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Technical Note

Minimally invasive one-level lumbar decompression and fusion surgery with posterior instrumentation using a combination of pedicle screw fixation and transpedicular facet screw construct

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Abstract

Background: Minimally invasive lumbar spine fusion surgery has gained popularity in recent years. Routinely, this technique requires bilateral parasagittal incisions for decompression, interbody fusion, and posterior instrumentation. The following study is a description of a new minimally invasive technique for one-level transforaminal lumbar interbody fusion (TLIF) using a unilateral parasagittal incision (Wiltse approach), with placement of pedicle screws and then a percutaneous transpedicular facet screw insertion on the contralateral side. The biomechanical stability of this posterior construct will be discussed while the efficacy and complications of this technique have been examined.

Methods: Forty patients underwent this new technique of one-level TLIF with posterior instrumentation using unilateral pedicle screw fixation supplemented with contralateral percutaneous transpedicular facet screw construct. Data regarding surgical time, estimated blood loss (EBL), hospital length of stay (LOS), and complications related to the posterior instrumentation are recorded.

Results: The average surgical time of this new procedure was 124 minutes; average EBL was 140 cc; average hospital LOS was 3 days. Two patients developed new leg pain on the side where the facet screw had been placed. Both patients had the facet screw removed.

Conclusion: This novel technique of unilateral pedicle screw fixation combined with contralateral percutaneous transpedicular facet screw construct has further reduced the amount of normal tissue injury while maintaining the same biomechanical advantages of bilateral pedicle screw fixation. However, caution is needed during the placement of the percutaneous facet screw in order to avoid nerve root injury.

Key Words: Minimally invasive spine surgery, percutaneous facet screw, transforaminal interbody fusion, Wiltse approach

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INTRODUCTION

In 1968, Dr. Wiltse pioneered a posterior parasagittal approach to the lumbar spine for surgical treatment of lumbosacral spondylolisthesis, hence it is now being known as the Wiltse approach.[19] The Wiltse approach involves two parasagittal incisions made at 3 cm just lateral to the mid-line on both sides. Dissection is then carried through a natural plane between the multifidus and longissimus muscle groups to the facet joint. Later, Dr. Wiltse developed several other indications using this approach, such as the far lateral disc excision, pedicle screw insertion, and spinal canal decompression.[20] The major advantages of the Wiltse approach are: (1) minimizing muscle cutting by dissecting through a natural plane between two muscle groups; (2) preservation of the mid-line structures consisting of the spinous processes, interspinous ligaments, and the muscle attachments to the spinous processes. These mid-line bone, disc, ligaments, and muscle restraints provide lumbar spine stability. The trunk muscles major function is to support the vertebral column. The musculature has proved to be the most important tissue in maintaining spinal stability under various conditions.[3] The Wiltse approach can reduce the degree of muscle injury during the surgery. There is an increasing enthusiasm for minimally invasive lumbar fusion techniques using the Wiltse approach due to these advantages.

In 1982, Harms pioneered the surgical technique of transforaminal lumbar interbody fusion (TLIF) with the advantages of a posterior unilateral approach of interbody support combined with bilateral posterior pedicle screw fixation.[6] There were also reports of high rates of clinical fusion with this technique.[7,14,18] One drawback of this procedure is that although TLIF uses a unilateral approach, two separate incisions are still required for a bilateral posterior pedicle screw fixation. In the evolving surgical trend of minimally invasive spinal surgery, some surgeons are advocating for unilateral pedicle screw fixation. They report comparable fusion rates to bilateral pedicle screw fixation and the unilateral instrumentation has the additional advantages of significant reduction in operative time, length of hospital stay (LOS), and medical expense.[16] However, prior biomechanical studies demonstrate that unilateral constructs were consistently less stable than bilateral constructs.[5] Biomechanical data published by Slucky *et al*. confirmed using human cadaveric specimens that unilateral pedicle screw fixation resulted in increased segmental motion, less stiffness, and off axis rotational movement resulted in half of the stiffness of bilateral pedicle fixation.[15] The same authors also showed that unilateral pedicle screw fixation supplemented with translaminar facet screw fixation on the contralateral side offered stability comparable to bilateral pedicle screw fixation. Based on this cadaveric biomechanical data, the current study reports a novel surgical technique; a unilateral Wiltse approach for decompression, TLIF procedure and pedicle screw fixation, combined with a contralateral percutaneous transpedicular facet screw placement through a separate 1 cm mid-line incision. As mentioned, compared with most minimally invasive lumbar fusion surgeries, which require bilateral parasagittal incision for decompression, interbody fusion, and posterior instrumentation, this novel technique further minimizes the destruction of normal tissue and also reduces the surgical time and blood loss.

