CURRENT MINIMALLY INVASIVE SURGICAL TECHNIQUES IN NARROWED SPINAL CANAL

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Abstract

Lumbar spinal stenosis is a common condition in elderly patients and may lead to progressive back and leg pain, muscular weakness, sensory disturbance, and mainly problems with ambulation. Multiple studies suggest that surgical decompression is an effective therapy for patients with symptomatic lumbar stenosis. Although traditional lumbar decompression is a time honored procedure, minimally invasive procedures are now available which can achieve the goals of decompression with many advantages such as less bleeding, smaller incisions, little muscle distraction and quicker patient recovery. This paper will review the techniques of performing ipsilateral or bilateral decompressions using some microsurgical instruments (microscope, endoscope) and Kit (*mild*).

Key Words: Lumbar stenosis, spine, minimal invasive

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INTRODUCTION

Lumbar spinal stenosis (LSS) is defined as reduction in the diameter of the spinal canal, lateral nerve canals or neural foramina. The stenosis may involve multiple level of the spinal canal or may be localized or segmental. The decrease in diameter of the canal may be caused by bone or ligamentous hypertrophy, disc protrusion, spondylolisthesis or any combination of these conditions.

Spinal stenosis usually affects patients older than 50 years, and is uncommon in younger patients unless they are predisposed to the disease by a congenitally narrowed canal, previous trauma or deformity. Pain in the back and legs are the main symptom. Patients typically report pain, paresthesias, weakness or heaviness in the buttocks radiating into the lower extremities as a result of prolonged standing or walking. Significantly, there is a relationship of symptoms to posture. Symptoms may intensify with extension and relieved with flexion posture. Patients often present with not much objective physical findings, and up to 95% of patients treated surgically have only subjective symptoms such as pain and paresthesias (1,2).

The physical examination of patients with LSS is often normal or shows only nonspecific findings. Many older patients have reduced spinal mobility, with or without spinal stenosis. Extension is usually more limited than flexion, and may reproduce lumbar or lower extremity symptoms of pain and/or paresthesias. Some patients assume a characteristic simian stance with their hips and knees flexed and the trunk forward. This posture may allow patients to stand or walk longer distances. Hamstring tightness is common and may produce a false positive straight leg-raising test. The neurologic examination typically is normal or may show subtle weakness, sensory changes and reflex abnormalities. Weakness of the muscles innervated by the L5 nerve root may occur. A positive lumbar extension test is strongly predictive of spinal stenosis. The patient is asked to stand with the spine hyperextended for 30 to 60 seconds; a positive test is defined by reproduction of buttock or leg pain (3).

The differential diagnosis of spinal stenosis is broad, and a variety of conditions should be ruled out. Peripheral neuropathy, vascular disease and disorders of the hip are common disorders with similar symptoms. Significant weight loss and intractable night pain should raise the suspicion of possible malignancy. Fever with localized back tenderness, recent infection or after an invasive procedure should raise the suspicion of a spinal infection. Patients with vascular claudication may have diminished pulses and are not expected to have both pain with standing and relief of pain with flexion as should be the case for those with spinal stenosis. Patients with peripheral neuropathy usually have a stocking glove distribution of pain or paresthesias. Vibratory sensation is often diminished, and numbness is typically constant in patients with peripheral neuropathy. A careful examination of the hips and surrounding soft tissues should be done to exclude significant hip arthritis and gluteal or trochanteric bursitis from the diagnosis. Vascular claudication should be considered in the differential diagnosis, as well as peripheral neuropathy (4,5,6).

LSS remains the most common indication for spine surgery in elderly patients (7). It is a pathologic state where the dural sac and nerve roots are compressed by a combination of degenerative features including bulging of the intervertebral discs, hypertrophy of the facet joints, and thickening of the lig. flavum. The traditional surgical approach for lumbar stenosis has been to perform a wide, bilateral decompressive laminectomy along with resection of the medial portion of the facet joints to decompress the affected neural elements (8). Although this approach can successfully alleviate nerve compression symptoms, there are drawbacks of the open approach, including amount of soft tissue dissection, blood loss, postoperative pain, forming laminectomy membrane and the potential for iatrogenic instability of the spinal segment (9).

The use of a minimal invasive technique for lumbar surgery was more than more popularized. The advantages of minimally invasive procedures include reduced complication rates, hospital stays and recovery periods. As experience has grown with these surgical approaches, surgeons are routinely treating patients with lumbar stenosis using a combination of a retractor system and an operative microscope. These approaches require less soft tissue destruction compared to an open lumbar decompression (10). As a result, the surgeon can expect less bleeding, less postoperative pain, and a reduced risk of iatrogenic instability in addition to no laminectomy membrane. Surgery with minimal invasive technique is especially beneficial in elderly patients where there are concerns regarding the physiologic stress and risks of a traditional open surgical approach (11).

