In defense of minimally invasive spine surgery

John Entwistle, Girish K. Hiremath[1]

Departments of Neurosurgery, Grant Medical Center, Columbus, Ohio 43215, [1]Riverside Methodist Hospital, Ohio Health Neurological Physicians, Columbus, Ohio, USA

ABSTRACT

Recently, minimally invasive techniques to address various lumbar spine pathologies have been developed. These techniques are associated with decreased approach-related morbidity, in addition to an accelerated postoperative recovery. In this article, we identify other factors, such as the maintenance of normal biomechanics, cost savings, as well as potentially the reduced need for reoperation that may be associated with the use of minimally invasive techniques, as compared with open surgical approaches.

Key words: Approach-related morbidity, biomechanics, minimally invasive spine surgery

HISTORY

"Get knowledge of the spine, for this is the requisite for many diseases." - Hippocrates, 460-377 BC.

Even since ancient times, the human spine has been recognized as an elaborate framework – the earliest written account of its importance can be found in the Edwin Smith papyrus from 1550 BC. In this artifact, the symbol used to reference, the spinal column was understood to mean stability and durability. Hippocrates understood that the intricate network of vertebrae, joint structures, and ligamentous and muscular tissues, can carry with it a range of pathologies that can compromise not only spinal integrity, but also other body systems.[1] The world of spine surgery has undergone vast changes on the heels of emerging surgical technologies, improved imaging modalities, and advancement in biologic materials. Each advance was driven by forces such as the need to return patients to daily activities, to diminish procedure-related pain, decrease healthcare costs, as well as to minimize present and potentially future complications. With insight into an extensive history, minimally invasive spinal surgery (MIS) has been at the forefront of these paradigm shifts, and continues to expand its application in practice. It addresses various pathologies by achieving the goals of surgical treatment with minimal compromise of normal, and structurally significant, anatomy. By respecting the importance of these anatomical structures, the minimally invasive approach aims to preserve the stability of the vertebral column, as well as to prevent progressive degeneration of the spine itself, and the body systems it affects.

Access this article online	
Quick Response Code:	Website: www.ijns.in
	DOI: 10.4103/2277-9167.131991

BIOMECHANICS

Minimally invasive spinal surgery continues to be on par with traditional open procedures for treatment goals. However, MIS sets itself apart with the ability to preserve the functional stability of adjacent segments. Due to the multifactorial nature of lumbar stenosis, surgical treatment has typically involved extensive resection of posterior spinal elements. The classic open procedure, used for decades, includes extensive muscle dissection, a wide bilateral decompressive laminectomy, varying degrees of medial facetectomy and foraminotomy.[2,3] As effective as this procedure has proven to be, it is not without its consequences. Disruption of the muscular complex as well as removal of the posterior tension band can contribute to a loss of flexion stability, increasing the risk of delayed spinal instability and adjacent segment disease.[2]

There is strong evidence that associates postoperative back pain and disability with prolonged muscle retraction, which is an inherent part of traditional spine approaches. Direct mechanical compression by the retractor can cause significant muscle ischemia and necrosis. In patients

Address for correspondence: Dr. Girish K. Hiremath,
Department of Neurosurgery, Riverside Methodist Hospital, Ohio Health Neurological Physicians, 931 Chatham Lane, Suite 200, Columbus, Ohio 43221, USA. E-mail: halebidu@yahoo.com

undergoing lumbar spinal surgery, there is histological evidence of muscle damage.[4-6] Electrophysiological and magnetic resonance imaging studies also provide evidence of paraspinal muscle damage in these patients.[7] Sihvonen *et al.*[8] described radiologic, neurophysiologic, and muscle biopsy evidence found in most of their patients suffering from the postoperative failed back syndrome. According to these findings, these patients had dorsal ramus lesions in one or more segments covered by the scar and local paraspinal muscle atrophy at the corresponding segments. These findings of disrupted paraspinal muscle innervation and loss of muscular support was an important cause of the failed back syndrome.[8]