MATERIALS AND METHODS

All patients who underwent this new surgical technique of a minimally invasive one-level lumbar decompression and fusion surgery presented low back pain and radicular leg symptoms, usually with one leg more severe than the other. The TLIF procedure was performed on the side with the more severe leg symptoms. Magnetic resonance imaging (MRI) of these patients showed significant central canal stenosis with foraminal stenosis at the level intended for surgery. All surgeries were performed by one surgeon (JH).

Data about the age and gender of the patients, the length of surgery, the estimated blood loss (EBL), the LOS, and complications associated with the surgery were retrospectively collected through the Epic electronic medical record. All patients were followed up for at least 18 months after the surgery.

Surgical technique

Wiltse approach

The patient was put in prone position on a Jackson table. O-arm fluoroscopy was used for A/P and lateral imaging during the surgery. A 4 cm parasagittal incision was made at the level of interest. The incision is about 3 cm from the mid-line, or along the line of the pedicles. The incision was made on the right side or left side depending on which side of the leg the patient felt more radicular pain. After the incision was made and the lumbar fascia opened, the natural muscle plane between the multifidus and longissimus muscle groups were identified [Figure 1]. Blunt dissection was made through this muscle plane using the surgeon's index finger. The facet joint could be felt. Retractor was applied, and the facet joint exposed. The facet joint was removed by a combination of osteotome and power drill. The bony fragments were collected for later fusion use. Kerrison rongeur was used to complete the decompression and the nerve in the foramen was exposed and decompressed. If indicated, the central canal and even contralateral lateral recess could be decompressed using the Kerrison rongeur while compressing on the thecal sac. After satisfactory decompression of the neural structures, diskectomy

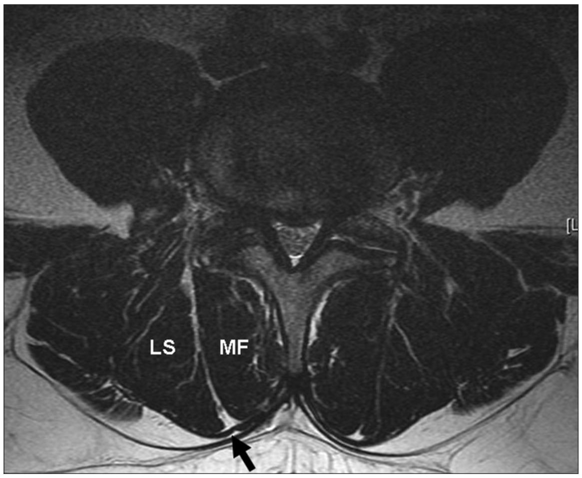

Figure 1: MRI of the axial view of lumbar spine and muscles. Arrow points to the path of Wiltse Approach, the muscle plane between the longissimus muscle (LS) and the multifidus muscle (MF)

