Advantages of Minimally Invasive Spine Surgery: A Literature Review

Peyman Pakzaban, MD
Houston MicroNeurosurgery

The impetus for devising a minimally invasive (MIS) approach to lumbar fusion was conceived in the 1990s when several studies showed significant adverse effects on the paraspinal musculature after lumbar spine surgery [1-5] . The unequivocal demonstration of histologic [4], anatomic [1, 2], radiographic [3], and functional [3, 5] damage to the paraspinal muscles after surgery led to the hypothesis that avoidance of such muscle damage may improve long-term functional outcome after lumbar fusion. In 2003, Foley et al. first described minimally invasive lumbar fusion and percutaneous pedicle screw fixation with the primary intent of minimizing paraspinal muscle injury [6]. Soon thereafter, Mummaneni and Rodts described mini-open transforaminal interbody fusion which aimed to provide better visualization for interbody access while maintaining the muscle-sparing benefits of percutaneous fusion [7].

Over the decade since the inception of these techniques, it has been demonstrated that MIS approaches (percutaneous and mini-open) reduce muscle damage [8-11] and provide long-term functional and radiographic outcomes that are equivalent but not superior to open fusion [12-17]. Although the original goal of improving upon the long-term outcome of lumbar fusion has not (yet) been achieved, there is abundant evidence that MIS fusion results in less blood loss, less post-operative pain, shorter hospital stays, faster recovery and fewer post-operative infections [8, 12-22]. Additionally, cost savings have been demonstrated with MIS compared to open fusion [23-25] – a factor that cannot be ignored in an increasingly cost-conscious medical environment. Certain highlights of these studies are summarized below.

Paraspinal Muscle Injury

In a prospective comparison of patients with open vs. MIS fusion, Kim et al. demonstrated significantly higher levels of serum markers of muscle injury (creatinine kinase and aldolase) and pro-inflammatory cytokines (IL-6 and IL-8) in the open fusion cohort [9]. In another study, creatinine kinase levels were found to be lowest when percutaneous pedicle screws were used in combination with anterior rather than posterior interbody fusion [11]. Fan et al. demonstrated that the increase in creatinine kinase correlated with greater multifidus muscle edema and atrophy levels after open fusion compared to MIS fusion [10]. Consistent with these findings, Stevens et al. demonstrated that the maximum intramuscular pressure was significantly less after the use of minimally invasive retractors compared to open retractors and that less muscle edema and injury was visible on 6-month post-operative MRI in MIS fusions compared to open fusions [8].

Intra-operative Blood loss, Post-Operative Pain, Recovery Rate and Outcome

In a prospective study of 85 patients with low-grade spondylolisthesis (42 patients treated with MIS TLIF vs. 43 patients with open TLIF), Wang et al. found significantly less blood loss, less need for transfusion, less postoperative pain and shorter hospital stays in the MIS group [12]. Clinical and radiographic outcomes were equivalent at 13-month minimum follow-up. In another prospective study of one-level MIS TLIF vs. open fusion, blood loss, transfusion, post-operative pain, serum creatinine kinase levels, time to ambulation and duration of hospital stay were found to be less in the MIS group [18]. Similarly, another short-term study by Rodriguez-Vela et al. demonstrated less blood loss, shorter hospital stay and significantly lower analgesics requirements in patient undergoing mini-open TLIF compared to open fusion [19]. A detailed short- and long-term prospective study by Peng et al. revealed less blood loss in MIS (150 ml) versus open (681 ml) TLIF procedures ($P < 0.05$). The total morphine used for MIS cases (17.4 mg) was less compared to open cases (35.7 mg, $P < 0.05$). MIS patients had shorter hospitalization (4 days) compared to open fusion patients (6.7 days, $P < 0.05$). Both groups showed significant improvements in Oswestry Disability Index (ODI) and Visual Analogue Scores (VAS) at 6 months and 2 years post-operatively with no significant inter-group difference.

In a prospective single-surgeon study of 61 patients who underwent single-segment PLIF either through an MIS retractor or through an open approach, Park et al. found no significant clinical or radiographic difference between the two groups at 1-year minimum follow-up, but found significantly less blood loss, less need for transfusion, less postoperative back pain, shorter recovery before ambulation, and shorter length of hospital stay [14]. Similar short term benefits were found in a retrospective study of MIS vs. open PLIF for single-segment fusion by Ntoukas and Muller with no difference in clinical or radiographic outcome at 1 year [15]. A retrospective comparison of mini-open TLIF to open TLIF by Dhall and Mummaneni in

42 patients with degenerative disc disease or spondylolisthesis showed no difference in long term clinical outcome but significantly shorter length of stay and blood loss in the mini-open group [16]. More recently, a long-term retrospective study of MIS TLIF vs. open TLIF for grade 1 degenerative spondylolisthesis by Adogwa et al. showed shortened hospital stays, reduced post-operative narcotic use and accelerated return to work in the MIS group with equivalent long-term improvements in pain and disability scores at 2 years [17].

