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Introduction

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Surgery without instrumentation for spondylolisthesis-related stenosis?

John A. Polikandriotis, Ph.D., Vernon R. Morris, Jr., M.D., and Michael W. Perry, M.D.

March 26, 2011 I Imaging In Rheumatology [1]

Degenerative spondylolisthesis usually is asymptomatic but may be associated with symptomatic spinal stenosis. Because the latter often is detected by imaging studies in asymptomatic patients, clinical correlation between symptoms and imaging is critical.

Abstract: Degenerative spondylolisthesis usually is asymptomatic but may be associated with symptomatic spinal stenosis. Because the latter often is detected by imaging studies in asymptomatic patients, clinical correlation between symptoms and imaging is critical. This patient presented with progressive exacerbation of symptoms of low back pain and leg weakness. An outpatient right endoscopic L4-5 laminotomy and foraminotomy was performed. After surgery, the patient reported complete resolution of his symptoms. Repeated flexion-extension x-ray films 16 months after the procedure showed no change in the degree of spondylolisthesis, and significant improvements were seen in outcome survey scores. We concluded that outpatient minimally invasive endoscopic decompression for spinal stenosis associated with degenerative spondylolisthesis is feasible. (J Musculoskel Med. 2011;28:125-136)

Introduction

Degenerative spondylolisthesis, the slippage forward of one lumbar vertebra on another, rarely occurs in persons younger than 50 years and most often occurs at the L4-5 level.[1] The condition generally is asymptomatic, but it may be associated with symptomatic spinal stenosis,[2] the most common reason for lumbar surgery in persons older than 65 years.

Patients who have spinal stenosis, a narrowing of the spinal canal with compression of the neural structures, typically present with neurogenic claudication (pain in the buttocks or legs with walking or standing that resolves with sitting or lumbar flexion). However, spinal stenosis often is detected by imaging studies in asymptomatic patients; thus, clinical correlation between symptoms and imaging is critical.[3]

Several studies have compared surgical techniques for degenerative spondylolisthesis, but many of the studies involved instrumentation.[4-6] In this case study, we assessed the feasibility and effectiveness of managing spondylolisthesis-related spinal stenosis via a minimally invasive outpatient approach that does not involve instrumentation. Our objective was to determine the optimal treatment strategy for patients with symptomatic degenerative spondylolisthesis.

Methods

Informed consent was obtained from the study participant. The patient underwent preoperative and 16-month postoperative flexion-extension imaging studies, which were reviewed for evidence of instability or progression of spondylolisthesis or both by independent radiologists blinded to the clinical results and unaffiliated with the operating institution.

Similarly, the patient completed a preoperative and 16-month postoperative outcome survey that included the Visual Analogue Scale (VAS), 36-item Short-Form (SF-36) Health Survey Questionnaire, and Oswestry Disability Index (ODI). VAS scores range from 0 to 10 (lower scores indicate less severe symptoms), SF-36 scores range from 0 to 100 (higher scores indicate less severe symptoms), and ODI scores range from 0 to 100 (lower scores indicate less severe symptoms).

Case report

A 60-year-old man presented with progressive exacerbation of symptoms of low back pain and leg weakness. The symptoms had begun 5½ years before surgical treatment with a gradual onset of pain that worsened over time. The patient denied any injury or trauma when the pain started. Associated symptoms included back pain, leg pain, buttock pain, leg weakness, and numbness and tingling, all bilateral. The patient stated that standing or walking aggravated the pain and sitting or lying down decreased it. The progressing pain and weakness had decreased his ability to exercise and greatly diminished his quality of life. Previous treatment included 6 to 8 weeks of physical therapy; there was no significant relief.

The patient's primary care physician recommended MRI. Found at L4-5 were severe spinal stenosis (**Figure 1**) and grade 1 spondylolisthesis (**Figure 2**). The patient went to a local orthopedic surgeon and was offered an open posterior laminectomy and fusion at L4-5. He sought an alternative opinion, and his primary care physician referred him to another surgeon, who also recommended a fusion procedure.

Figure 1 — This MRI scan shows a severe spinal stenosis at L4-5 in the study participant, a 60-year-old man who presented with progressive exacerbation of symptoms of low back pain and leg weakness.

Figure 2 — This patient also had spondylolisthesis at L4-5, as seen in this MRI scan.

The patient was hesitant to have major open back surgery and opted for an outpatient minimally invasive endoscopic surgery that did not involve hardware implantation. He underwent an outpatient right endoscopic L4-5 laminotomy and foraminotomy with thermal ablation of the facets bilaterally at L3-4, L5-S1, and the sacroiliac joints as well as left-sided facet ablation at L4-5.

The patient tolerated the procedure well. He was transferred to the recovery room via stretcher awake in stable condition and was released 2 hours postsurgery. There were no complications.

Results

The same day, after surgery, the patient was up and walking and reported complete resolution of his radicular pain, tingling, burning, and weakness. In addition, an independent review of repeated flexion-extension x-ray films showed no change in the degree of spondylolisthesis 16 months after the procedure. The patient reported that the back pain and leg weakness had not returned. He had been able to start exercising regularly and lost considerable weight.

Significant VAS and ODI improvements were seen at 16 months postsurgery (**Table 1**). Similarly, significant improvements were seen in the patient's SF-36 metrics for physical function, physical limitation, and bodily pain at 16 months postsurgery (**Table 2**). Although the mental well-being score decreased from 88.0 to 84.0, both of these numbers are above the mean and fall well within a standard deviation of the general US population.[7,8]

Table 1 – VAS and ODI outcome scores for a patient who underwent outpatient minimally invasive endoscopic surgery without instrumentation

	Preoperative	16-month postoperative
VAS	6.3	1.5
ODI	40.0	0.0

VAS, Visual Analogue Scale, ODI, Oswestry Disability Index.

