SURGICAL TECHNIQUE

The “TFP” Fusion Technique for Posterior 360° Lumbar Fusion: a Combination of Open Decompression, Transforaminal Lumbar Interbody Fusion, and Facet Fusion with Percutaneous Pedicle Screw Fixation

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Because degenerative spondylolisthesis is prevalent in the elderly with associated osteoporosis, the rate of failure of pedicle screws is high; this leads to pseudoarthrosis and potentially requires reoperation. The burden of recurrent symptoms and reoperation is sufficiently significant to warrant prevention. We here describe a hybrid technique that involves a combination of a unilateral approach to bilateral decompression via a midline incision, transforaminal lumbar interbody fusion (TLIF), contralateral facet fusion, and percutaneously placed pedicle screws without compromising operative time and visualization. This approach is familiar to spine surgeons, adheres to the basic principles of minimally invasive spine surgery technique, minimizes dural and neural injury because of the unilateral TLIF approach, and provides a superior fusion construct because of facet fusion. In this procedure, patients with degenerative spondylolisthesis or scoliosis with moderate-severe canal/foraminal stenosis undergo a midline unilateral TLIF and contralateral facet fusion with closure of the midline incision. Percutaneous pedicle screws are inserted under stereotactic guidance with reduction of the deformity using a pedicle screws construct. Rods are inserted percutaneously to link the pedicle screws. Image intensification is used to confirmed satisfactory screw placement and reduction of the spondylolisthesis.

Key words: Degenerative deformity; Percutaneous lumbar pedicle screws; Transforaminal lumbar interbody fusion

Introduction

Degenerative lumbar spondylolisthesis associated with central canal stenosis and/or foraminal stenosis can present with neurogenic claudication and/or radiculopathy, respectively. In a non-randomized as-treated environment (with control of potentially confounding baseline factors) of patients with degenerative spondylolisthesis and spinal stenosis, the spondylolisthesis arm of the spine patient outcomes research trial (SPORT) concluded that, after 2 years, surgical outcomes were significantly better in regards to pain and function than in those treated non-surgically (SPORT trial)¹. One of the available treatment options for such cases is surgical

decompression with instrumented fixation. Open and minimally invasive surgery (MIS) options are equivalent in terms of functional and radiological outcomes; however, a few studies have reported less blood loss, less analgesic requirement, and earlier mobilization in the latter^{2,3}.

Although pedicle screw fixation is commonly utilized to provide rigidity to assist in fusion, its role is still controversial^{4,5}. Published reports cite high success rates for pedicle screw-augmented interbody fusion, however, there is a risk of failure of pedicle screws⁶. Because degenerative spondylolisthesis is prevalent in the elderly with associated osteoporosis, the rate of failure of pedicle screws is high; this

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Fig. 1 Rationale for MIS pedicle screw fixation: Minimization of muscle trauma with percutaneous pedicle screw insertion technique. (A) Normal anatomy of the lumbar vertebra. (B) Traditional fusion. (C) Minimally invasive fusion.

leads to pseudoarthrosis and potentially requires reoperation⁷. The burden of recurrent symptoms and reoperation is sufficiently significant to warrant prevention. Thus, we propose augmentation of fusion rigidity with facet fusion.

Although outcomes of minimally invasive posterior fusion techniques are comparable to those of open fusion techniques, there is concern about the accuracy of pedicle screw insertion, adequacy of central canal decompression, contralateral foraminal encroachment syndrome, and area available for fusion³.

The alternative to conventional open and minimally invasive posterior fusion techniques that is presented here involves a combination of open and minimally invasive approaches, with the aim of maximizing the benefits and avoiding the disadvantages of both approaches. We consider that the “TFP technique” (unilateral transforaminal lumbar interbody fusion [TLIF], contralateral facet fusion, and bilateral percutaneous screws) minimizes dural and neural exposure (unilateral exposure), augments the fusion construct by addition of facet fusion on the contralateral side, while retaining minimally invasive goals by utilizing percutaneous screws.