The classic laminectomy for surgical treatment of spinal stenosis has considerable morbidity. This is further magnified by the disease being more common in elderly with associated medical comorbidities and being usually global involving multiple levels. The purpose of this study is to present and to evaluate new minimal invasive techniques for lumbar spinal canal decompression. This paper will review the minimal invasive operative techniques for treating lumbar stenosis with their retractor system and operative microscope.

Unilateral Hemi-Laminotomy for Bilateral Lumbar Decompression

The procedure is typically performed under general anesthesia, although epidural or spinal anesthesia can be used according to surgeon preference. Prophylactic antibiotics and lower extremity compression stockings are provided at the initiation of the procedure. The patient is positioned at sitting prone, which allows decompression of the abdomen for less bleeding and widens the interlaminar corridor on a radiolucent table (12).

After dyeing with sterile gauze, the location of the spinous processes is marked out on the skin as a guide when localizing the surgical incision. A spinal needle is introduced at the proposed location of the surgical incision, and lateral C-arm fluoroscopy is used to check the position of the needle relative to the site of the neural compression. After confirming correct localization of the needle, the surgical incision is made in 10 mm lateral to the midline for ipsilateral decompression, while bilateral decompression requires an incision about 20 mm lateral to the midline to allow angulation of the retractor to reach the contralateral side of the spinal canal. The length of the incision should be equal to the diameter of the retractor to be used. The authors prefer to use a 10-12 mm outer diameter of William's retractor when performing a decompressive procedure for lumbar stenosis. The lumbar fascia should be sharply incised in line with the skin incision. Next, a small elevator is placed through the incision down to the spinal lamina, and subperiosteal elevation of muscle tissues away from the lamina is performed. The dilation of the soft tissue corridor is carried out followed by placement of the correct length retractor. A lateral fluoroscopic image is used to confirm correct localization of the retractor if needed. The operative microscope is then used to visualize the operative field at the base of the Williams retractor. Any residual soft tissues are removed with electrocautery to expose the lamina and medial edge of the facet joint prior to proceeding (12).

A curved curette is used to separate the lig. flavum from the undersurface of the lamina. Then, the ipsilateral lamina is partially removed (1-5 mm) with a high speed drill. The laminotomy can progress to the cranial edge of the lig. flavum when desired. If only the ipsilateral side requires decompress, the lig. flavum is then removed. However, if bilateral decompression is required, the lig. flavum is left intact until after the drilling maneuver has been completed across to the contralateral side. After removal of the lig. flavum, the medial half portion of the facet joint can be trimmed as needed to achieve decompression of the lateral recess. The overlying inferior articular process may need to be thinned with a high speed drill, but care should be taken to preserve adequate bone stock in this region so as to reduce the risk of an iatrogenic instability or fracture. A kerrison rongeur is used to undercut the lateral recess while preserving the overlying bone stock of the facet complex. Resecting the superior tip of the superior articular process as needed to decompress the exiting nerve root decompresses the ipsilateral foramen (Fig.1A). The disc space is examined, and any herniated disc fragments are removed. Finally, the adequacy of decompression is confirmed with the use of a nerve hook. When a bilateral decompression is required, the refractor is angled to the contralateral side after the ipsilateral lamina has been opened. The operative table can be angled away from the surgeon and the operative microscope repositioned to provide visualization at the base of the spinous process. Next, a high speed drill is used to drill away the ipsilateral base of the spinous process dorsal to the lig. flavum (Fig.1B). Bone bleeding in this region is controlled with bone wax. A small curette is used to separate the lig. flavum from below contralateral lamina, and the drilling is continued through the contralateral lamina until the contralateral facet joint is reached. It is important to note that a bone bridge is left connecting the contralateral base of the spinous process and dorsal surface of the contralateral lamina. The internal laminectomy is continued along the contralateral lamina until the contralateral facet joint is reached. The medial portion of the contralateral facet is thinned until it can be successfully undercut with a Kerrison Rongeur to adequately decompress the lateral recess and foraminal area. After the drilling maneuver is completed, the ligament flavum is separated from its bony attachments and removed. Under direct visualization of the neural elements, any remaining bony or ligamentous compression is alleviated. The adequacy of the decompression is often confirmed with a nerve hook. After completion of the contralateral decompression, the tubular retractor is adjusted back to the ipsilateral side, and the decompression of the ipsilateral side is completed as described above. The fascia, subcutaneous tissues, and skin are closed in a routine fashion. The subcutaneous tissues and facet joints are injected with a long acting local anesthetic to reduce postop pain, followed by placement of a small dressing (12,13).