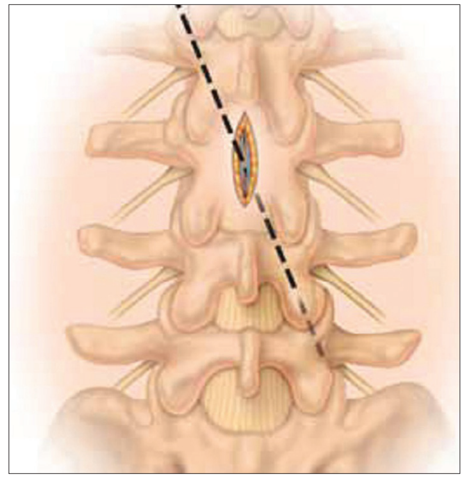

Figure 2a: Artist's drawing. 1 cm mid-line skin incision is made at least one level above the desired surgical level. The planned trajectory should begin at mid-line and proceeds medial to lateral. Aim for the center of the inferior articular process of the superior facet in order to cross the facet joint into the pedicle

was then performed through the Kambie's triangle.[8] Extra effort was made for a thorough diskectomy and preparation of the end plates to facilitate the interbody fusion. The interbody space was then packed with the graft materials. The graft materials were made up of the patient's autologous bone fragments from the removed facet joint and synthetic bone graft mixed with the patient's bone marrow aspirate from the vertebral body. A peek cage packed with the graft materials was then inserted obliquely from the Kambin's triangle into the disc space. Pedicle screws were then inserted through the same incision under direct visualization and with the help of lateral imaging. The pedicle screws were connected using a lordortic rod. The fascia and the skin were then closed with absorbable suture.

Percutaneous facet screw placement

A separate 1 cm mid-line incision was made at about one to two levels cephalad to the fusion level. The distance was adjusted according to the lordotic curvature and the body mass index of the patient. The planned trajectory aimed for the center of the contralateral inferior articular process of the superior facet in order to cross the facet joint into the pedicle [Figure 2]. A Jamshidi Needle was inserted through the mid-line incision and the tip was docked on the inferior articular surface of the superior facet. Trajectory was confirmed by using A/P and lateral fluoroscopy. In the A/P view, the tip of the needle was aimed toward the 5 or 7 O'clock position of the pedicle of the lower vertebra. In the lateral view, the trajectory was passing through the facet joint into the pedicle of the lower vertebra body. The Jamshidi Needle was gently tapped until the distal tip reached the inferior facet. The inner stylet of the Jamshidi Needle was removed, and a sharp tip guidewire was inserted into the Jamshidi Needle. Using a high-speed cannulated power drill, the guidewire was advanced across the superior and inferior facets and into the pedicle. The wire depth was confirmed with lateral fluoroscopy to ensure that the guidewire had reached beyond the pedicle into the body. The appropriate length of the facet screw was measured through the markings on the guidewire. The cannulated high-speed drill assembly was placed across the wire and the drill bit was advanced through the superior and inferior facets and into the pedicle. Using the cannulated self-retaining screwdriver, the lagged facet screw was guided through the guidewire, down to the inferior articular surface of the superior facet, and into the pedicle. The appropriate implant positioning with fluoroscopy to make sure that the facet joint is fully lagged and that the screw has been sufficiently tightened into position is then confirmed.

RESULTS

During the study period from January 2010 to December 2011, a total of 40 patients received a one-level decompression and TLIF with pedicle screws insertion through a unilateral Wiltse approach and then a contralateral percutaneous transpedicular facet screw insertion [Figures 3 and 4]. There were 20 men and 20 women with an average age of 57.5 (range, 27-82) years. Twenty-three patients had surgery at the L4-L5 level, 14 at the L5-S1 level, and 3 at the L3-L4 level. The average surgical time was 124 (range, 97-167) minutes. The surgery documented at 167 minutes was a trial of computer-assisted navigation system and was the only case where the navigation was used. The EBL of the surgery was 140 cc. No blood transfusion was necessary in any of these patients. The average LOS in the hospital after the surgery was 3 (range, 1-6) days.