More recently, the correlation between muscle injury, and subsequent back pain and disability were evaluated. Datta *et al.*[9] evaluated 20 patients undergoing two-level decompressive lumbar laminectomy. The visual analog score (VAS), Oswestry Disability Index (ODI), and short-form 36 (SF-36) were utilized to assess back pain and disability. Intramuscular pressure (IMP) was monitored continuously during surgery and the intramuscular perfusion pressure (IPP) was indirectly recorded. During deep muscle retraction, a rapid increase in IMP was noted and IPP approached 0 mmHg. The mean duration of muscle retraction was greater than 60 min, which was associated with worse VAS, ODI, and SF-36 scores for disability at 6 months postoperatively ($P < 0.05$).[9] MIS techniques prevent such morbidity as a result of the muscle-dilating approaches used. Significant muscle ischemia is reduced because the dilation is performed in a well-vascularized region of the paraspinal musculature, rather than in the midline, and there is minimal "retraction" as such.

In a biomechanical study, Bresnahan *et al.*[2] investigated the impact of graded posterior element removal associated with emerging decompression techniques. The standard open laminectomy was compared to micro-endoscopic decompression and interlaminar laminotomy using a previously validated[10] three-dimensional intact lumbar finite element model. The study concluded that increased motion directly correlates with the amount of posterior element removal. Removal of the spinous process, supra- and inter-spinous ligament in the open model produced almost twice as much motion in flexion than was generated when these elements remained intact; this increased motion also resulted in increased stress on the annulus.[2] Even the least invasive approach resulted in some increased motion; however, results indicated that the extent of removal of the posterior elements had a direct correlation to the degree of increased motion. Therefore, minimizing bone and ligament removal, common in minimally invasive procedures, results in greater preservation of normal lumbar spine motion postoperatively and theoretically could diminish the risk of progressive adjacent segment disease. Future study of the use of minimally invasive techniques would hopefully confirm the long-term clinical impact of the results found in these biomechanical studies.

VALIDITY

Minimally invasive spinal surgery: Discectomy

The advantages of MIS have been disputed in the treatment of localized pathologies when compared to traditional methods. The Sciatica Micro-Endoscopic Discectomy randomized controlled trial compared the use of MIS, using the tubular method, versus open lumbar discectomy. The study included 328 patients and concluded that there was no advantage to tubular discectomy over traditional open surgery.[11] Although this study showed no distinct advantage, tubular discectomy remains a viable option, especially when considering the potential complications and patient type. German *et al.*[12] in their study have reported a retrospective review of 172 patients comparing open and minimally invasive discectomy procedures. Specifically noting complications, the authors concluded that although the percent of patients who developed a cerebrospinal fluid leak was similar between the groups, their experience suggests that most patients who undergo a minimally invasive approach fare better because they do not require bed rest, may be discharged home on the day of surgery, and do not require further intervention for symptomatic headaches or poor wound healing.[12] In addition, what has become more apparent is that as the morbidity of the procedure and/or debility of the patient increases, the advantages of MIS approach are likely to be increased. For example, minimally invasive techniques may be particularly useful for obese patients. A longer distance between the skin and spine, as is common in obese patients, does not require additional time for dissection when using a minimally invasive tubular retraction system. In addition, use of minimally invasive techniques requires relatively small, standard-length skin incisions regardless of the depth of the spine, unlike open surgery, in which a longer skin incision is often needed for adequate exposure of a deep spine.[13] It is our opinion that future studies will show the advantage of tubular discectomy compared with traditional microdiscectomy in such select patient groups.

Minimally invasive spinal surgery: Laminectomy

With the advancements in medical care, life expectancy has increased over the last 50 years, but has also carried with it an increase in the prevalence of disorders associated with aging. Lumbar stenosis is one of the most common diseases of the spine in the geriatric population,

and is currently the leading cause for spinal surgery.[14] Even at specialized centers, traditional open surgery has been associated with complication rates ranging from 28% to 86%,[15] and the risk of morbidity has been shown to increase with age.[16] In addition, postoperative back pain is a significant problem following open procedures. Paraspinal muscle stripping, and subsequent prolonged wide retraction seen in conventional lumbar surgery can result in ischemia and denervation of the paraspinal musculature, which may lead to postoperative muscle atrophy and pain.[17] In contrast, MIS has modified this approach through muscle-dilating, significantly diminishing the amount of iatrogenic soft-tissue injury. As a result, MIS has shown potential to reduce a number of complications related to the traditional open procedure including decreasing intraoperative blood loss and the intensity of postoperative pain.[18]