Patients are mobilized after recovery from anesthesia and discharged on the same day as surgery in most cases. Early return to ambulation and normal activities of daily living is encouraged. Pain management is generally provided by an oral analgesic depending on the preferences of the patient.

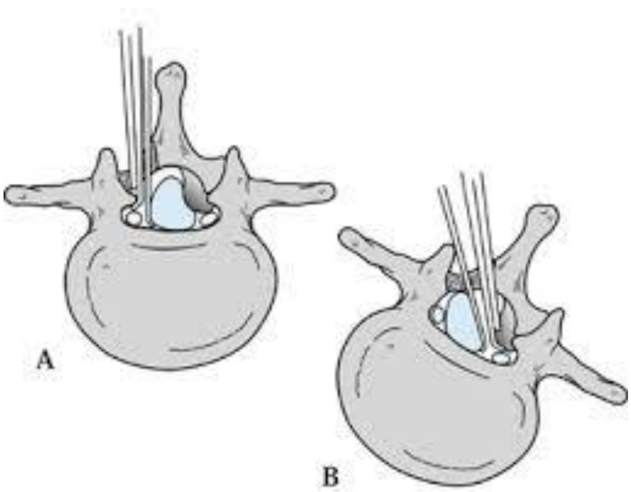

Figure 1*A,B.*

The mild Procedure for Lumbar Decompression

The *mild* procedure offers a minimally invasive alternative to a standard laminotomy or laminectomy. Typically, *mild* is performed using local anesthesia and sedation to keep the patient comfortable. This procedure treats LSS by removing small, but adequate portions of laminar bone and debulking the lig. flavum. This improves the space in the spinal canal while minimizing trauma to the surrounding tissue and bony structures. The restoration of space is confirmed during the procedure utilizing the continuous contralateral oblique epidurogram (14).

Purposeful design elements of the surgical instruments used in the *mild* procedure include built-in safety features such as blunt tips to protect structures at the posterior approach and special top cutting surfaces for precision cutting at the desired angle (Fig. 2). The disposable *mild* kit also includes a portal stabilizer to minimize medial and lateral movement during the procedure, and an instrument depth guide. The typical *mild* patient is elderly, often 65 years of age or older, and presents with lumbar spine neurogenic claudication symptoms thought to be concordant with findings of lumbar stenosis verified through MRI or CT imaging studies. Conservative measures have not alleviated symptoms satisfactorily. Neurogenic claudication is triggered by axial loading activities and unlike intermittent or vascular claudication, is relieved by flexion and not by mere cessation of walking as in vascular claudications.

At the beginning of the procedure the patient is placed in the prone position on a radiolucent operating table, and sterilely prepared. Appropriate cushion is used as needed. An epidurogram is then performed for the purpose of identifying the hypertrophic lig. flavum (Fig 3). Utilization of the contralateral oblique view presents the thickest cross section of the lamina, providing optimal lig. infolding imaging. Next, the interlaminar space is identified through fluoroscopic visualization (Fig. 3). After the trajectory has been planned and the patient's skin marked, the *mild* 6G portal and 7G trocar are inserted percutaneously.

Figure 2. *mild Devices:* ***a.*** *mild Tissue Sculpter;* ***b.*** *mild Portal Stabilizer;* ***c.*** *mild Bone Sculpter Rongeur;* ***d.*** *mild Surgical Clamp;* ***e.*** *mild Portal;* ***f.*** *mild Depth Guide;* ***g.*** *mild Trocar and Handle.*

These devices are advanced along the desired trajectory under fluoroscopic guidance. Once positioned, the trocar is removed, leaving the access portal in the interlaminar space. The physician carefully rotates this device, which precisely cuts and then removes small pieces of bone. Once sufficient access is obtained, the Rongeur is removed and the *mild* Tissue Sculptor is advanced through the portal under the lamina into the dorsal aspect of the hypertrophic lig. flavum. Debulking of the lig. flavum is accomplished by removing the collagen laden posterior portion of the ligament, while leaving the ventral fibers of the ligament intact. An improved contrast flow (reduction of infolding), along with limited availability of tissue to be removed, are clear indicators of the decompression endpoint on epidurogram (Fig. 3b). The procedure can be performed bilaterally and on multiple vertebral levels at one or more settings. It should be noted that the angle of the cutting tip on the instrumentation requires a new incision and instrument insertion when the procedure is being performed bilaterally or at another level (15).