Table 2 – SF-36 Health Survey Questionnaire outcome scores for a patient who underwent outpatient minimally invasive endoscopic surgery without instrumentation

	Preoperative	16-month postoperative
Physical function	44.4	88.9
Physical limitation	25.0	100.0
Bodily pain	45.0	90.0
Mental well-being	88.0	84.0

SF-36, 36-item Short-Form.

Discussion

Many authors have challenged the traditional treatment of patients with spinal stenosis in which wide laminectomy and facetectomy are performed with or without instrumentation.[9-14] Although the goal of minimally invasive procedures without the use of instrumentation is to reduce postoperative pain and disability, the concern regarding the increased risk of postoperative spondylolisthesis remains.

The risk of spondylolisthesis has been as regarded a contraindication to decompression surgery, and many authors have suggested that concomitant fusion is indicated.[6,9,15,16] In this patient, who underwent an outpatient right endoscopic L4-5 laminotomy and foraminotomy with facet ablation, increased instability did not occur, as demonstrated in the x-ray films (**Figure 3**), and there was complete resolution of his pain and disability, as demonstrated in his VAS, ODI, and SF-36 scores 16 months postsurgery.

Palmer and associates[17] reported similar results. In their study, 8 consecutive patients with spinal stenosis and grade 1 spondylolisthesis underwent bilateral decompression via a similar minimally invasive outpatient approach. The mean preoperative VAS pain score was 7.6, and the average postoperative pain score was only 2.

Regarding facet ablation, numerous studies that involved such techniques as radiofrequency, laser, and cryodenervation reported rapid symptomatic relief; success rates range from 20% to 70%.[18-24] Although there are published studies documenting efficacy, most studies are small and have limited follow-up. In addition, because peripheral nerves have the capacity to regenerate, we currently are evaluating the long-term outcomes. Note that postoperative imaging was not performed in this case to verify decompression. Verification of the decompression of nerve roots and the spinal canal may be based on 2 sets of criteria, anatomical with imaging and clinical response. In our experience, because a disconnect may exist between symptoms and imaging, the clinical response demonstrated by relief of symptoms of neurogenic claudication is more relevant and provides sufficient evidence to indicate decompression, as was the case for this patient.

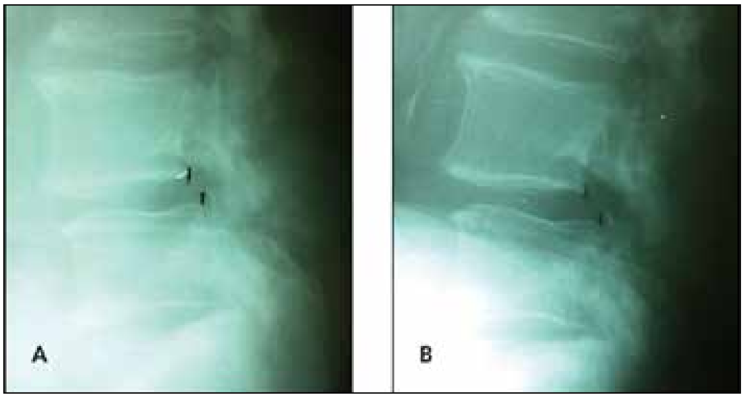

Figure 3 — In flex x-ray films obtained for the patient, no increase in instability was seen between 4 months presurgery (A) and 16 months postsurgery (B), supporting the use of outpatient minimally invasive endoscopic decompression for spinal stenosis associated with degenerative spondylolisthesis.

Ultimately, although decompression in conjunction with a fusion is the standard of care for lumbar degenerative spondylolisthesis, we contend that some patients may be treated with decompression alone. The criteria for endoscopic laminotomy and foraminotomy decompression without fusion in cases with same-level spondylolisthesis are the following:

- **Symptoms related to neural compression.**
- **Conservative treatment has not been successful.**
- **Stable spondylolisthesis as determined by flexion and extension x-ray films.**
- **No previous surgery at said level.**

Conclusion

Our results demonstrate the feasibility of performing outpatient minimally invasive endoscopic decompression for spinal stenosis associated with degenerative spondylolisthesis. The maintained stability that was observed in this patient may be the result of increased preservation of the normal ligamentous and muscular architecture with the minimally invasive procedure. Although this is only a single case study, the lack of increased instability validates investigation into a larger study, which we are pursuing.

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Minimally invasive surgical treatment for severe symptomatic lumbar spinal stenosis: A case study

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Abstract: Minimally invasive spine surgeries using endoscopic techniques have shown to be effective at treating lumbar spinal stenosis. However, there lacks evidence that bilateral decompression of the nerve root can be achieved through a unilateral endoscopic technique. Thus, this case study examines whether an outpatient surgical treatment for severe lumbar spinal stenosis (LSS) requiring bilateral decompression through a unilateral approach can be performed endoscopically.

Methods: A 63-year old non-smoking African American male presented with symptoms of pain in the left buttock that radiated into the posterior left thigh. Magnetic resonance imaging (MRI) confirmed severe L4/5 spinal stenosis bilaterally. The patient underwent out-patient minimally invasive unilateral laminotomy for bilateral L4/5 decompression of central canal stenosis. This procedure included a partial facetectomy with removal of the contralateral ligamentum flavum, and decompression of the lateral recesses.

Results: The procedure lasted one hour and 16 minutes. Post-operative MRI confirmed bilateral decompression of the spinal canal. The patient tolerated the surgery well and was released two hours post-operative awake and in stable condition. There were no operative complications and an estimated blood loss of 25 millilitres. The patient reported the ability to walk with complete resolution of ridiculer pain, tingling and numbness the same day as surgery as well as at 3-, 6- and 18-months post-operatively.

Conclusion: This case study indicates that an outpatient endoscopic unilateral laminotomy for bilateral decompression of the central canal and lateral recesses is effective at reducing pain and disability level immediately following surgery and up to 18-months post-operative. Results also indicate that this outpatient procedure can treat severe LSS with short operative times, no operative complications, and minimal blood loss.