Infection

Parker et al. performed a systematic review of the literature to determine the incidence of surgical site infections in MIS vs. open TLIF procedures [20]. They found 10 reported MIS TLIF cohorts (362 patients) and 20 open TLIF cohorts (1,133 patients) containing data on infection rates. The cumulative incidence of infection was found to be 0.6% in MIS TLIF vs. 4% in open TLIF (p=.0005). Utilizing their own institution's data, they estimated direct cost savings of $98,974 per 100 MIS TLIF cases related to infection avoidance. McGirt et al. took a different approach, looking at hospital billing and discharge records from a large patient database over a 6-year period to identify surgical site infection rates in minimally invasive PLIF and TLIF procedures vs. open fusions [21]. In 5,170 patients, the overall surgical site infection rate was 5.6%. There was no statistically significant difference in infection rates in one-level fusions (4.5% in MIS vs. 4.8% in open, p=0.77). However, a significant difference between MIS and open fusion infection rates was found in 2-level fusions (4.6% in MIS vs. 7.0% in open, p = 0.037).

Cost

Parker et al. performed a prospective 2-year analysis of direct and indirect costs on a small group of 30 patients undergoing MIS TLIF vs. open fusion [25]. They included data on the cost of medical resources, missed work and health state values (quality-adjusted life years). The mean total 2-year cost was $35,996 for MIS TLIF vs. $44,727 for open fusion. The $8,731 cost saving per patient did not reach statistical significance (p = 0.18) in this study because of the small sample size. In contrast, Wang et al. did find a statistically significant cost saving for MIS fusion when they analyzed a large US database of 6,106 lumbar fusion patients [23]. They looked at direct costs (hospitalization expenses) for one- and two- level lumbar fusions and excluded revision surgeries, deformity cases and anterior fusion. A covariance analysis was carried out to adjust for comorbidities, age, sex, race, payer and hospital geography and setting. Total direct cost was found to be $33,879 for MIS fusion and $35,984 for open fusion, providing a statistically significant (p = 0.0023) cost saving in MIS cases. Not surprisingly, they found that the majority of cost savings were related to rapid mobilization and discharge in MIS cases.

Final Thoughts

As has been demonstrated, the literature convincingly supports the advantage of minimally invasive fusion with regard to decreased blood loss, faster and more comfortable recovery, and shorter hospitalization. There is also some evidence in favor of diminished infection rate and cost savings with MIS fusion. The fact that such gains can be achieved while maintaining good clinical and radiographic outcomes equivalent to open fusion is a testament to the conscientious and meticulous techniques of the experienced surgeons that have reported these studies. This point cannot be over-emphasized. Minimally invasive fusion is more than just "dropping in" a TLIF implant and few pedicle screws under fluoroscopy. One must employ the same rigor that one would apply to open fusion with regard to proper neural decompression, careful pedicle screw placement, adequate evacuation and preparation of disc space and proper sizing and placement of the interbody implant. One must also be aware that the benefits of MIS fusion come at the cost of increased radiation use, longer surgery times and slightly increased risk of screw misplacement in inexperienced hands [22].

Experienced MIS surgeons know that not every fusion lends itself to an MIS approach, while novice MIS surgeons will find that as they climb the MIS learning curve, their ability to customize the operation to the specific clinical and radiographic findings of each case is significantly enhanced. One may choose an open technique for a high grade spondylolisthesis, a mini-open technique for low- grade spondylolisthesis, or a percutaneous technique for a case that requires limited lateral decompression. One may also mix and match, inventing hybrid techniques for different operations. For instance, in the case of severe central stenosis with spondylolisthesis a small midline incision for laminectomy and PLIF can be combined with bilateral percutaneous pedicle screw insertion. It is also imperative to utilize a versatile instrumentation system that allows one to devise hybrid strategies and switch between percutaneous, mini-open and open approaches as required by the intraoperative circumstances. Armed with such an armamentarium and a thoughtful and flexible mindset, the spine surgeon will find new and exciting possibilities for treating the varied pathologies that he/she encounters.