As the knowledge of the pathoanatomy of lumbar stenosis has improved, it has become clear that neurological compression is most commonly seen at the level of the interlaminar window. As a result, surgeons have adopted the technique of multilevel focal laminotomies, as opposed to the traditional wide laminectomy.[19] In a study by Rosen *et al.*,[20] 50 patients older than 75 years, with significant medical comorbidities, underwent MIS for spinal canal decompression. This study confirmed the successful application of the procedure in this age group. More importantly, the study showed that the authors were able to reduce their average length of postoperative stay to 29 h.[20] Khoo and Fessler[14] compared open to micro-endoscopic decompressive (MED) procedures in a group of 50 patients. This study showed longer surgical times in the MED group with comparable clinical outcomes. However, the MED arm had decreased blood loss, hospital stay, and postoperative narcotic usage.

Minimally invasive spinal surgery Lumbar fusion

Conventional lumbar fusion requires significant muscle stripping and retraction causing short- and long-term adverse effects.[21,22] There have been multiple authors describing MIS techniques for various indications that have shown equivalent fusion rates and functional outcomes compared with standard open procedures.[18,23-25] Wang *et al.* have reported on the successful application of MIS fusion techniques to treat adult spinal deformities.[26] In a review of 42 patients, Dhall *et al.*[27] compared mini-open transforaminal lumbar interbody fusion (TLIF) against the open TLIF with a mean follow-up of 24 and 34 months for the mini-open group and open groups, respectively. The mean estimated blood loss was 194 ml for the mini-open group and 505 ml for the open group ($P < 0.01$). The mean length of stay was 3 days for the mini-open group and 5.5 days for the open group ($P < 0.01$). Isaacs *et al.*[28] compared a series of 20 patients who underwent endoscopically assisted minimally invasive TLIF with a group of patients who underwent the open posterior lumbar interbody fusion procedure for single-level degenerative disc disease. They determined that intraoperative blood loss, hospital stay, and postoperative narcotic use were significantly less in patients who underwent the minimally invasive TLIF procedure; no procedure-related complications were noted. In a recent retrospective review by Rouben *et al.*,[29] 169 patients who underwent either single or two-level MIS TLIF were evaluated for long-term clinical and radiographic durability. This study showed 96% fusion rate at 1-year follow-up. About 97% of patients returned to work at an average of 8 weeks. The ODI improved 36% at the first follow-up and was improved by 41% at 49 months postoperatively ($P < 0.001$) showing continued improvement at long-term follow-up. The authors also noted a decrease in narcotic use from 100% to 31% 6 months postoperatively. The single-level and two-level fusions improved comparably in ODI and VAS. Many groups have also investigated the application of minimally invasive approach to adult deformity. In a retrospective review of 23 patients, clinical and radiographic results were reviewed following minimally invasive surgery for adult thoracolumbar deformity. 84 of 86 treated levels exhibited clear evidence of fusion on radiographs, with no indication of interbody pseudoarthrosis. In their patient cohort, coronal plane deformities had mean pre- and post-operative Cobb angles of 31.4 and 11.5°. Sagittal deformities were measured by the degree of lordosis between the thoracolumbar junction and S1 endplate, and a mean average increase in lumbar lordosis of 8.0° was noted.[15] In the same patient cohort, VAS scores for leg pain averaged 4.35 preoperatively and improved to 1.57 postoperatively; the VAS scores for axial back pain averaged 7.3 preoperatively and improved to 3.35 postoperatively ($P < 0.01$).[15]