Introduction

First described by Baily and Casamajor in 1911 [1], lumbar spinal stenosis (LSS) is the narrowing of the spinal canal caused by age-related degenerative processes such as bony overgrowth, enlargement of the facet joints, ligamentum flavum hypertrophy, or bulging and herniated discs [2-6]. As degenerative processes cause the spinal canal to narrow, the neural elements within the canal can get compressed. This typically results in intense back pain, neurogenic claudication, and radicular symptoms [7].

Symptomatic LSS can be treated with a variety of different modalities. Conservative treatment can consist of physical therapy, pain management, chiropractic care, acupuncture, and medications. When conservative treatments fail, surgery would then be an option. The Spine Patient Outcomes Research Trial (SPORT) [8,9] compared conservative treatment of LSS with a surgical intervention. Follow-up analyses at both 2- and 4-years post-operative indicated that patients that underwent surgical correction of LSS fared better than those who received conventional treatments.

Although invasive open surgery (i.e., laminectomy) is considered the conventional treatment for LSS, out-patient minimally invasive spine surgery (MIS) has been evolving over the past few decades. Studies indicate that MIS for the treatment of LSS is as effective at providing satisfactory decompression as open surgery without adverse effects including damage to the posterior ligamentum, muscles and tissues, dural leaks, and large incisions that are associated with open surgery [10-17]. This is important because the weaknesses caused by the extensive surgical dissection and muscle detachment have sometimes lead to paraspinal muscle denervation and atrophy; which is correlated with an increased incidence of "failed back syndrome" and chronic pain [18,19].

Standard out-patient MIS using endoscopy for the treatment of LSS does not require a large degree of bone or ligament removal. However, in more severe cases in which bilateral decompression is needed, more bone removal is required to obtain sufficient decompression. The use of an endoscopic procedure to achieve bilateral decompression has been examined in a study by Çelik [20]. In this study, patients diagnosed with severe LSS were randomized to undergo a total laminectomy (TL) or MIS using endoscopy to perform a bilateral laminotomy. After surgery, all patients were ambulatory the first day after surgery and post-operative imaging demonstrated adequate decompressions in both treatment conditions. Perioperative complications, post-operative instability, and the overall rate of dural injuries were all significantly higher among the TL group than the MIS condition ($p<.05$). Although the study indicates that endoscopy, instead of open surgery, can be used to achieve bilateral decompression through a bilateral laminotomy, the ability to achieve bilateral decompression through an outpatient unilateral laminotomy endoscopically is still uncertain.

In patients with severe LSS, the ability to provide complete bilateral decompression through a unilateral endoscopic approach has structural benefits including the preservation of the contralateral structures, lamina, and facet joint at the index surgery level [10]. To the best of our knowledge, Hong et al. [10] is the only study to compare unilateral and bilateral laminotomies for bilateral decompression in patients with LSS over 3-year post-operative. Results indicated that both unilateral and bilateral laminotomies provided adequate decompression and pain reduction. However, unilateral laminotomy was performed with shorter operative times, less blood loss, and induced less translational motion increase after surgery than patients who received the bilateral laminotomy. Thus, unilateral laminotomy, compared to bilateral laminotomy for bilateral decompression, may reduce the risk of late instability, result in less operative blood loss, and have a shorter operative time. However, this study did not examine whether a unilateral laminotomy can be performed as an outpatient procedure with only intravenous (IV) sedation, or whether it can reduce the level of disability experienced by patients.

This case study examines the use of an outpatient minimally invasive endoscopic procedure that a unilateral laminotomy to perform bilateral decompression of central canal stenosis with decompression of bilateral lateral recess for the treatment of severe symptomatic LSS.

Methods

Informed consent was obtained from the patient. Pre-operative and post-operative MRI (without contrast) were conducted. The scans were reviewed for evidence of LSS by independent radiologist blinded to the clinical results and unaffiliated with the operating institution.

Outcome measures

The Visual Analog Scale (VAS) [21] was used to measure pain intensity pre- and postoperatively. The Oswestry Disability Index (ODI) [22] was used to measure disability level pre- and postoperatively. To measure the safety of this surgical procedure, data pertaining to estimated blood loss (EBL), perioperative complications, and length of surgery were retrieved from the patients' medical records.

Case report

A 63-year old non-smoking African American male with a body mass index of 24.2 presented with symptoms of pain in the left buttock that radiated into the posterior left thigh. The patient denied that the pain was initiated from any injury or trauma but rather a gradual onset of symptoms that began approximately 1-year prior. Pain severity was reported to increase with activities such as walking or standing and was alleviated when assuming a seated or lying down position. As a practicing surgeon, the patient was finding it difficult to continue his practice due to the pain experienced while standing. Previous attempts to alleviate pain included the use of over-the-counter pain medications for six weeks with no significant pain relief. Other types of treatments such as physical therapy, chiropractic care, or acupuncture were not used by the patient as a treatment for pain. The patient did not have any prior surgical consults or surgeries pertaining to the spine.

Pre-operative MRI scans revealed severe central stenosis at the L4/5 level caused from both a congenital basis as well as the result of a bulging disk, bilateral facet, and ligamentum flavum hypertrophy. There was moderate biforaminal narrowing due to a disk bulge and osteophytic spurring. The L4/5 level had moderate to severe bilateral lateral recess stenosis which can be seen in figure 1. Degenerative disc disease was noted at L2/3 and L5-S1. The MRI scans also revealed a bulging disk and foraminal narrowing at L2-L4 due to osteophytic spurring and a bulging disc. Imaging provided no evidence of malalignment or spondylolisthesis. Based off these findings, the patient was diagnosed with lumbar osteoarthritis, degenerative disc disease, and LSS. No other pertinent abnormalities were observed. Pre-operative MRI scans are presented in **figure 1**.

Figure 1: Pre-operative axial and sagittal magnetic resonance imaging showing severe lumbar spinal stenosis at the L4-5 level.