An open midline unilateral laminotomy with bilateral decompression and unilateral TLIF is performed at the level of the affected disc to minimize operative time and provide adequate exposure. This allows minimization of intraoperative adverse events as well as providing a contingency plan in the event of adverse events should they occur (e.g. incidental durotomy). The TLIF is augmented by facet fusion and a posterolateral graft is excluded to minimize muscle dissection and retraction laterally without compromising rates of

fusion. Finally, percutaneous pedicle screws are placed in all pedicles to minimize muscle dissection off the facet joints, thus minimizing post-operative wound pain (Fig. 1).

Technique

In Figure 2, we emphasize the important steps involved in the “TFP technique”. The first step involves unilateral laminotomy, neural decompression, discectomy, preparation of endplates, and insertion of an interbody cage. The contralateral facet joint is prepared to create a reasonable sized gutter (Fig. 3). Next, pedicle screws are inserted percutaneously and the spondylolisthesis reduced. The senior author (RJM) has also previously described the “80:20 technique” and “50:50 technique”⁸. Details of the TFP technique are as follows.

Step 1 – preoperative preparation

Under general anesthesia, the patient is positioned prone on a Jackson or similar operating table. It is essential that the operative table is radiolucent at the level of the surgery to facilitate image intensifier X-rays.

Step 2 – unilateral laminotomy, neural decompression, discectomy, preparation of endplates, and insertion of an interbody cage

A midline incision is performed directly over the appropriate disc space, the level being confirmed radiologically. Because lateral retraction is not necessary, only a short incision is required, most incisions being 3.5–5 cm long. A retractor system of the surgeon’s choice is used and unilateral laminectomy and inferior facetectomy (on the symptomatic side) is

Fig. 2 Workflow for TFP technique: (A) Midline incision with unilateral laminotomy. (B) Posterolateral view after performance of transforaminal lumbar interbody fusion. (C). Percutaneous screw insertion with contralateral facet fusion. (D) Wound closure showing the sizes of the incisions and demonstrating unilateral laminotomy and contralateral facet fusion.

performed, followed by central canal decompression and bilateral rhizolysis. In the senior author's (RJM) experience, central decompression from unilateral laminotomy is technically easy whereas contralateral rhizolysis is relatively challenging; however, with practice can result in effective decompression. The intervertebral disc is then removed and the endplates prepared (Fig. 3). The bone from the laminotomy and inferior facetectomy is cleaned of residual ligament/soft tissue and milled using a bone mill. It is then combined with osteobiologic materials before being packed into a TLIF cage that is then inserted into the disc space.

Step 3 – contralateral facet joint is prepared

The contralateral facet joint is identified and a gutter of reasonable size is fashioned in the joint using a curette and power driven drill. In addition, the exposed lamina and spinous processes are also roughened to create a large freshened area for fusion. Osteobiologics for fusion are laid inside the facet gutter and freshened bony surfaces (Fig. 2).

Step 4 – pedicle screws are inserted

A 3D Arcadis Orbic (Siemens, Erlangen, Germany) X-ray/II machine is moved into position to target the pedicles in anteroposterior and lateral views and a spin is done to help register the scan. Anatomical landmarks and a check screw inserted on a spinous process are used to confirm the accuracy of stereotaxy. Guided by stereotaxy, skin stab incisions are

made and extended to the fascia. A pedicle probe is inserted under stereotactic guidance, followed by insertion of a K-wire. The pedicle probe is removed and a tap threaded over the K-wire. Pedicle screws of appropriate size are inserted and the K-wire removed once the pedicle screws are beyond the pedicle and into the vertebral body. Pedicle screw placement is confirmed with the image intensifier. Reduction of the spondylolisthesis is then performed using the instrumentation of the surgeon's choice. Lastly, the four stab incisions are closed (Fig. 2) with a single suture for the deep fascia and a single suture for the skin incision. The midline incision is closed in layers: fascia, subcutaneous tissue and skin.

