operative T2WI MR image showing mild multifidus atrophy. One year postoperative T2WI MR image showing the appearance of the multifidus does not differ significantly from its pre-operative appearance.

TABLE 6 Fatty infiltration grade (number of cases) in the two groups

Group	Preoperation				Postoperation			
	A	B	C	D	A	B	C	D
Wiltse TLIF	50	102	46	0	0	118	56	26
Conventional open	58	103	22	0	0	0	66	117

The Wiltse approach is through a natural physiological muscle gap and does not require extensive retraction of the paravertebral muscles, thus minimalizing the damage of

the paravertebral muscles. The ingenious structure of the retraction systems (inner/out hooks, Quadrant channel) also help avoided excessive retraction²². During surgery, the inner

hook can pull the multifidus muscle to the inner side, which is convenient to use and adjust; the out hook's head is used as a fulcrum during the operation to expose the operative site. Through the combination of the two hooks, we can minimize the length of the incision and the tissue damage. The Quadrant channel also helps a lot because of the wide and smooth blade. It retracts the muscles in four directions, which reduces muscle pulling strength per unit. This is a huge advancement in the field of minimally invasive surgery under the premise of surgical fields exposure.

In our patients, the time to ambulation and VAS score were obviously decreased in the Wiltse TLIF group. This is closely related to the protection of muscle and soft tissue in the operation.

As we all know, the serum concentration of creatine kinase can be used to evaluate early muscle injury after spinal surgery²³⁻²⁵. Serum creatine kinase activity increases after surgery, reaching a maximum on day 1, and subsequently declining to normal levels in 5 days²⁸. Similar to the study by Kim *et al.*¹⁷, our results showed serum creatine kinase levels were significantly lower in the Wiltse approach group than that in the conventional group on postoperative day 1 and 3.

Previous studies have reported MRI can evaluate the long-term effects of muscle injury²⁷. MRI can show the deposition of fat and connective tissue in the muscle, which gives high signal intensity in T2-weighted images. In the current study, the rate of multifidus atrophy was significantly lower in the Wiltse TLIF group than in the conventional open group. These results, combined with those in the literatures^{26,28}, confirm that the Wiltse approach causes less muscle injury than the conventional approach.

Details of Mini-invasive TLIF via the Wiltse Approach

At present, most papers underscored the minimally invasive aspects of the Wiltse approach. However, the description of this technique in the published literature is relatively simple. There are few papers using graphics to introduce the details of this operation. We summarized the experience of more than 700 Wiltse approach TLIF operations and invite professional medical painters to draw pictures to provide a step-by-step description of the Wiltse approach TLIF which can help popularize this surgical approach in clinical work.

Preparation and Positioning

The patient should be placed in the prone position on an appropriately sized Wilson or Andrews spinal frame, taking care that the abdomen hangs free. A suspended abdomen can significantly reduce intraoperative bleeding (Fig. 4). The patients were placed in a fully lordotic position to obtain a good lumbar curve. We recommend the surgeon is equipped with headlight and 2.5Xlopes, which help perform precise hemostasis and decompression.

Tips to identify the incision and find the muscle gap

The first and most important step in this operation is to accurately identify the incision and find the natural gap. The pedicle of the target segments should be marked by fluoroscopy before surgery. During the operation, the pedicle screw cannot exceed the pedicle level line. Then the surgeon should measure the distance between the gap and the spinous process *via* preoperative MRI images. The incision is generally chosen to be 3–4 cm lateral to the mid-line of the spinous process (the inner edge of the posterior superior iliac spine, Fig. 5). The surgical incision of the L₅/S₁ segment is suggested to be moved 1–1.5 cm to the upward according to the pedicle projection. After opening the back fascia to reveal muscle fascia, two tips are helpful in finding the muscle gap: (i) there are many perforating vessels between the multifidus and longissimus muscles, which pass through the muscle membrane from the muscle gap and extend along the surface of the muscle membrane. These vessels can be used as a guide to find the muscle gap; and (ii) press the back fascia longitudinally with the periosteal dissector, and the obvious depression also leads you to the muscle gap.