After the physician informed the patient of the diagnosis, the physician explained available treatment options including conservative treatments (e.g., physical therapy), intensive open surgical procedures, and MIS using endoscopy to the patient in length. With MIS being the recommended treatment, it was explained in detail to the patient along with the potential risks and outcomes associated with it. The physician also stressed the importance of physical therapy as an adjunct to the procedure. After discussing all treatment options, the patient and physician agreed on pursuing the MIS procedure based on imaging and patient symptoms.

Surgical procedure

The patient underwent an outpatient MIS endoscopic left approach L4/5 bilateral laminotomy decompression of the central canal and bilateral lateral recess with left foraminotomy including partial facetectomy with the removal of the ipsilateral and majority contralateral ligamentum flavum. The patient was given IV sedation for the procedure.

The patient was brought to the surgical suite and placed in a prone position on the operating room table. The safety strap and monitors were applied. The patient's lumbar spine was then prepped with Chloraprep and draped in the usual sterile fashion. The C-arm was also draped. A time out was performed; the patient, procedure, level and approach were again verified by the surgeon and operating room team. A needle holder was used to mark the position of the decompression site at L4/5. The superficial skin was anesthetized with 1% lidocaine with epinephrine as well as penetrating deeper for the decompression site. An incision was made utilizing a #15 blade; a 3 cm horizontal incision at the L4/5 level. The guide pin was placed at the left L4 lamina followed by the first dilating tube. This placement was verified by C-arm fluoroscopy in the anteroposterior (AP) view. Sequential dilating tubes were incorporated until the appropriate working tube was placed and remaining tubes were removed. The working tube and guide pin placement were documented with AP and lateral intraoperative fluoroscopy.

The endoscope was placed for visualization. Soft tissue was removed using a combination of electrocautery, laser, and Ferris Smith straight biting rongeurs to clean the remaining soft tissue and expose the L4 lamina. The medial aspect of the facet joints and lamina were cleared of soft tissue in order to identify the superior lamina, medial facets and spinous process. Using a diamond tip burr, the least amount of bone necessary was removed from the superior lamina left, then undercutting the spinous process to gain access the right lamina, and the medial facet left. First the outer cortex was carefully burred followed by medullary bone. Then the inner cortex was identified and once confirmed, minimal burring was performed. When enough bone had been removed, the Kerrison rongeurs were first used between the ligamentum flavum, which was excessively hypertrophied on the left and right, and the superior lamina. The left and right superior laminar bones were partially removed and the ligamentum flavum was removed on the left and the majority on the right.

The Murphy probe was also used to probe the left and right traversing nerves in the lateral recess at the L4/5 level, which were narrowed by excessive osteophytes. Decompression of the traversing nerve roots with the burr and Kerrison rongeurs was carefully performed. Soft tissue and bone was removed until an adequate decompression of the lateral recess allowed the Murphy probe to easily follow the traversing nerves around the pedicles. We were also able to retract the dura medially to visualize the mobility of the traversing nerves on the left and the right.

Measures	Pre-Operative	Post-Operative		
		3-Months	6-Months	18-Months
Vas*	3.25	0.00	0.00	0.00
ODI*	17.77	0.00	0.00	0.00

Table 1: VAS and ODI Scores for a patient who underwent endoscopic minimally invasive surgery for severe symptomatic lumbar spinal stenosis.

*Lower scores indicate better pain and level of disability

When the decompression looked adequate by thorough inspection using the Murphy probe to verify central decompression along with bilateral lateral recess, the procedure was deemed complete. The area was thoroughly irrigated with antibiotic solution and aspirated throughout. Therapeutic steroid injection was performed. Marcaine 0.25% with epinephrine was injected into the skin and subcutaneous tissue around the incisions to aid in postoperative pain. Following removal of the instrumentation, the incision and skin were closed with 2-0 antibacterial Vicryl, 3-0 Monocryl sutures and Steri-strips. Sterile 4x4's and Medipore tape was applied. All counts were correct. The patient was transferred to a stretcher, rolled to a supine position, and then escorted to the recovery room in stable condition.

Results

The procedure took one hour and 16 minutes to complete. The patient tolerated the surgery well and was released two hours postoperative awake and in stable condition. There were no (0.00%) operative complications and an EBL of 25 millilitres was reported. Postoperative MRI (without contrast) of L4/5 confirmed decompression of the spinal canal (Figure 2). The patient reported the ability to walk with complete resolution of radicular pain, tingling and numbness the same day as surgery. Analysis indicate that scores on the VAS and ODI were significantly better post-operatively (0.00 and 0.00 respectively) than pre-operatively (3.25 and 17.77 respectively). In fact, the complete resolution of pain and disability (0.00 and 0.00 respectively) was reported at 3-, 6-, and 18-months post-operatively by the patient (Table 1).

Figure 2: Post-operative axial magnetic resonance imaging showing complete decompression of lumbar spinal stenosis at the L4-5 level.

Discussion

This case study examined the use of MIS for a patient with severe symptomatic LSS at L4/5 requiring decompression bilaterally performed unilaterally. The procedure resulted in a small incision, minimal soft-tissue injury, no operative complications, minimal blood loss, and the preservation of the posterior ligamentum and muscle. In addition to positive operative outcomes, this study provides evidence that MIS performed unilaterally for bilateral decompression is effective at resolving symptoms of pain. Even though the patient indicated a low level of pain on the VAS pre-operative (score of 3.25), he emphasized having a low pain tolerance and stated that his pain was sufficient enough to disrupt his ability to perform his occupational practice as a surgeon. The patient reported the absence of pain and disability immediately post-operative and at 3-, 6-, and 18-months post-operative.

