Formosan Journal of Musculoskeletal Disorders 1 (2010) 26–30

Contents lists available at ScienceDirect

Formosan Journal of Musculoskeletal Disorders

journal homepage: www.e-fjmd.com

Original Article

Minimal invasive transforaminal lumbar interbody fusion and percutaneous pedicle fixation—A preliminary experience

Gary Rau [a], Chang-Jung Chiang [a,b], Yi-Jie Kuo [a,c], Chia-Hsien Chen [a,d], Yang-Hwei Tsuang [a,*]

[a] Department of Orthopaedic Surgery, Taipei City Hospital, Taipei, Taiwan
[b] Institute of Biomedical Engineering, National Yang-Ming University, Taipei, Taiwan
[c] Institute of Clinical Medicine, National Yang-Ming University, Taipei, Taiwan
[d] Institute of Microbiology and Immunology, National Yang-Ming University, Taipei, Taiwan

Keywords:
minimally invasive decompression
percutaneous pedicle fixation
transforaminal lumbar interbody fusion

A B S T R A C T

Introduction: Standard techniques for lumbar decompression, fusion, and pedicle screw fixation involve open exposures, extensive muscle dissection, and posterior element destruction. The purpose of this study was to report the initial clinical experience with minimally invasive decompression, transforaminal interbody fusion, and percutaneous pedicle fixation of the lumbar spine.

Aim: Transforaminal lumbar interbody fusion (TLIF), a unilateral posterior approach for achieving interbody arthrodesis, is performed through a unilateral facetectomy, which will expose the posterolateral disc space. To perform discectomy, distraction is through posterior element. After discectomy is done, a bullet-shaped cage is inserted into the interspace. After decompression and fusion, percutaneous pedicle fixation is applied with minimal manipulation and muscle dissection.

Methods: Twenty-one patients (8 men and 13 women with age ranged from 39 to 86 years) underwent minimal invasive TLIF and pedicle screw fixation in which the rod insertion device was used. All patients underwent successful percutaneous fixation. Seven patients underwent single-level fusions, and 14 underwent two levels. All patients underwent preoperative radiographic and magnetic resonance imaging examination were then followed up with computed tomography after 12 months.

Conclusion: The use of minimally invasive decompression, TLIF, and percutaneous lumbar pedicle screw placement in spinal patients offers several distinct advantages over conventional open surgery. It eliminates the need for a large midline incision and significant paraspinous muscle dissection. Pedicle screws and rod insertion are placed through stab incisions. Paraspinous muscles are bluntly split compared with complete dissection, leading to potentially shorter periods of hospital stay and recovery. Blood loss and tissue injuries are minimized. The goal of this minimally invasive surgery is to minimize approach-related morbidity while retaining the same results as more traditional invasive approaches. Certainly, preliminary experience with the procedure has been promising.

1. Introduction

Minimal invasive surgery has become a trend in recent years. In spine surgery, transforaminal lumbar interbody fusion (TLIF) has gained more popularity over posterior

* Corresponding author. Yang-Hwei Tsuang, Department of Orthopaedic Surgery, Taipei City Hospital, 145 Zheng Zhou Road, Taipei 10341, Taiwan. Tel.: +886 2 2552 3234x3698; fax: +886 2 2559 6548.
E-mail address: tsuangyh@ms28.hinet.net (Y.-H. Tsuang).

2210-7940/$ – see front matter
doi:10.1016/j.fjmd.2010.10.005

lumbar interbody fusion (PLIF) due to its far-lateral procedure, which allows less mobilization of the thecal sac, and minimal, if any, neural retraction. This far-lateral approach could decrease muscle damage by less muscle dissection and make minimal invasive approach possible. The TLIF procedure could provide equal or even better fusion rate compared with PLIF and conventional posterolateral fusion method, but TLIF is more technically demanding.[3,13]