During the routine clinic follow-up, all patients had shown improvement in their preoperative low back pain and radicular leg symptoms. However, two patients complained of new onset leg pain on the side where the facet screw was placed. Computed tomography (CT) scan suggests that the facet screw was not in the ideal position. Subsequently, they were brought back to the operating room to have the facet screw removed. One patient had resolved leg pain after the removal of the screw, the other did not. Other than these two complications, there were no postoperative complications such as wound infection or cerebrospinal fluid (CSF) leak. No other patients needed to be brought back to the operating room for reasons related to the original surgery. No patient developed radiographic instability at the level of fusion using flexion-extension view during the period of follow-up.

DISCUSSION

Studies have shown that unilateral pedicle screw fixation does not provide the same biomechanical stability when compared with bilateral posterolateral instrument fixation.[5,15] Currently, most minimally invasive lumbar fusion surgeries are performed through bilateral parasagittal incisions for decompression, interbody fusion, and bilateral pedicle screw fixation. Using human cadaveric specimens, Slucky *et al*. concluded that unilateral pedicle screw placement combined with contralateral translaminar facet placement provides a comparable biomechanical stability to TLIF with bilateral pedicle screw fixation.[5] Based on this biomechanical data generated from human cadaveric specimens, we performed a similar technique on 40 patients. The only difference between our surgical technique and the technique used by Slucky *et al*. with the cadaveric specimens is that we used percutaneous transpedicular facet screws instead of translaminar facet screws. In our study, none of the 40 patients developed radiographic instability at the level of fusion. However, there were two patients who developed new leg pain on the side where the facet screw was placed. Both patients subsequently had the facet screw removed and one patient's symptoms resolved. There is a learning curve for percutaneous facet screw placement. Finding the correct trajectories through A/P and lateral imaging is the key to successful placement

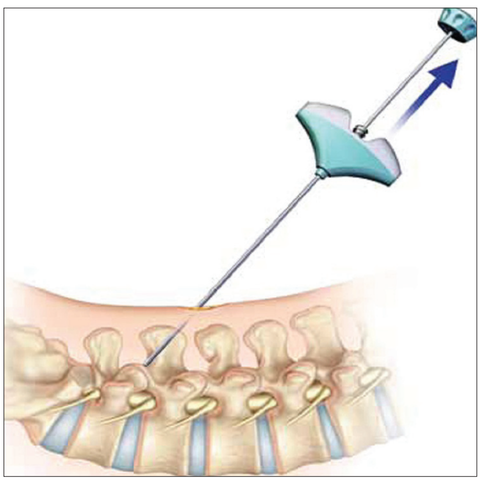

Figure 2b: Artist's drawing. Insert a Jamshidi Needle through the mid-line incision and dock the tip on the inferior articular surface of the superior facet. Confirm position by using lateral fluoroscopy. Gently tap the Jamshidi Needle until the distal tip has reached the inferior facet

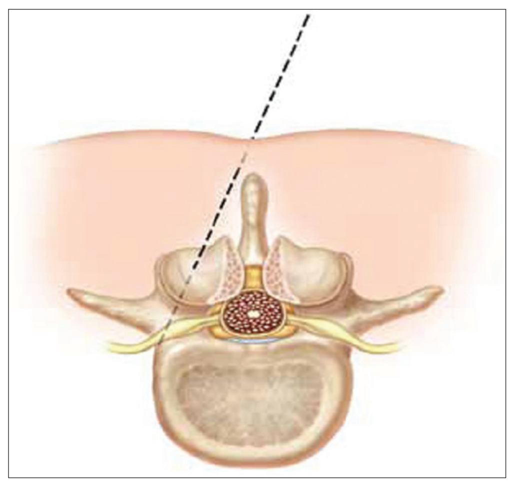

Figure 2c: Artist's drawing. Axial view to show the trajectory of the percutaneous facet screw