In a recent prospective clinical study, Perez-Cruet *et al.*[30] demonstrated the short- and long-term outcomes in 304 patients undergoing MIS TLIF. Statistically significant improvements were noted in VAS, ODI, and SF-36 at short- and long-term follow-up. VAS specifically noted an average decrease from 7.0 to 4.5 points ($P < 0.001$) at 2 weeks post operatively, indicating an immediate short-term improvement. In addition, average follow-up time was 47 months (range, 2-8 years), and the VAS scores maintained improvement, averaging 4.5 ($P < 0.001$) and 3.5 ($P < 0.05$) at 34 and 47 months. Similarly, ODI scores averaged 43.1 preoperatively and decreased to 28.7 at 6 months ($P < 0.001$) and 28.2 at 47 months ($P < 0.05$). Reoperation rate in the series was 3.9% ($n = 12$); 2% required reoperation at the original surgical site

due to interbody failure (broken or retropulsed) or a failed pedicle screw. The other 2% required reoperation at the adjacent level; three of these patients required MIS laminectomy, while the other three had prior open laminectomy procedures, and therefore required MIS fusion. This low rate of adjacent level pathology is thought to be due to the preservation of the paraspinal muscular, bony, and ligamentous anatomy afforded by the minimally invasive TLIF approach. In short, this study has established the durability of successful outcomes afforded by the use of MIS fusion techniques in a large group of patients over the long-term, with a significantly reduced rate of adjacent level surgery.[30]

Cost-effectiveness

In the United States, a major motivating force in medical care continues to be the cost associated with the management of spinal disorders. It is estimated that the annual cost of spinal disorders surpasses $100 billion.[31] Authors have evaluated many variables contributing to escalating costs including hospital stay length, surgical site infections (SSIs), procedure cost, and hospital direct costs. Minimally invasive procedures have been associated with a shorter hospital stay, decreased narcotic use, and lower infection rates.[14,20,30]

Parker *et al.*[32] have reported on the cost savings associated with MIS TLIF when compared to the open TLIF. When evaluating a total mean 2-year cost to treat, the minimally invasive TLIF group represented savings of $8731 when compared with the open TLIF arm. Wang *et al.*[33] performed a multicenter study in which 6106 patients who underwent either MIS TLIF (1667 patients) or open TLIF (4439 patients) were examined. Although, there was no significant cost-saving difference between one-level open and MIS TLIF groups, total inflation-adjusted acute hospitalization cost averaged $2106 less ($P = 0.0023$) for patients who underwent two-level MIS TLIF compared with those who underwent two-level open TLIF.[33] A meta-analysis of 5170 patients who underwent MIS-versus open-TLIF examined the cost-savings associated with lower SSI rates.[34] The incidence of SSI was 65 (4.5%) for the MIS group versus 227 (6.1%) for the open group ($P = 0.037$), and the direct costs associated with the diagnosis and management of the SSIs identified in the study was $1,024,950 for MIS versus $3,593,862 for the open technique.

A recent analysis by Udeh *et al.*[35] evaluated the cost-effectiveness of 3 options to treat lumbar spinal stenosis. The options included epidural steroid injections (ESI), open laminectomy and minimally invasive lumbar decompression. This analysis included patients with lumbar stenosis who have moderate to severe symptoms and have failed conservative therapies. The measurement was a change in quality-adjusted life years (QALY) from preprocedure to 2 years postprocedure. Minimally invasive lumbar decompression was the most cost-effective at $43,760/QALY, followed by ESI at $81,518/QALY, and open laminectomy being the lease cost-effective at $125,985/QALY.

CONCLUSION

Ailments of the lumbar spine are among the most common reasons for disability – this is especially true with an aging population as in the United States. Although traditional surgical interventions have proven beneficial, they are associated with significant approach-related morbidity as well as increased cost, and a high rate of reoperation as a result of adjacent level pathology. MIS techniques have been shown to be as effective in achieving the goals of traditional approaches, with durability of good outcomes over the long-term. Moreover, they are associated with significantly reduced approach-related morbidity, decreased costs, and likely a significantly reduced rate of adjacent level pathology requiring reoperation.