The Key Points of Pedicle Screw Placement

After exposing the muscle gap, the inner hook can help pull the multifidus muscle to the inner side. Then use the nerve stripper to explore the upper edge of the transverse process, put the outer hook in the root of transverse process. Connecting point of the transverse process, the upper articular process and the vertebral lamina is the entry point to the pedicle(Fig. 6).

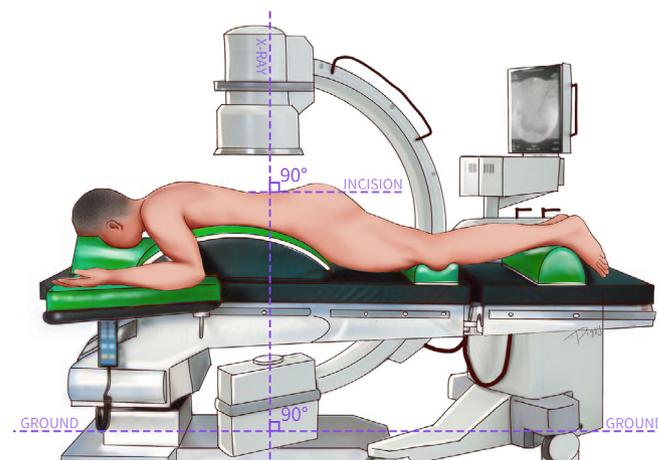


Fig. 4 Preparation and Positioning. The patient should be placed in the prone position, with care that the abdomen hangs free. Adjust the low back skin to the horizontal position. The C-arm X-ray machine is vertical to the ground and the incision.

Fig. 5 Tips to identify the incision and find the muscle gap (A–B) measure the distance between the gap and the spinous process via the preoperative MRI image, the surgical incision is generally chosen to be 3-4 cm lateral to the mid-line of the spinous process (the inner edge of the posterior superior iliac spine); (C) The constant perforating blood vessels guide you to find the muscle gap accurately.

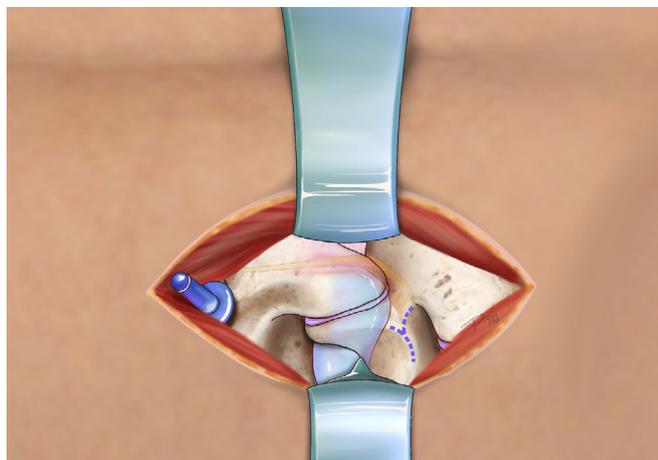
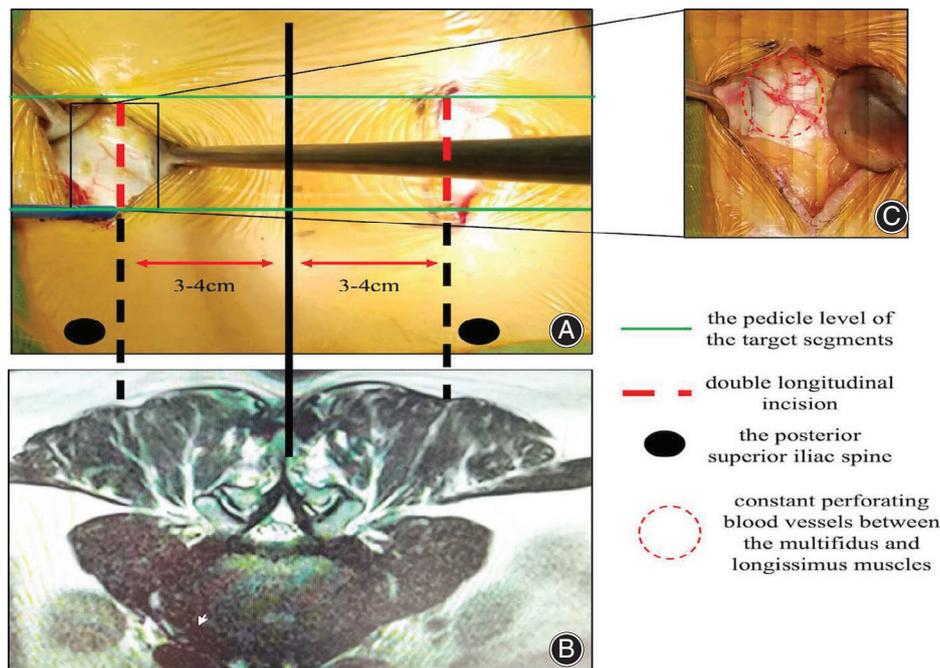