Pedicle screw-rod fixation is often used to enhance the initial stiffness of the fusion construct. However, conventional pedicle screw instrumentation requires extensive soft tissue dissection and muscle retraction to expose anatomic landmarks for a proper lateral-to-medial screw insertion. This creates more damage to paraspinous musculature, more perioperative blood loss, and prolongs operative time. It also increases the risk of postoperative pain, instrumentation failure, neurologic injury and lengthened recovery time.[11,20,21] Recently, percutaneous placement of pedicle screws and rods are gradually on the rise because of its theoretical benefits to reduce the drawbacks of conventional pedicle screw implantation.[5,6,11]

In the present study, we report our experiences with minimal invasive TLIF (mis-TLIF) and percutaneous pedicle screw fixation for the treatment of single-level and two-level degenerative lumbar instability.

2. Materials and methods

2.1. Patient population

A total of 21 patients underwent mis-TLIF and percutaneous pedicle fixation procedure at the Taipei City Hospital between December 2007 and December 2008. There were 8 men and 13 women with age ranging from 39 to 86 years (average, 61 years). The index diagnosis was degenerative disc disease with herniated nucleus pulposus in 12 patients, Grade I spondylolisthesis in 8 patients, and Grade II in 1 patient. Fourteen patients required a two-level fusion, and seven patients required a single-level fusion. Of the single-level fusions, one was at L2–L3, two were at L3–L4, and four were at L4–L5. Of the two-level fusions, 1 was from L2 to L4, 12 were from L3 to L5, and 1 was from L3 to S1 (Table 1).

Table 1
Summary of preoperative findings and fusion levels.

Characteristics	Patients ($N = 21$)
Male	8
Female	13
Preoperative findings	
Grade I spondylolisthesis	8
Grade II spondylolisthesis	1
Spondylosis with radiculopathy	12
No. of fusion levels	
Single level	7
L2–L3	1
L3–L4	2
L4–L5	4
Two levels	14
L2–L3–L4	1
L3–L4–L5	12
L4–L5–S1	1

2.2. Surgical technique of mis-TLIF and percutaneous pedicle screw fixation

The mis-TLIF procedure was performed on the more symptomatic side. The whole procedure was under the control of a C-arm image intensifier. A 2.5 cm skin incision deep through fascia was made about 4 cm lateral to the midline on the interspace of interest. Sequential tubular dilators were inserted to create muscle-sparing tract, and then MAST Quadrant dilating retractors (Medtronic Sofamor Danek, Memphis, TN, USA) were placed onto the facet complex. A facetectomy was performed using a high-speed burr or osteotome to expose the posterolateral aspect of the targeted disc, and the disc space preparation was followed by a standard discectomy and cartilaginous endplate removal. Xenograft bone substitute (Sinbone, Purzer, Taiwan) and a commercially prepared allograft demineralized bone matrix, Allomatrix (Wright Medical Technology, Inc., Arlington, TN, USA), were placed anteriorly and contralaterally within the disc space, followed by one Capstone cage insertion (Medtronic Sofamor Danek, Memphis, TN, USA). Fluoroscopy was used to ensure satisfactory placement of the cage.

An 11-gauge Jamshidi needle was positioned on the lateral border of the pedicle through the previous incision under fluoroscopic guidance, followed by trocar into the pedicle, and then a 1.8-mm blunt-tipped guide wire replaced the Jamshidi needle. Screw tapping was done, and desired pedicle screw (Sextant system; Medtronic Sofamor Danek, Memphis, TN, USA) was inserted into vertebral body. Similar procedure was repeated on another targeted pedicle ipsilaterally. The soft tissue passage for rod insertion was dilated by a blunt tip trocar, and then a precontoured rod was passed through both screw heads under fluoroscopic confirmation. The screw constructs were compressed and set screws tightened. The entire process was repeated for the contralateral side, after which the incisions were irrigated and closed.