REFERENCES

1. Samartzis D, Shen FH, Perez-Cruet MJ, Anderson DG. Minimally invasive spine surgery: A historical perspective. Orthop Clin North Am 2007;38:305-26.
2. Bresnahan L, Ogden AT, Natarajan RN, Fessler RG. A biomechanical evaluation of graded posterior element removal for treatment of lumbar stenosis: Comparison of a minimally invasive approach with two standard laminectomy techniques. Spine (Phila Pa 1976) 2009;34:17-23.
3. Postacchini F. Surgical management of lumbar spinal stenosis. Spine (Phila Pa 1976) 1999;24:1043-7.
4. Kawaguchi Y, Matsui H, Tsuji H. Back muscle injury after posterior lumbar spine surgery. Part 2: Histologic and histochemical analyses in humans. Spine (Phila Pa 1976) 1994;19:2598-602.
5. Kawaguchi Y, Matsui H, Tsuji H. Back muscle injury after posterior lumbar spine surgery. A histologic and enzymatic analysis. Spine (Phila Pa 1976) 1996;21:941-4.
6. Kawaguchi Y, Yabuki S, Styf J, Olmarker K, Rydevik B, Matsui H, *et al*. Back muscle injury after posterior lumbar spine surgery. Topographic evaluation of intramuscular pressure and blood flow in the porcine back muscle during surgery. Spine (Phila Pa 1976) 1996;21:2683-8.
7. Gejo R, Kawaguchi Y, Kondoh T, Tabuchi E, Matsui H, Torii K, *et al*. Magnetic resonance imaging and histologic evidence of postoperative back muscle injury in rats. Spine (Phila Pa 1976) 2000;25:941-6.
8. Sihvonen T, Herno A, Paljärvi L, Airaksinen O, Partanen J, Tapaninaho A. Local denervation atrophy of paraspinal muscles in postoperative failed back syndrome. Spine (Phila Pa 1976) 1993;18:575-81.
9. Datta G, Gnanalingham KK, Peterson D, Mendoza N, O'Neill K, Van Dellen J, *et al*. Back pain and disability after lumbar laminectomy: Is there a relationship to muscle retraction? Neurosurgery 2004;54:1413-20.
10. Renner SM, Natarajan RN, Patwardhan AG, Havey RM, Voronov LI, Guo BY, *et al*. Novel model to analyze the effect of a large compressive follower pre-load on range of motions in a lumbar spine. J Biomech 2007;40:1326-32.