Fig. 6 Exposure the entry point to the pedicle. The inner hook pulls the multifidus muscle to the inner side, the outer hook was put in the root of transverse process, connecting point of the transverse process, the upper articular process and the vertebral lamina is the entry point to the pedicle (marked with purple dotted line).

Spinal Decompression

The conventional surgery is performed through subperiosteal dissection of multifidus muscle over lamina and the facet joint by electro-surgical knife. In our surgery, we dissected the multifidus at the level of the transverse process longitudinally, and then bluntly separated it inward to the root of the spinous process with an osteotomy. Uses of an electro-surgical knife may cause damage to blood vessels and dorsal branches, which could avoid damage with blunt separation.

Before the decompression process, one could place the Quadrant channel to fully expose the articular processes and most part of the lamina, then adjust the channel according to the decompression area. After removing the soft tissue on the surface of the vertebral lamina and the articular process, the decompression area can be clearly exposed. We propose a four-cut method for the articular osteotomy. First cut, use a narrow bone knife to remove the tip part of the lower articular process of the upper vertebrae; second cut, use a wide bone knife to cut the vertebral lamina along the spinous process root of the upper vertebrae; third cut, cut down the pedicle isthmus of the upper vertebrae transversely; and fourth cut, excise the upper articular process of the lower vertebrae. Compared with the traditional osteotomy method, the first cut makes it easier to remove the excised lamina (Fig. 7).

After the osteotomy process, use the rongeurs and nucleus pulposus forceps to decompress the nerve root and remove the ligamentum flavum.

Exposure of the Intervertebral Disc and Vertebral Clearance Processing

The dural sac and nerve root are under direct vision after the decompression. Before exposing the intervertebral disc, bipolar coagulator should be used extensively to coagulate the blood vessels behind the intervertebral disc (Fig. 8). Then, the surgeon can perform a sharp separation of the vessels together with the soft tissue to reduce bleeding. Use the nerve stripper to push the walking root inward along the surface of the intervertebral disc, put a cotton piece (about 1x2 cm) between the walking root and the disc, do the same process to the outlet root. The intervertebral disc can be clearly revealed (Fig. 9).