The results of this study coincide with the findings from Hong et al. [10] that a unilateral laminotomy for bilateral decompression can result in short operative times, low operative blood loss, and a reduced level of pain. However, this study also indicates that this may also significantly reduce level of disability, and can be performed as an outpatient procedure using IV sedation. Successful decompression can be determined by either clinical outcomes or anatomical decompression as observed by post-operative imaging studies. This case study showed total decompression via MRI and total resolution of symptoms as indicated by his VAS and ODI scales. Confirmation of decompression from both MRI scans and patient self report is important being that studies indicate that there is a poor association between imaging findings and the severity of clinical symptoms reported by patients [23]. According to patient feedback and post-operative MRI scans, this procedure was effective at achieving complete decompression.

Conclusion

This case study demonstrates the efficacy of performing an outpatient minimally invasive endoscopic bilateral laminotomy for the treatment of severe LSS. The small incision, minimal tissue injury, no operative complications or hospital stay, minimal blood loss, and preservation of the posterior ligamentum and muscle make this procedure a potentially safe surgical treatment for LSS. Although this is a single case study, the efficacy of the minimally invasive surgery for the treatment of LSS validates the need for future research with a larger sample size.

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Minimally invasive surgery through endoscopic laminotomy and foraminotomy for the treatment of lumbar spinal stenosis

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Abstract: Lumbar spinal stenosis is a common cause of radicular and generalized back pain among older adults. Endoscopic minimally invasive surgery, in contrast to open decompression, may provide the opportunity for a less invasive surgical intervention. Thus, the purpose of this study is to evaluate the safety (operative complications, estimated blood loss, operative room time) and effectiveness (pre- versus postoperative level of disability and pain severity) of minimally invasive surgery using endoscopic laminotomy and foraminotomy among a large sample of patients with lumbar spinal stenosis. Methods: This study is composed of 320 consecutive patients with lumbar spinal stenosis who underwent posterior lumbar laminotomy and foraminotomy between 2008 and 2011. Outcome measures consisted of perioperative complications, estimated blood loss, operative room time, level of disability, and pain severity. Pain severity and level of disability were prospectively analyzed to an average of 18 months (12-36 months) post-surgery. Results: There was an average estimated blood loss of 39.3 cc and a mean operative room time of 74 min. Seven patients experienced minor operative complications. All patients were discharged the same day as surgery and reported a significantly lower level of disability ($p = 0.00$) and pain severity ($p = 0.00$) postoperative compared to preoperative. Conclusions: Minimally invasive surgery using endoscopy for the treatment of lumbar spinal stenosis has a short operative time, a low operative complication rate, and minimal estimated blood loss. This study also indicates that MIS for the treatment of LSS can significantly reduce pain and disability level. Thus, minimally invasive surgery using endoscopic laminotomy and foraminotomy appears to be a safe and effective alternative surgical treatment for open decompression surgery in adult patients with lumbar spinal stenosis.

Introduction

Lumbar spinal stenosis (LSS) is an age-related progressive condition and the most common reason for back surgery in patients over the age of 65. LSS refers to the narrowing of the central spinal canal that may cause compression on the nerve root, resulting in intense radiating pain in the buttocks or legs.1 Patients who do not respond to conventional pain treatment methods such as medications, steroid injections, chiropractic treatment, or physical therapy typically turn to surgery as their next attempt at pain relief.

While invasive open spine surgeries are an acceptable surgical treatment and reported satisfactory for spinal decompression,2 they often result in hospital stays, general anesthesia, large operative blood loss, a long length of recovery and rehabilitation, soft tissue damage, and the risk for operative complications.3 With the goal of reducing the negative components associated with open surgeries of the spine,4 minimally invasive surgery (MIS) using endoscopy have become increasingly popular for the treatment of LSS. This is because studies found that MIS may achieve the same objectives as open procedures but with reduced postoperative pain and level of disability,5 minimal blood loss,6-8 less disruption of surrounding soft tissue structures,6-8 and no hospital stay or general anesthesia.5-7 However, some of these studies report on a small sample of patients (e.g. Refs. 5, 9, 10). In this study, the safety (perioperative complications, operative blood loss, and operative time), and effectiveness (level of postoperative pain and disability compared to preoperative) of endoscopic MIS using laminotomy and foraminotomy for the treatment of LSS was examined among a large sample of 320 consecutive patients.

Materials and methods

Participants

Patients were deemed candidates for MIS if they had all of the following: 1) LSS documented by magnetic resonance imaging (MRI) or computerized tomography (CT); 2) LSS symptoms noted on physical exams; and 3) at least 3-months of failed conventional pain management such as physical therapy, chiropractic treatment, anti-inflammatory and pain medications, or steroid injections. Patients who underwent the lumbar endoscopic laminotomy and/or foraminotomy regardless of diagnosis that completed both preoperative and minimum 1-year postoperative outcome questionnaire were included in analyses. Patients who underwent previous spinal surgery were excluded from analysis in order to reduce possible variables that may influence the results of this study.

Informed consent was obtained from all patients. Analyses were conducted on 320 patients between 22 and 90 years of age (M = 60.8 years, SD = 13.5). The sample included mostly men (n = 192) and were mostly Caucasian in race (n = 278). Body mass index (BMI) for this sample was 28.4 (SD = 5.16). Approximately 40 (12.5%) of patients reported being smokers at the time of surgery. Patients reported being in pain for an average of 9.3 years (SD = 11.04). Baseline patient characteristics are displayed in Table 1.

Measures

Patient demographics (age, race, gender, BMI, and smoking status) and information pertaining to the safety of the surgical procedure (EBL, perioperative complications, and length of surgery) were obtained through patient medical records.

Table 1— Baseline patient characteristics.