Step 5 – postoperative management

Following reversal of anesthesia, the patient is extubated post-operatively and transferred to the ward. Mobilization can be attempted from post-operative day 1. Post-operative CT of the lumbar spine is performed to confirm reduction of the spondylolisthesis, as well as satisfactory positioning of the interbody devices, bone graft and all four pedicle screws. Follow-up is routinely performed at 6 weeks with flexion/extension X-rays and 3 months with CT scan (Fig. 4) to confirm a solid fusion and reduction of the spondylolisthesis.

Discussion

Our posterior fusion technique has evolved from the previously described "80:20" technique⁸ to the current "TFP" technique, which incorporates unilateral TLIF and facet

Fig. 3 Intraoperative photographs of two level midline TLIF and facet fusion technique via “TFP” approach: (A) Midline incision and unilateral laminotomy and bilateral decompression (first level). (B) Discectomy and preparation of interbody (disc) space. (C) Two level laminotomies on one side with contralateral facet joint preparation (discectomy with cage and bone graft insertion not visible). (D) Final appearance of incisions.

fusion. The rationale for the TFP technique involves unique advantages at each step of the procedure.

The posterior midline approach is very familiar to spine surgeons. Interbody fusion provides high fusion rates comparable with, if not superior to, posterolateral fusion and has the potential to correct spondylolisthesis and improve coronal and sagittal balance⁹. As compared with posterior lumbar interbody fusion, the TLIF technique limits dural and nerve root retraction and provides more bone to utilize for fusion⁹. That it is a unilateral TLIF approach further diminishes the risk of dural and nerve root injury. In addition, the surgical corridor can be extended if occurrence of adverse events requires this.

Although, in a prospective study, Zdeblick proved that addition of pedicle screws improves the fusion rates in lumbar fusions⁶, this instrumentation provides stable construct only in the early postoperative period; in the long-term bony fusion is needed for durability of the fusion construct¹⁰. There is no definition of “adequate rigidity” in regard to interbody fusion; although no published studies have substantiated this, additional augmentation would likely be beneficial⁷. Facet fusion can be added to posterior or posterolateral fusion by careful curettage of the joint followed by insertion of bone graft⁸, thus augmenting stability and possibly eliminating facetogenic back pain. Both biomechanical and clinical studies have proven that facet fusion is equivalent to pedicle screws^{9,10}. Generally facet fusion (instrumented) is presented as an alternative to pedicle

screw technique¹⁰. The current technique utilizes bony facet fusion rather than an instrumented alternative; however, pedicle screws are also utilized.

The basic principles of a MIS approach in spine surgery are: (i) avoid muscle crush injury by using self-retaining retractors; (ii) do not disrupt tendon attachment sites of key muscles, particularly the origin of the multifidus muscle from the spinous process; (iii) use known anatomic neurovascular and muscle compartment planes; and (iv) minimize collateral soft tissue injury by limiting the width of the surgical corridor¹¹. The TFP technique utilizes several of these principles. A midline incision without spinous process removal prevents damage to the multifidus attachment. Although a self-retaining retractor is employed, the total time of retraction is minimal because the retractor is removed once TLIF and facet fusion have been completed. Hence, crushing of the multifidus muscle is minimized. The percutaneous pedicle screws are inserted through separate incisions, utilizing the natural anatomical planes to split muscles, without midline retractors *in situ*. Denervation of the muscle is prevented, because the midline dissection is limited in extent (hence away from the medial posterior ramus).