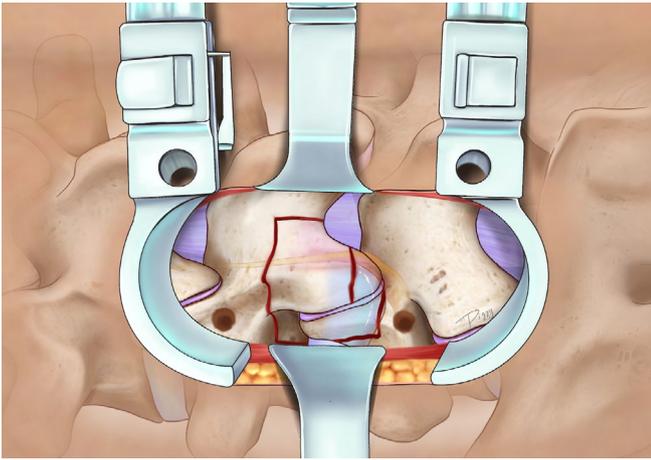


Fig. 7 Four-cut method for the articular osteotomy. Four-cut method for the articular osteotomy. The First transverse cut remove the tip part of the lower articular process of the upper vertebrae; the second longitudinal cut along the spinous process root of the upper vertebrae; the third transverse cut just below the inferior margin of the upper pedical to remove the left lamina of the upper vertebrae; the fourth transverse cut excise the upper articular process of the lower vertebrae just above the superior margin of the adjacent pedical. Compared with the traditional osteotomy method, the first cut makes it easier to remove the upper excised lamina.

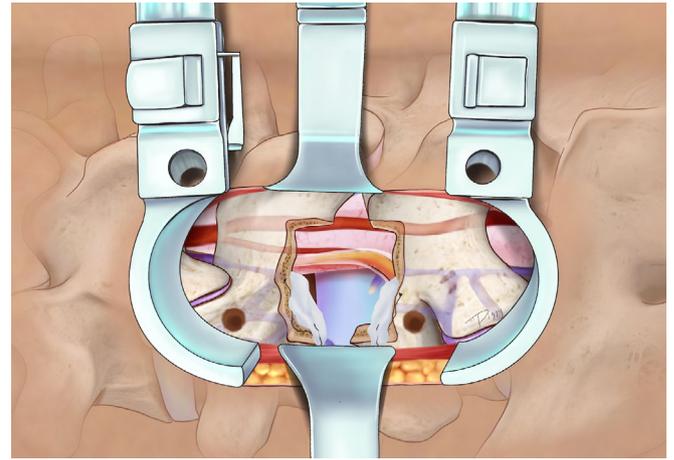


Fig. 9 Use the nerve stripper to push the walking root inward along the surface of the intervertebral disc, put a cotton piece (about 1×2 cm) between the walking root and the disc, do the same process to the outlet root.

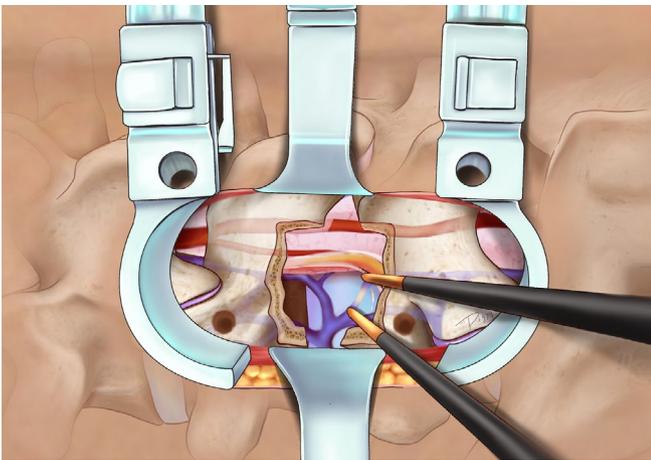


Fig. 8 Exposure of the intervertebral disc. Before exposure the intervertebral disc, bipolar coagulator should be used to extensively coagulate the blood vessels behind the intervertebral disc.

When there is spondylolisthesis or the severe intervertebral altitude loss, the surgeon can insert the nerve stripper to ensure the direction of the intervertebral space, and then use the narrow osteotome and intervertebral distractor to expand intervertebral space gradually. And we recommend using the contra-lateral screws to maintain the