2.3. Clinical and radiological assessments

All patients underwent preoperative evaluations including clinical examination, static and dynamic plain lumbar spine radiography, computed tomography (CT), and/or magnetic resonance imaging. Plain radiography was performed at 3 months, 6 months, and then every 6 months after surgery to assess fusion status. Solid fusion on plain radiographs was further confirmed by CT follow-up 1-year postoperatively. Solid fusions were judged by two individual orthopedists on radiographs through trabecular bony bridging, based on the Bridwell classification.[14]

Clinical outcomes in terms of neurogenic symptoms, visual analog scale (VAS) for back and leg pain, and Oswestry Disability Index (ODI) scores were evaluated preoperatively, postoperatively, and 1 year after surgery. Odom criteria were also used to assess clinical improvements after surgery.

3. Results

The minimum follow-up was 12 months (range, 12–24 months). There were no conversions from minimally invasive

Table 2
Perioperative parameters of the patients.

Parameters	Single-level fusions	Two-level fusions
Average operative time (min)	198 (190–215)	350 (240–525)
Mean estimated blood loss (mL)	60.7 (50–100)	318 (50–550)
Average length of stay (d)	6 (4–8)	7 (4–8)

approach to an open surgery. For single-level fusions, the average operative time was 198 minutes (range, 190–215 minutes). The mean estimated blood loss was 60.7 mL (range, 50–100 mL). The average length of stay was 6 days (range, 4–8 days). For two-level fusions, the average operative time was 350 minutes (range, 240–525 minutes). The mean estimated blood loss was 318 mL (range, 50–550 mL). The average length of stay was 7 days (range, 4–8 days) (Table 2). All 21 patients in this series with preoperative radiculopathy had resolution of their symptoms postoperatively. Patients increased their daily activity levels progressively and returned to full activity at 3 months postoperatively. There were significant decreases in terms of both VAS and ODI scores (Table 3), and satisfaction level ranged from good to excellent (84.7%). At a minimum of 12 months' follow-up, all cases showed solid fusions on radiographs and CT images through trabecular bony bridging, no loosening of hardware, and $<3^{\circ}$ of motion on flexion-extension views (Figs. 1 and 2).

Table 3
Pain and disability scores in 21 patients.

Scale	Preoperative scores	3-month postoperative scores	12-month postoperative scores
VAS	8.0 (5–10)	2.5 (0–8)	2.0 (0–5)
ODI	45 (12–81)	25 (0–60)	14 (0–58)

VAS = visual analog scale; ODI = Oswestry Disability Index.

4. Discussion

Lumbar interbody fusion technique provides a "360°" spinal fusion by maintaining load-bearing capacity; this has been reported to have higher fusion rates than posterolateral onlay technique.[3,12,13] There is also growing evidence that a unilateral posterior-only approach (TLIF) to achieve interbody lumbar fusion may be as effective as or better than bilateral approach (PLIF).[1,2,9] The transforaminal approach of lumbar interbody fusion not only completes medial and lateral decompressions and restores intervertebral disc height but also lessens the need for significant retraction and manipulation of nerve roots or thecal sac while accessing the disc space.[1,7,8] Although there are many potential benefits to TLIF procedures, conventional open technique does have its drawbacks such as iatrogenic soft tissue and muscle injury during surgical exposure. The prolonged usage of retractor blades[14] pressurize the paraspinous muscle during surgery and leads to muscular ischemic changes with elevated serum level of creatine phosphokinase, a direct marker of muscle injury.[4,10] This iatrogenic muscle injury could cause long-term problems resulting in trunk muscle weakness.[11,15,19]

The development of serial tubular dilator devices allows the spinal surgeon to dissect muscle and fascia through fiber splitting method, which minimizes tissue trauma and decrease the risk of muscle bleeding. This minimally invasive approach method could be easily performed in the paraspinous muscular area and make TLIF procedure feasible.

Fig. 1. A 52-year-old female with L4–L5 Type IIa Grade I spondylolisthesis received minimal invasive transforaminal lumbar interbody fusion with cage insertion and percutaneous pedicle fixation at 1-year follow-up.

Fig. 2. A 69-year-old female presented with L2–L3 and L3–L4 spondylosis with instability. She received two-level minimal invasive transforaminal lumbar interbody fusion with cage insertion and percutaneous pedicle fixation at 1-year follow-up. Computed tomography showed trabecular bony bridging.