Proponents of minimally invasive posterior fusion techniques cite reduced destruction of soft tissues, leading to reduced postoperative pain, analgesia and length of stay^{2,3,8}. One option is medio-latero-superior trajectory of pedicle screw insertion¹². They do acknowledge, however, that limited

Fig. 4 CT scans 3 months post operation: (A) Coronal view of facet fusion. (B) Coronal view of interbody fusion. (C) Axial CT demonstrating unilateral laminotomy with contralateral facet fusion. (D) Sagittal view of facet fusion.

exposure potentially increases the chance of intra-operative adverse events and that there is a small operative field for correcting any adverse events, such as an unintended durotomy. Although contentious, previous studies have shown that both intra-operative durotomy rates and the length of the procedure are increased compared with open techniques^{4,13}.

By combining open midline exposure and retaining percutaneous pedicle screws, the TFP technique gains the advantages and potentially avoids the disadvantages of both open

and MIS techniques. In addition, this technique has the advantage of achieving superior fusion construct because we also perform facet fusion; this is unique to this technique.

The TFP technique, combining as it does a unilateral midline approach to bilateral decompression and TLIF with contralateral facet fusion combined with percutaneous pedicle screw fixation is an MIS technique that minimizes post-operative wound pain and dural and neural injury while allowing for superior fusion (because of the addition of facet fusion).

References

1. Weinstein JN, Lurie JD, Tosteson TD, *et al.* Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. *N Engl J Med*, 2007, 356: 2257–2270.
2. Ghahreman A, Ferch RD, Rao PJ, Bogduk N. Minimal access versus open posterior lumbar interbody fusion in the treatment of spondylolisthesis. *Neurosurgery*, 2010, 66: 296–304.
3. Archavlis E, Carvi y Nieves M. Comparison of minimally invasive fusion and instrumentation versus open surgery for severe stenotic spondylolisthesis with high-grade facet joint osteoarthritis. *Eur Spine J*, 2013, 22: 1731–1740.
4. Schwender JD, Holly LT, Rouben DP, Foley KT. Minimally invasive transforaminal lumbar interbody fusion (TLIF): technical feasibility and initial results. *J Spinal Disord Tech*, 2005, 18 (Suppl.): S1–S6.
5. Bjarke Christensen F, Stender Hansen E, Laursen M, Thomsen K, Büngrer CE. Long-term functional outcome of pedicle screw instrumentation as a support for posterolateral spinal fusion: randomized clinical study with a 5-year follow-up. *Spine*, 2002, 27: 1269–1277.
6. Zdeblick TA. A prospective, randomized study of lumbar fusion. Preliminary results. *Spine*, 1993, 18: 983–991.
7. Wu ZX, Gong FT, Liu L, *et al.* A comparative study on screw loosening in osteoporotic lumbar spine fusion between expandable and conventional pedicle screws. *Arch Orthop Trauma Surg*, 2012, 132: 471–476.
8. Mobbs RJ, Sivabalan P, Li J, Wilson P, Rao PJ. Hybrid technique for posterior lumbar interbody fusion: a combination of open decompression and percutaneous pedicle screw fixation. *Orthop Surg*, 2013, 5: 135–141.
9. Grob D, Humke T. Translaminar screw fixation in the lumbar spine: technique, indications, results. *Eur Spine J*, 1998, 7: 178–186.
10. Sethi A, Lee S, Vaidya R. Transforaminal lumbar interbody fusion using unilateral pedicle screws and a translaminar screw. *Eur Spine J*, 2009, 18: 430–434.

11. Kim CW. Scientific basis of minimally invasive spine surgery: prevention of multifidus muscle injury during posterior lumbar surgery. *Spine*, 2010, 35 (26 Suppl.): S281–S286.

12. Mobbs RJ. The “medio-latero-superior trajectory technique”: an alternative cortical trajectory for pedicle fixation. *Orthop Surg*, 2013, 5: 56–59.

13. Polly DW Jr, Santos ER, Mehdod AA. Surgical treatment for the painful motion segment: matching technology with the indications: posterior lumbar fusion. *Spine*, 2005, 30 (16 Suppl.): S44–S51.