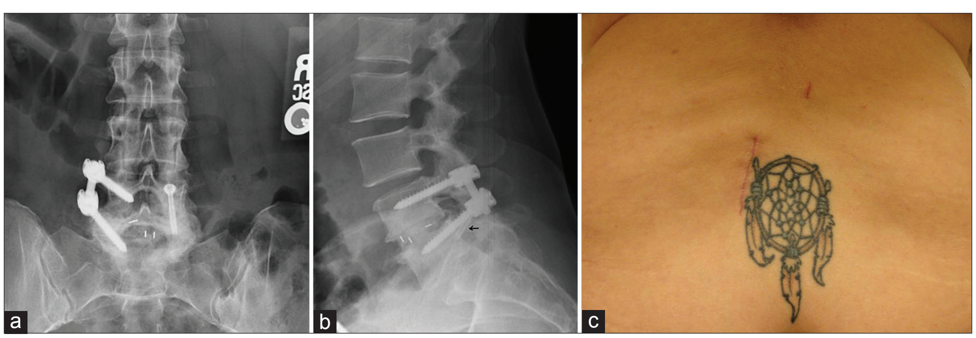

Figure 3: (a) Postoperative image of an A/P view to show the left TLIF with left side L4, L5 pedicle screw fixation and right side transpedicular facet screw. (b) Lateral view of the same patient. The arrow points to the location of the transpedicular facet screw. (c) Picture of the same patient showing the left side 4 cm incision for the TLIF and pedicle screw fixation. A mid-line 1 cm incision for the percutaneous transpedicular facet screw

Figure 4: (a) Sagittal CT image to show the transpedicular facet screw into the vertebral body. (b) Sagittal CT image to show bony interbody fusion

of the facet screw. Placement of the percutaneous facet screw is usually a 15-30 minute procedure, depending on the experience of the surgeon. Percutaneous facet screws are contraindicated in patients who have fracture at the pars interarticularis.

In addition to applying the *in vitro* biomechanical data using pedicle screws combined with facet screws into clinical practice, this technical report seeks to emphasize the importance of preserving the mid-line structures using the Wiltse approach. The traditional mid-line open approach for lumbar fusion surgery will inevitably cause a direct injury to the ligaments and paraspinal muscles. Furthermore, retraction of these muscles with excessive pressure can cause indirect injury resulting in muscular ischemia and atrophy.[12] Recently, many authors have studied the relationship between back muscle injury and excessive muscle dissection, retraction time and retraction pressure of the paraspinous muscles using histological, enzymological, and radiological quantification of back muscle injury and degeneration.[1,4,9,10] A direct surgical injury as well as indirect injury via prolonged retraction of the paraspinal muscles during posterior lumbar fusion surgery results in muscular atrophy and scarring and can cause postoperative dysfunction of the spinal muscles, ultimately leading to prolonged postoperative back pain.[1,10,12,17] One-level TLIF through the Wiltse approach has the advantage of minimizing muscle injury by bluntly dissecting through the natural muscle plane between the two muscle groups (multifidus and longissimus) through a skin incision of 4 cm or less. This approach thus preserves the integrity of all of the mid-line structures including the spinous processes, interspinous ligament, and attachments of the multifidus muscle to the spinous processes. The integrity of these structures is very important for spinal stability.[13] The back muscle is essential in the dynamic control of segmentation movement. A low level of co-contraction of the trunk muscles is necessary for core stability, which is an important concept in clinical rehabilitation.[2] There are reports showing that the Wiltse approach can reduce the degree of low back pain during the long-term follow-up after surgery.[11,12] With the preservation of the integrity of the mid-line structures, it will also be of great interest to see if one-level TLIF through the Wiltse approach will decrease the rate of adjacent level degeneration in long-term follow-up.