Patient demographics	Preoperative (n = 320)
Age, mean (range)	60.8 (22-90)
Race, no. (%)	
Caucasian	278 (86.9%)
White Hispanic	14 (4.4%)
African American	6 (1.9%)
Hispanic	2 (0.6%)
American Indian	1 (0.3%)
Asian	1 (0.3%)
Asian/Pacific Islander	1 (0.3%)
Other	3 (0.9%)
Missing	12 (3.8%)
Refused	2 (0.6%)
Male, no. (%)	192 (60.0%)
Smokers, no. (%)	41 (17.8%)
Non-smokers, no. (%)	264 (82.5%)
Not indicated, no. (%)	15 (4.7%)
Years in pain, no. (range)	9.4 (0.2-60)
BMI, no. (range)	28.4 (16.7-47.5)

To measure pain intensity pre- and postoperatively, the prospective visual analog scale (VAS)11 was used. Administration consists of patients being presented with a 10-cm line anchored with the phrases “no pain” and “worst possible pain.” Patients are instructed to bisect the line at the point matching their current level of pain. The pain score is determined by the length of the segment beginning from “no pain” and terminating at the point indicated by the patient. VAS scores range from 0 to 10 with lower scores indicating less severe symptoms of pain. The Oswestry disability index (ODI) 12 was used to measure disability level pre- and postoperatively. More specifically, patients were instructed to answer ten multiple choice questions relating to how back pain has affected their ability to manage in everyday life. Scores range from 0 to 100% with lower scores indicating less disability.

Surgical procedure

In brief, intravenous antibiotics were administered preoperatively. The procedure was performed under Monitored Anesthesia Care sedation. The entry site was determined via fluoroscopy. A scalpel was used to make a stab wound through which a guide-wire was inserted down to the facet region of the vertebral body associated with stenosis. Over this guidewire, a commercially available dilating system was used to dilate the tissues to approximately 18 mm. A drill bit was used to create a window into the foraminal canal. This was done through fluoroscopy to determine the depth of penetration of the drill unit. Electrocautery and holmium lasers were used for hemocoagulation and soft tissue removal. Once the bone and the newly drilled hole were visualized, a standard mechanical burr system was utilized to grind away the lamina of the vertebral body and widen the opening that was created with the bit. Kerrisons and pituitaries rongeurs were utilized during the entire process to smooth the edges of the bone that had been burred and for general debulking of soft tissues and loose bone fragments. Once the region of the lamina and foraminal canal was properly opened, the dilation tube was removed and the procedure was completed. All surgeries were performed in an outpatient setting.

Statistical analysis

Statistical modeling was performed with use of IBM SPSS Statistics software (version 20.0). Significance was defined as $p < 0.05$ on the basis of a two-sided hypothesis test. A two-sided t-test comparing ODI and VAS was conducted to determine if there were any significant differences before and after surgery in level of pain and disability.

Results

Patient demographics

320 consecutive primary lumbar endoscopic laminotomy/foraminotomy patients that met inclusion and exclusion criteria were evaluated to an average of 18 months (range 12-36 months) postoperative.

Outcomes measures

All 320 patients were discharged from the surgical center the same day as surgery. The average surgery time was 74 min. (SD = 28 min.) and the average EBL was minimal at 39 cc (SD = 42.3 cc). Surgical complications occurred in seven (2.2%) patients. All of these patients experienced a dural leak, in which all were repaired intraoperatively.

The two-sided t-test indicated a significant difference between preoperative and postoperative level of pain ($p = 0.00$) with significantly better mean VAS scores at postoperative compared to preoperative (6.0-3.40, respectively). Analyses also indicated a significant difference between preoperative and postoperative level of disability ($p = 0.00$) with mean ODI scores being significantly lower postoperatively than preoperatively (40.1-22.6, respectively). Mean preoperative and postoperative ODI and VAS scores are presented in Table 2.

Table 2—Preoperative and postoperative VAS and ODI mean scores

	Preoperative score mean (SD)	Postoperative score mean (SD)	p-Value
VAS	6.0 (2.0)	3.0 (2.7)	<0.001
ODI	40.1 (17.2)	22.6 (19.8)	<0.001

Abbreviations: VAS, visual analog scale; ODI, Oswestry disability index.

Discussion

This paper examined the safety (operative time, perioperative complications, and estimated blood loss) and effectiveness (pain and disability) of MIS using endoscopic laminotomy and foraminotomy among a large case series for the treatment of LSS.

Results indicate that MIS using endoscopy for the treatment of LSS is associated with short operative times, low complication rates, and minimal average EBL. Results also indicate that patients who underwent MIS also reported less pain and disability postoperatively than preoperatively. These findings support the current literature that MIS using endoscopy may be both a safe and effective treatment for LSS (e.g. Refs. 13-15).

There are a few notable weaknesses to this study. To start, this study suffers from inherent bias by including only patients that completed both preoperative and postoperative ODI and VAS outcome forms. Nevertheless, this study reports on a large cohort of patients treated by multiple surgeons at multiple sites: adding power and applicability to the results. Secondly, postoperative imaging was not performed in these patients to verify decompression. In our experience however, a disconnect may exist between reported symptoms and imaging. Thus, the clinical response demonstrated by the relief of symptoms may be more relevant and provided sufficient evidence to indicate decompression. Another study limitation pertains to the fact that this is a case series so it is unable to directly compare MIS using endoscopy to open decompression. Studies that have made the direct comparison between the two have reported endoscopic techniques to be as successful as open techniques at lumbar decompression with less disruption of surrounding tissue structures, less operative blood loss, and shorter hospitalizations for patients.6,8 In fact, this study demonstrates that this type of surgery only requires IV sedation (instead of general anesthesia), and did not require any hospital stays.

Regardless of the few limitations, results from this study indicates that MIS using endoscopy for the treatment of LSS has a short operative time, a low operative complication rate, minimal EBL, and can significantly reduce pain and disability level. Thus, MIS using endoscopic laminotomy and foraminotomy appears to be a safe and effective surgical treatment for adult patients with LSS.

Conflicts of interest

All authors have none to declare.

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Comprehensive treatment of the aging spine part 3-Conservative treatment modalities

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Key Points

- Define yoga.
- Know different types of yoga.
- Learning yoga postures for the aging spine.
- Benefits of yoga for the aging spine.
- Muscles involved in postures.