Pedicle screw is the standard means to internally immobilize the targeted spinal segments and thereby enhances the fusion rate. However, for an ideal lateral-to-medial screw trajectory, a significant degree of tissue dissection and muscle retraction are required which increases blood loss, postoperative pain, and possibly poor outcomes. Combination of tubular dilator system, cannulatedly designed pedicle screw with polyaxial screw head, and fluoroscopic guidance, percutaneous placement of pedicle screws diminishes injury to adjacent structures while accomplishing the same goal of rigid fixation.[5,16,17]

In this study, the authors successfully performed mis-TLIF procedures with percutaneous pedicle fixations in 21 patients using the Sextant system. As a result, the estimated blood loss of one-level spinal fusion in our series averaged only 60.7 mL, 318 mL in two-level fusion, including pedicle screw placement. In this series, 3 of the 21 patients (14.3%) required intraoperative blood transfusion; of the patients who required transfusion, all underwent two-level fusions. This happened quite early in this series and may be due to unfamiliar procedural steps and progressive learning curve and also the anesthesiologist's decision. The average hospital stay for one-level and two-level fusions is 6 days and 7 days, respectively. Compared with our open procedures,[2] in the beginning of the study, hospital stay days did not drop drastically because of the novel technique, but as our series went on, hospital stay did decrease. Another reason for longer hospital stays is patient's insurance reimbursement, in which patient wishes to stay due to their insurance coverage. The VAS and ODI data showed drastic reduction after this operation. Patients are all satisfied with this surgical procedure.

Although mis-TLIF procedure has many potential benefits, there are some limitations and drawbacks in the current study. First, we reported relatively longer operative time in our series, 198 minutes in one-level fusion and 350 minutes in two-level compared with the study by Schwender et al.[18] This is probably due to early phase in our experience and requirement for a longer learning curve to master this new surgical technique. In this minimally invasive approach, anatomic disorientation could easily occur due to the smaller working area created for accessing the disc space and pedicle insertion. It is truly more technically demanding than open surgery. In addition, spinal surgeons must be familiar with anteroposterior and lateral fluoroscopic images for applying pedicle screws accurately and safely. Second, there is no group-matched open TLIF for comparison, and the follow-up period is too short. However, at the end of follow-up, we observed fusion achieved in all patients according to the bony bridge formation on radiographs and CT.

In our experience, mis-TLIF with percutaneous pedicle screw fixation offers a number of advantages including less blood loss, less initial postoperative pain due to minor muscle damage, shorter hospitalization, faster recovery time, and similarly good clinical outcomes and fusion rate.[18] Although it is technically demanding, this procedure is feasible with relative lower complication and promising outcomes. Further prospective studies investigating long-term clinical and functional outcomes are needed to assess the definitive merits of this technique in the spine.