References

1. Sihvonen, T., et al., Local denervation atrophy of paraspinal muscles in postoperative failed back syndrome. Spine (Phila Pa 1976), 1993. **18**(5): p. 575-81.
2. Rantanen, J., et al., The lumbar multifidus muscle five years after surgery for a lumbar intervertebral disc herniation. Spine (Phila Pa 1976), 1993. **18**(5): p. 568-74.
3. Mayer, T.G., et al., Comparison of CT scan muscle measurements and isokinetic trunk strength in postoperative patients. Spine (Phila Pa 1976), 1989. **14**(1): p. 33-6.
4. Kawaguchi, Y., H. Matsui, and H. Tsuji, Back muscle injury after posterior lumbar spine surgery. A histologic and enzymatic analysis. Spine (Phila Pa 1976), 1996. **21**(8): p. 941-4.
5. Gejo, R., et al., Serial changes in trunk muscle performance after posterior lumbar surgery. Spine (Phila Pa 1976), 1999. **24**(10): p. 1023-8.
6. Foley, K.T., L.T. Holly, and J.D. Schwender, Minimally invasive lumbar fusion. Spine (Phila Pa 1976), 2003. **28**(15 Suppl): p. S26-35.
7. Mummaneni, P.V. and G.E. Rodts, Jr., The mini-open transforaminal lumbar interbody fusion. Neurosurgery, 2005. **57**(4 Suppl): p. 256-61; discussion 256-61.
8. Stevens, K.J., et al., Comparison of minimally invasive and conventional open posterolateral lumbar fusion using magnetic resonance imaging and retraction pressure studies. J Spinal Disord Tech, 2006. **19**(2): p. 77-86.
9. Kim, K.T., et al., The quantitative analysis of tissue injury markers after mini-open lumbar fusion. Spine, 2006. **31**(6): p. 712-6.
10. Fan, S., et al., Multifidus muscle changes and clinical effects of one-level posterior lumbar interbody fusion: minimally invasive procedure versus conventional open approach. Eur Spine J, 2009. **30**: p. Epub ahead of print.
11. Dickerman, R.D., et al., Anterior and posterior lumbar interbody fusion with percutaneous pedicle screws: comparison to muscle damage and minimally invasive techniques. Spine (Phila Pa 1976), 2009. **34**(25): p. E923-5.
12. Wang, J., et al., Comparison of one-level minimally invasive and open transforaminal lumbar interbody fusion in degenerative and isthmic spondylolisthesis grades 1 and 2. Eur Spine J, 2010. **19**(10): p. 1780-4.
13. Peng, C.W., et al., Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion. Spine (Phila Pa 1976), 2009. **34**(13): p. 1385-9.
14. Park, Y. and J.W. Ha, Comparison of one-level posterior lumbar interbody fusion performed with a minimally invasive approach or a traditional open approach. Spine (Phila Pa 1976), 2007. **32**(5): p. 537-43.
15. Ntoukas, V. and A. Muller, Minimally invasive approach versus traditional open approach for one level posterior lumbar interbody fusion. Minim Invasive Neurosurg, 2010. **53**(1): p. 21-4.
16. Dhall, S.S., M.Y. Wang, and P.V. Mummaneni, Clinical and radiographic comparison of mini-open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up. J Neurosurg Spine, 2008. **9**(6): p. 560-5.
17. Adogwa, O., et al., Comparative effectiveness of minimally invasive versus open transforaminal lumbar interbody fusion: 2-year assessment of narcotic use, return to work, disability, and quality of life. J Spinal Disord Tech, 2011. **24**(8): p. 479-84.
18. Shunwu, F., et al., Minimally invasive transforaminal lumbar interbody fusion for the treatment of degenerative lumbar diseases. Spine (Phila Pa 1976), 2010. **35**(17): p. 1615-20.
19. Rodriguez-Vela, J., et al., Perioperative and short-term advantages of mini-open approach for lumbar spinal fusion. Eur Spine J, 2009. **18**(8): p. 1194-201.
20. Parker, S.L., et al., Post-operative infection after minimally invasive versus open transforaminal lumbar interbody fusion (TLIF): literature review and cost analysis. Minim Invasive Neurosurg, 2011. **54**(1): p. 33-7.
21. McGirt, M.J., et al., Comparative analysis of perioperative surgical site infection after minimally invasive versus open posterior/transforaminal lumbar interbody fusion: analysis of hospital billing and discharge data from 5170 patients. Journal of neurosurgery. Spine, 2011. **14**(6): p. 771-8.
22. Habib, A., et al., Minimally invasive transforaminal lumbar interbody fusion: a perspective on current evidence and clinical knowledge. Minim Invasive Surg, **2012**. 2012: p. 657342.
23. Wang, M.Y., et al., Acute hospital costs after minimally invasive versus open lumbar interbody fusion: data from a US national database with 6106 patients. Journal of spinal disorders & techniques, 2012. **25**(6): p. 324-8.
24. Parker, S.L., et al., Cost-utility analysis of minimally invasive versus open multilevel hemilaminectomy for lumbar stenosis. J Spinal Disord Tech, 2013. **26**(1): p. 42-7.
25. Parker, S.L., et al., Cost-effectiveness of minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis associated low-back and leg pain over two years. World Neurosurg, 2012. **78**(1-2): p. 178-84.

Additional Resource

http://www.aesculapimplantsystems.com/elementMIS

Physician Disclosure

Peyman Pakzaban, MD, FAANS, is a board-certified Neurosurgeon and is Vice Chairman of the Department of Surgery at Bayshore Medical Center and is in private practice at Houston MicroNeurosurgery in Pasadena, Texas. Dr. Pakzaban is a paid consultant for Aesculap Implant Systems, LLC.

About Aesculap Implant Systems, LLC

Aesculap Implant Systems, LLC, a B. Braun company, is part of a 175-year-old global organization focused on meeting the needs of an ever-changing healthcare community. Through close collaboration with its customers, Aesculap Implant Systems develops advanced spine and orthopaedic implant technologies to treat complex disorders of the spine, hip and knee. Aesculap Implant Systems strives to deliver products and services that improve the quality of patients' lives. For more information, call 800-234-9179 or visit aesculapimplantsystems.com.

Advantages of Minimally Invasive Spine Surgery: A Literature Review
Peyman Pakzaban, MD, Houston MicroNeurosurgery