Introduction

Yoga is a physical and mental discipline that originated many centuries ago in ancient India. It is derived from a Sanskrit word meaning to "take control" or "to unite." Yoga incorporates the body, mind, and spirit to achieve harmony and balance with a universal consciousness. It is now associated with a form of exercise in which techniques are learned to control the body and mind through a series of asanas (postures).

There are five principles of yoga that form the basis of teachings and disciplined methods for attaining these goals: proper exercise (asanas), proper breathing (pranayama), proper relaxation (savasana), proper diet, and meditation (dhyana). Proper exercise is achieved through asanas or postures that stretch and tone the muscles and ligaments, increase spine and joint flexibility, and ease physical tensions through movement. Proper relaxation relieves muscle tension, conserves energy, and regulates body and mind function. Proper breathing provides for good health, by using all parts of the lung to increase vital oxygen uptake. Yoga breathing exercises control of prana, the life force, which in turn increases energy levels and focuses the mind. Proper diet, consumed in moderation, nourishes the body and mind. Positive thinking and meditation facilitate a peaceful mind, while relaxing the body.[1]

Clinical and basic science

Yoga is classified by the National Institutes of Health as a form of Complementary and Alternative Medicine. There are many well-documented benefits to yoga, including improved flexibility and range of motion, improved posture, increased strength, decreased pain, improved balance, and improved coordination.[2] Individuals with an aging spine benefit from yoga because it "promotes a full range of motion, helps to restore flexibility, and improve circulation in muscles and around joints."[2] Yoga therapy also creates a sense of well-being through the release of beta-endorphins, breaks up chronic muscle tension and stress, and prevents osteoporosis through weight-bearing exercises.

Yoga places "an emphasis on standing poses to develop strength, stability, stamina, concentration, and body alignment."[3] Abnormalities of the deep spinal intrinsic muscles lead to postural and functional imbalances. Yoga therapy goals for the treatment of the aging spine include educating patients on proper body mechanics, correcting underlying internal malfunctions, and preventing recurrence of pain through healthy postural movement patterns. According to yoga philosophy, a person's age is determined by the flexibility of the spine and not by the number of years lived.[4] Yoga benefits the aging spine by imparting flexibility to the spine, firming up the skin, eliminating tension from the body, and strengthening abdominal muscles.

There are many different types of yoga that are practiced throughout the world. Hatha Yoga is what most people in the West associate with the word "yoga," and is practiced for mental and physical health throughout the West. In the aging spine, individuals should focus their attention on the following types of Hatha Yoga: Iyengar, Ashtanga, Bikram, and Vini. Iyengar Yoga places great attention to detail and precise focus on body alignment with the use of props, such as cushions, benches, blocks or straps. It focuses on the structural alignment of the physical body through the development of postures with the use of props to assist individuals that lack flexibility or compensate for injuries. Ashtanga Yoga allows for individual specialization of yoga moves that link breath and movement in flowing exercises. This form of yoga focuses on powerful flowing movements that increase flexibility, balance, and concentration to rehabilitated spines. Bikram Yoga is conducted in a very warm environment, which maintains body heat, making the spine more flexible by allowing the tissues to stretch. Room temperatures average 105°F (40° C), which is not always suitable for individuals with significant heart disease. Vini Yoga involves synchronizing the breath with progressive series of postures, which in turn produce intense internal heat and a profuse, purifying sweat that detoxifies muscles and organs. The flowing movements create heat in the body, which removes toxins and improves tendon, tissue, and muscle flexibility.[5]

Limited scientific research exists examining the benefits of yoga therapy for individuals with low back pain and aging spines. One study by Vidyasagar et al. looked at the effect of Hatha Yoga therapy in individuals with nonspecific low back pain. Their findings reveal that after completing 9 weeks of yoga therapy, the majority of the selected participants noted pain relief, although the study lacked long-term follow-up and a description on assessment of pain status.[6] Another study by Williams et al. looked at chronic low back pain patients who participated in a 16-week Iyengar Yoga therapy. Their results show less pain, less functional disability, and a decrease in pain medication usage after 3 months.[7] A more recent study by Tekur et al. examined the effect of short-term intensive yoga therapy versus physical exercise therapy in individuals with chronic low back pain. Their findings show that 7 days of intensive yoga therapy improved spinal flexibility in terms of flexion, extension, and lateral rotation better than physical therapy in individuals with chronic back pain.[8] Another study by Sherman et al. compared 12 weeks of home yoga therapy with 12 weeks of a home exercise program and educational material. Their findings show that over 3 to 6 months, yoga is more effective than traditional exercises or an educational reference for improving function and pain in individuals with chronic low back pain.[9] One study by Greendale et al. showed that elderly women with an excessive curvature of the upper part of the spine may benefit from practicing yoga. They report that specific yoga postures that target the upper back appear to help straighten the spine and restore physical function in patients with hyperkyphosis.[10]

Yoga-based spinal exercises attempt to correct dysfunctions of the head, spine, thoracic cage, and pelvis. Altering leg positions changes the movement at different levels of the spine; flexed legs target the thoracic region, while extended legs target the lumbar segments. Correct posture and proper breathing enhance spinal stability. Yoga therapy exercises require relaxation of the rib cage through complete activation of the diaphragm in inhalation. This will activate the deep spinal stabilizers, including the abdominal wall (core training), diaphragm, multifidi, and pelvic muscles, which will increase abdominal pressure while reducing axial pressure on the vertebral discs and spine. The goal of yoga-based spinal exercises is to restore normal motor function.[11] There are certain exercises that can be used for both strengthening and stretching of the spine. It is important to learn these postures correctly, as poor technique may cause injury (Tables 23-1 and 23-2).