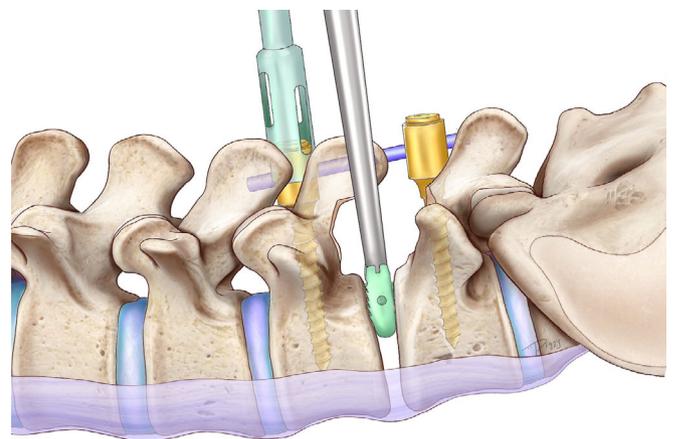


Fig. 10 Tip to obtain the lumbar curve: press the cage to the ventral side and lock the opposite side screw-rod system.

intervertebral altitude during this process. Moreover, we find that a double longitudinal incision is more conducive to assisting the recovery of intervertebral altitude loss because the double longitudinal incision can reduce the traction of the soft tissue when inserting the instrument (such as a screwdriver and a rod handle).

When scraping the cartilage endplate, we use a new method different from the traditional approach. We use a 4mm diameter straight curette to push insert to the interface of cartilage and bony end plate and push it along the gap posterior to anterior and to the opposite side. This method significantly improved the efficiency of thorough clearance of vertebral process and reduces the risk of bony endplate injury.

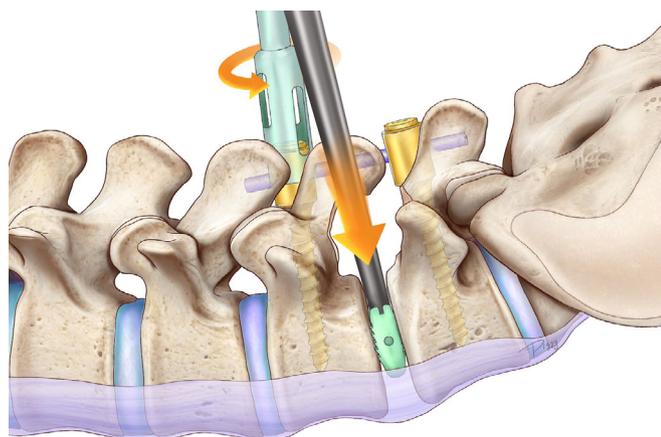


Fig. 11 Tip to obtain the lumbar curve: press the cage to the ventral side and lock the opposite side screw-rod system.

Tip to Obtain the Lumbar Curve

With the cage, enter the intervertebral space, loosen the opposite side screw-rod system, press the cage to the ventral side and lock the opposite side screw-rod system. The suspended abdomen and the fully lordotic position can help obtain the physiological lumbar curve. (Fig. 10).

Because of this, the thrust to the ventral side will obtain a very natural physiological curvature of the lumbar spine (Fig. 11).

Important Hemostatic Techniques

The control of intra-operative bleeding can greatly reduce the operation time and the occurrence of postoperative

complications. The main bleeding sites in this operation: (i) hemorrhage of the perforating vessels between the multifidus and longissimus muscles. To reduce bleeding, one can bluntly dissect the natural plane. The surgeon can also use the bipolar coagulator to stop bleeding if necessary; (ii) hemorrhage of the segmental vessels at the upper edge of the transverse process and the medial edge of the inter-transverse ligament. To reduce bleeding, the surgeon should avoid unnecessary disturbance. The bipolar coagulator also can be used to stop the bleeding; (iii) hemorrhage of the venous plexus in the spinal canal (behind the disc). Before incising the intervertebral disc, bipolar coagulator should be used to extensively coagulate the blood vessels behind the intervertebral disc. Then, the surgeon can perform a sharp separation of the vessels together with the soft tissue to reduce bleeding; and (iv) bleeding from a ruptured bony endplate. The process is moderate, especially for patients with osteoporosis.

The conclusion

Compared with conventional open approach, TLIF via Wiltse approach can significantly reduce damage to the multifidus and the postoperative incidence of chronic LBP.

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An authorship declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and are in agreement with the manuscript.

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