While the obvious advantages of unilateral Wiltse approach are reduced operative time, estimated blood loss, and postoperative incision pain, some may argue that a unilateral approach does not allow bilateral nerve root decompression. From our experience in the 40 patients, bilateral decompression through a unilateral approach can be done by compressing the thecal sac for contralateral decompression through an acute angle using the Kerrison rongeur, but this maneuver carries a higher risk of rending the dura. In addition to direct decompression, indirect decompression of the contralateral foramen can also be achieved by restoring the disc space height during the insertion of the interbody cage, or by correcting the low-grade spondylolisthesis during the process of pedicle screw fixation using a persuader.

This technical report is based on the case series of 40 patients from whom the data were retrospectively collected. There is insufficient data to determine the clinical outcome using a disability score and fusion rate assessed by CT scan. However, this report serves as a good pilot study of this technique based on the results of these 40 patients. A prospective study on the clinical and radiographic outcomes of patients who have surgery using the same technique is in progress. This report is to emphasize the technical aspect, advantages and safety of the TLIF procedure using the Wiltse approach followed by unilateral pedicle screw fixation supplemented with a contralateral percutaneous transpedicular facet screw construct. This new technique has advanced minimally invasive lumbar fusion surgery by allowing even less normal tissue destruction. Furthermore, the mechanical stability of this novel posterior instrumentation is also supported by biomechanical data generated from human cadaveric specimens.

CONCLUSION

In this study, we described an alternative minimally invasive surgery of one-level TLIF with posterior instrumentation using a novel technique of unilateral pedicle screw fixation supplemented with a contralateral percutaneous transpedicular facet screw construct. This technique provides a similar biomechanical stability to the traditional bilateral parasagittal approach but avoids a bilateral parasagittal dissection. This reduction of surgical morbidity and tissue disruption not only has the advantages of reducing surgical time and blood loss, but may also improve long-term patient outcomes in terms of postsurgical complication rate, fusion rate, pain, and disability.

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Commentary

The authors present a variant on the bilateral fixation of the posterior spinal structures using unilateral pedicle screws and translumbar interbody fusion (TLIF), and contralateral facet screw fixation. The authors claim that their approach provides similar stability to that obtained by bilateral screw fixation. They report 40 patients with 2 patients (5%) having neurological problems resulting from the facet screws.

While bilateral posterior column fixation is preferred in most fusion situations, and greater stability is obtained with bilateral pedicle screws, the stability required for a single level fusion can easily be achieved with unilateral pedicle screws. Numerous studies have shown that unilateral pedicle screw fixation is sufficient to achieve solid fusion in TLIF procedures, since the additional mobility provided by a unilateral fixation, is generally not enough to prevent fusion, absent a significant comorbidity, such as smoking, morbid obesity, severe osteoporosis, advanced age, or uncontrolled diabetes.

The morbidity added to the procedure by the facet screws, is easily understood by the graphic demonstration of the facet screw trajectory provided by the authors in their illustrations. The angle of incidence of the facet screw is too acute [Figure 2b], since it does not follow the direction of the pedicle, and instead traverses from the superior to the inferior margin of the pedicle. The acuteness of the angle of incidence is clearly demonstrated by the CT scan image, which shows the tip of the facet screw at the level of the cortex of the pedicle [Figure 4a]. Using fluoroscopic imaging, the probability of penetration of the cortex of the pedicle is greater, since it is hard to know exactly where the tip of the screw lies. It must be remembered that the exiting nerve root hugs the inferior surface of the pedicle above, and can be easily injured by any transgression of the pedicle cortex.

In over 350 cases without comorbidities, using computer navigation unilateral pedicle screw fixation and TLIF fusion, the incidence of contralateral nerve root injuries was zero, the incidence of fusion was 97%, average operative time was 90 minutes, estimated blood loss was 75 ml and length of stay was 1.7 days.

I believe the authors present an interesting alternative to single level lumbar fusion, but the approach leaves concerns to the practicing surgeon, that can be avoided by unilateral pedicle screw fixation.

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