11. Arts MP, Brand R, van den Akker ME, Koes BW, Bartels RH, Peul WC, *et al*. Tubular diskectomy vs conventional microdiskectomy for sciatica: A randomized controlled trial. JAMA 2009;302:149-58.
12. German JW, Adamo MA, Hoppenot RG, Blossom JH, Nagle HA. Perioperative results following lumbar discectomy: Comparison of minimally invasive discectomy and standard microdiscectomy. Neurosurg Focus 2008;25:E20.
13. Cole JS 4th, Jackson TR. Minimally invasive lumbar discectomy in obese patients. Neurosurgery 2007;61:539-44.
14. Khoo LT, Fessler RG. Microendoscopic decompressive laminotomy for the treatment of lumbar stenosis. Neurosurgery 2002;51:S146-54.
15. Wang MY, Mummaneni PV. Minimally invasive surgery for thoracolumbar spinal deformity: Initial clinical experience with clinical and radiographic outcomes. Neurosurg Focus 2010;28:E9.
16. Zheng F, Cammisa FP Jr, Sandhu HS, Girardi FP, Khan SN. Factors predicting hospital stay, operative time, blood loss, and transfusion in patients undergoing revision posterior lumbar spine decompression, fusion, and segmental instrumentation. Spine (Phila Pa 1976) 2002;27:818-24.
17. Hyun SJ, Kim YB, Kim YS, Park SW, Nam TK, Hong HJ, *et al*. Postoperative changes in paraspinal muscle volume: Comparison between paramedian interfascial and midline approaches for lumbar fusion. J Korean Med Sci 2007;22:646-51.
18. Holly LT, Schwender JD, Rouben DP, Foley KT. Minimally invasive transforaminal lumbar interbody fusion: Indications, technique, and complications. Neurosurg Focus 2006;20:E6.
19. Aryanpur J, Ducker T. Multilevel lumbar laminotomies: An alternative to laminectomy in the treatment of lumbar stenosis. Neurosurgery 1990;26:429-32.
20. Rosen DS, O'Toole JE, Eichholz KM, Hrubes M, Huo D, Sandhu FA, *et al*. Minimally invasive lumbar spinal decompression in the elderly: Outcomes of 50 patients aged 75 years and older. Neurosurgery 2007;60:503-9.
21. Gejo R, Matsui H, Kawaguchi Y, Ishihara H, Tsuji H. Serial changes in trunk muscle performance after posterior lumbar surgery. Spine (Phila Pa 1976) 1999;24:1023-8.
22. Styf JR, Willén J. The effects of external compression by three different retractors on pressure in the erector spine muscles during and after posterior lumbar spine surgery in humans. Spine (Phila Pa 1976) 1998;23:354-8.
23. Anand N, Baron EM, Thaiyananthan G, Khalsa K, Goldstein TB. Minimally invasive multilevel percutaneous correction and fusion for adult lumbar degenerative scoliosis: A technique and feasibility study. J Spinal Disord Tech 2008;21:459-67.
24. Kim JS, Kim DH, Lee SH. Comparison between Instrumented Mini-TLIF and instrumented circumferential fusion in adult low-grade lytic Spondylolisthesis: Can Mini-TLIF with PPF replace circumferential fusion? J Korean Neurosurg Soc 2009;45:74-80.
25. Kim JS, Kang BU, Lee SH, Jung B, Choi YG, Jeon SH, *et al*. Mini-transforaminal lumbar interbody fusion versus anterior lumbar interbody fusion augmented by percutaneous pedicle screw fixation: A comparison of surgical outcomes in adult low-grade isthmic spondylolisthesis. J Spinal Disord Tech 2009;22:114-21.
26. Wang MY, Anderson DG, Poelstra KA, Ludwig SC. Minimally invasive posterior fixation. Neurosurgery 2008;63 3 Suppl: 197-203.
27. Dhall SS, Wang MY, Mummaneni PV. 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;9:560-5.
28. Isaacs RE, Podichetty VK, Santiago P, Sandhu FA, Spears J, Kelly K, *et al*. Minimally invasive microendoscopy-assisted transforaminal lumbar interbody fusion with instrumentation. J Neurosurg Spine 2005;3:98-105.
29. Rouben D, Casnellie M, Ferguson M. Long-term durability of minimal invasive posterior transforaminal lumbar interbody fusion: A clinical and radiographic follow-up. J Spinal Disord Tech 2011;24:288-96.
30. Perez-Cruet MJ, Hussain NS, White GZ, Begun EM, Collins RA, Fahim DK, *et al*. Quality-of-life outcomes with minimally invasive transforaminal lumbar interbody fusion based on long-term analysis of 304 consecutive patients. Spine (Phila Pa 1976) 2014;39:E191-8.
31. Indrakanti SS, Weber MH, Takemoto SK, Hu SS, Polly D, Berven SH. Value-based care in the management of spinal disorders: A systematic review of cost-utility analysis. Clin Orthop Relat Res 2012;470:1106-23.
32. Parker SL, Lerner J, McGirt MJ. Effect of minimally invasive technique on return to work and narcotic use following transforaminal lumbar inter-body fusion: A review. Prof Case Manag 2012;17:229-35.
33. Wang MY, Lerner J, Lesko J, McGirt MJ. Acute hospital costs after minimally invasive versus open lumbar interbody fusion: Data from a US national database with 6106 patients. J Spinal Disord Tech 2012;25:324-8.
34. McGirt MJ, Parker SL, Lerner J, Engelhart L, Knight T, Wang MY. 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. J Neurosurg Spine 2011;14:771-8.
35. Udeh BL, Costandi S, Dalton JE, Ghosh R, Yousef H, Mekhail N. The 2-year cost-effectiveness of 3 options to treat lumbar spinal stenosis patients. Pain Pract. 2014 [Epub ahead of print].

How to cite this article: Entwistle J, Hiremath GK. In defense of minimally invasive spine surgery. Indian J Neurosurg 2014;3:3-7.
Source of Support: Nil, **Conflict of Interest:** None declared.