Lumbar Exercises TABLE 23-1

Muscles Involved	Yoga Stretching Exercises	Yoga Strengthening Exercises
Multifidi	Cobra	Extended Triangle
Lumbar paraspinals	Extended Triangle	Side Angle Pose
Abdominals	Upward Stretch Legs	Cobra
	Boat	Bow
Oblique/Intercostals	Extended Triangle	Extended Triangle
	Spinal Twist	Spinal Twist
	Abdominal Twist	Abdominal Twist

Cervical Exercises TABLE 23-2

Muscles Involved	Yoga Stretching Exercises	Yoga Strengthening Exercises
Sternocleidomastoid	Spinal Twist	Twisting Poses
Cervical paraspinals	Extended Triangle	
	Camel	
Trapezius	Camel	Bridge
	Cobra	Shoulder Stand

As we now know, there are many factors that influence and are associated with degeneration of the spine. In addition to normal aging, high BMI, high LDLc, occupational lifting, and sports activities are associated with degenerative disease.[12] These factors can be either controlled or greatly reduced with the multi-pronged benefits of yoga, thereby curbing the progression of the aging spine. Aside from disc degeneration, other factors lend themselves to the overall process of the aging spine. Spinal stenosis, lumbar facet arthritis, and osteopenia/osteoporosis play a role in the spine as it ages. Although no modality can prevent these changes from occurring, the quality of life of the patient is what is primarily at stake. Pain is the obvious result, yet the emotional toll is usually not taken into account. The benefit of yoga has been shown not to only positively influence the physical effects of the aging spine, but also the emotional aspect. The mind and body are connected in many ways. The pain cycle is a double-feedback loop: when a person experiences pain, his or her mood/depression worsens. As a result, he may experience more pain symptoms. This loop continues until the cycle can be broken. Yoga is one modality which can be used to accomplish this goal. Although further studies are needed, it seems "the initial indications are of potentially beneficial effects of yoga interventions on depressive disorders."[13]

Therapeutic benefits of yoga in individuals with an aging spine uses a three headed approach to alleviate back pain, including yoga therapy, breathing, and relaxation. The tenets of yoga therapy include deep stretching postures that stretch and relax the spinal musculature, along with core strengthening that builds up muscles that support the spine (Figures 23-1 through 23-7). Yoga therapy postures also correct structural irregularities in the spine and increase flexibility of the spinal vertebrae. Specific yoga therapy postures that are of benefit to the aging spine include: Trikona Asana (The Triangle), Tada Asana (Mountain Pose), Ek Pada Asana (One-Legged Posture), Bala Asana (Child Pose), Bhujanga Asana (Cobra Pose), and the Parivritta Parshvakona Asana (Half-Revolved-Belly Pose).[14] Breathing control techniques can eliminate additional stress that is placed on the spine and back due to irregular respiratory patterns. Medication and relaxation alleviate back pain not only by removing tension and stress from the muscles, but also by battling pain on a psychological level.

FIGURE 23-1 | The Boat pose

FIGURE 23-2 | The Bridge pose

FIGURE 23-3 | The Camel pose

FIGURE 23-4 | The Cobra pose

FIGURE 23-5 | The Spinal Twist pose

FIGURE 23-6 | The Extended Triangle pose

FIGURE 23-7 | The Side Angle Pose

Conclusion

Yoga can benefit individuals with an aging spine in many different ways, if practiced under proper guidance. However, patients can actually do more harm than good by engaging in various yoga poses without a proper understanding of the fundamentals. There is concern that beginners will be unable to obtain correct alignment of the spinal vertebrae and musculature in certain poses without the guidance of an experienced teacher.[14] Patients who have been diagnosed with advanced spinal stenosis should avoid extreme extension of the spine, such as back bends in yoga. Patients with advanced cervical spine disease should avoid doing headstands and shoulder stands in yoga. It is extremely important to consult your physician before participating in a yoga regimen. You should also consult a yoga expert (yogi) to teach proper technique and limitations with the aging spine. Yoga therapy movements are fluid in nature. Great care must be taken if an individual experiences pain, which is not part of the normal yoga cycle.

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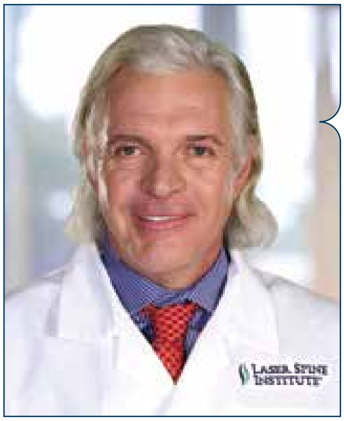

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- "Metastatic Disease of Spine, Diagnosis and Treatment." Society of Military Orthopedic Surgeons. 1992.
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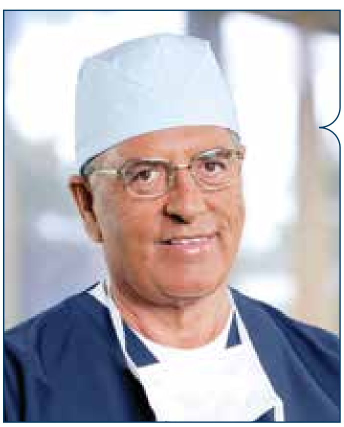

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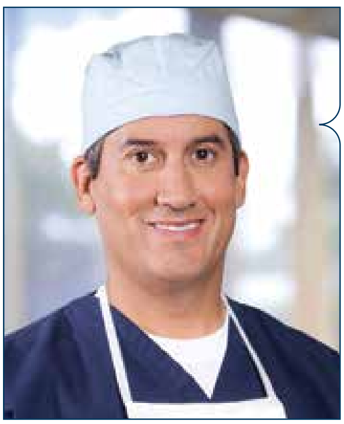

Stefan Prada, M.D.

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Timothy Luke, M.D.

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Timothy A. Luke, M.D. (continued)

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- **The Torsional Strength of Bioabsorbable Interference Screws** Yacoubian SV, Luke TA, Rovner AD, McGillicuddy J.

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