References

1. C.A. Chastain, J.C. Eck, S.D. Hodges, S.C. Humphreys, P. Levi, Transforaminal lumbar interbody fusion: a retrospective study of long-term pain relief and fusion outcomes, Orthopedics 30 (2007) 389–392.
2. C.H. Chen, Y.J. Kuo, C.J. Chiang, Y.H. Tsuang, Perioperative comparison of transforaminal lumbar interbody fusion and posterior lumbar interbody fusion using cages for treatment of degenerative lumbar disorders, J Orthop Surg Taiwan 26 (2009) 120–126.
3. C.L. Branch Jr., The case for posterior lumbar interbody fusion, Clin Neurosurg 47 (2000) 252–267.
4. R.D. Dickerman, J.W. East, K. Winters, J. Tackett, A. Hajovsky-Pietla, Anterior and posterior lumbar interbody fusion with percutaneous pedicle screws: comparison to muscle damage and minimally invasive techniques, Spine 34 (2009) E923–E952.
5. K.T. Foley, S.K. Gupta, J.R. Justis, M.C. Sherman, Percutaneous pedicle screw fixation of the lumbar spine, Neurosurg Focus 10 (2001) E10.
6. K.T. Foley, S.K. Gupta, Percutaneous pedicle screw fixation of the lumbar spine: preliminary clinical results, J Neurosurg 97 (1 Suppl) (2002) 7–12.
7. L. Hackenberg, H. Halm, V. Bullmann, V. Vieth, M. Schneider, U. Liljenqvist, Transforaminal lumbar interbody fusion: a safe technique with satisfactory three to five year results, Eur Spine J 14 (2005) 551–558.
8. J.K. Houten, N.H. Post, J.W. Dryer, T.J. Errico, Clinical and radiographically/neuroimaging documented outcome in transforaminal lumbar interbody fusion, Neurosurg Focus 20 (2006) E8.
9. S.C. Humphreys, S.D. Hodges, A.G. Patwardhan, J.C. Eck, R.B. Murphy, L.A. Covington, Comparison of posterior and transforaminal approaches to lumbar interbody fusion, Spine 26 (2001) 567–571.
10. Y. Kawaguchi, S. Yabuki, J. Styf, K. Olmarker, B. Rydevik, H. Matsui, H. Tsuji, Back muscle injury after posterior lumbar spine surgery. Topographic evaluation of intramuscular pressure and blood flow in the porcine back muscle during surgery, Spine 21 (1996) 2683–2688.
11. D.Y. Kim, S.H. Lee, S.K. Chung, H.Y. Lee, Comparison of multifidus muscle atrophy and trunk extension muscle strength: percutaneous versus open pedicle screw fixation, Spine 30 (2005) 123–129.
12. Z. Lidar, A. Beaumont, J. Lifshutz, D.J. Maiman, Clinical and radiological relationship between posterior lumbar interbody fusion and posterolateral lumbar fusion, Surg Neurol 64 (2005) 303–308.

13. M.R. McLaughlin, R.W. Haid Jr., G.E. Rodts, B.R. Subach, Posterior lumbar interbody fusion: indications, techniques, and results, Clin Neurosurg 47 (2000) 514–527.
14. C.W. Peng, W.M. Yue, S.Y. Poh, W. Yeo, S.B. Tan, Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion, Spine 34 (2009) 1385–1389.
15. J. Rantanen, M. Hurme, B. Falck, H. Alaranta, F. Nykvist, M. Lehto, S. Einola, et al., The lumbar multifidus muscle five years after surgery for a lumbar intervertebral disc herniation, Spine 18 (1993) 568–574.
16. F. Ringel, M. Stoffel, C. Stüer, B. Meyer, Minimally invasive transmuscular pedicle screw fixation of the thoracic and lumbar spine, Neurosurgery 59 (2006) ONS361–ONS366.
17. K.M. Scheufler, H. Dohmen, V.I. Vougioukas, Percutaneous transforaminal lumbar interbody fusion for the treatment of degenerative lumbar instability, Neurosurgery 60 (2007) 203–213.
18. J.D. Schwender, L.T. Holly, D.P. Rouben, K.T. Foley, Minimally invasive transforaminal lumbar interbody fusion (TLIF) technical feasibility and initial results, J Spinal Disord Tech 18 (Suppl 1) (2005) S1–S6.
19. T. Sihvonen, A. Herno, L. Paljärvi, O. Airaksinen, J. Partanen, A. Tapaninaho, Local denervation atrophy of paraspinal muscles in postoperative failed back syndrome, Spine 18 (1993) 575–581.
20. K. Thomsen, F.B. Christensen, S.P. Eiskjaer, E.S. Hansen, S. Fruensgaard, C.E. Bünger, 1997 Volvo Award winner in clinical studies. The effect of pedicle screw instrumentation on functional outcome and fusion rates in posterolateral spinal fusion. A prospective, randomized, clinical study, Spine 22 (1997) 2813–2822.
21. B.R. Weber, D. Grob, J. Dvorak, M. Müntener, Posterior surgical approach to the lumbar spine and its effect on the multifidus muscle, Spine 22 (1997) 1765–1772.