Once adequate decompression has been achieved at the final operative level, the portal is removed and the wound typically closed with a sterile adhesive bandage. Since there is minimal soft tissue trauma, patients are usually observed for two hours after the procedure and subsequently discharged as clinically indicated. Patients are allowed to ambulate as tolerated and instructed to increase activities slowly. No implants are left behind and future treatment is not impeded by this procedure.

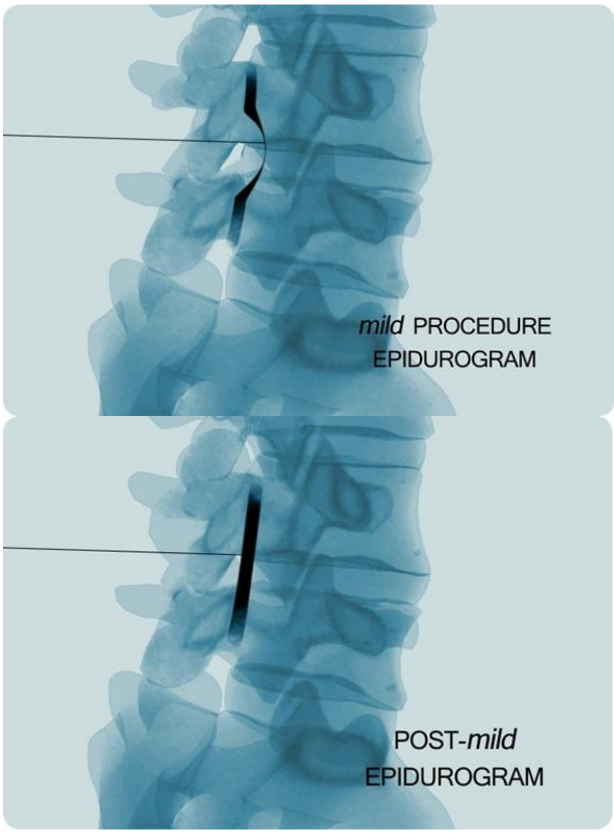

Figure 3a,b. *Epidurogram is performed with low volume intermittent injections using flow patterns to determine decompression and stopping point.*

Physicians use fluoroscopic guidance to remove small portions of excess bone and tissue to decompress the spinal canal and relieve the patient's discomfort. There have been more than 20 peer reviewed clinical journal articles published on *mild*. No major complications related to the devices or the procedure has been reported in clinical trials. To date, more than 15,000 patients have been treated with the procedure (16).

Endoscopic posterior decompression of lumbar stenosis

Surgery is performed in the prone position on a radiolucent table usually under general anesthesia. The skin incision is made after confirming level under image guidance. Surgeon stands on the more symptomatic side or on the left side if the compression is equal on both sides. Incision is given about 1-2 cm away from midline. Single incision usually suffices for two level pathologies. More than one incision can be used if pathology extends more than 2 vertebral levels.

All types of endoscopic spine surgeries utilize dilatation technology to create surgical access through subcutaneous fat, fascia and muscle rather than cutting in order to minimize tissue trauma. The operative sheath is placed at the desired lig. flavum and lamina. Soft-tissues on the lamina, facet joint and lig. flavum are removed. Burrs, trephines and rongeurs can be used for the resection of bone. An ultrasonic bone curette can be used for bone resection. Part of superior and inferior lamina along with the medial facet is removed. Removal of base of the spinous process, osteophytes of the opposite facet and under cutting of the opposite side lamina can be performed using same incision. There is an increased risk of dural tear in a high degree LSS. Lig. flavum is left intact to protect dura matter until all the bony resection. Such procedures should be done after achieving sufficient experience to decrease complications.

Various systems such as Destandau (Karl Storz GmbH and Co KG Tuttlingen Germany), EasyGO (Karl Storz GmbH and Co KG Tuttlingen Germany), SMART (Karl Storz GmbH and Co KG Tuttlingen Germany) etc., are available commercially (17,18,19). All these systems are effective and safe. This technique can be combined with transforaminal approach and lumbar interbody fusion in selected patients with instability of lesser than grade II listhesis. The combination of interspinous process implant fusion and endoscopic decompression can be used for decompression and stabilization of the spine. There is no valid evidence from randomized controlled trials on the effectiveness of transforaminal endoscopic surgery for LSS (20). The outcome of endoscopic treatment was good in most reported series. The results of endoscopic decompression were good with 70.8% patients without any significant leg pain and 22.2% occasional pain. These results were comparable with conventional procedures. The complication rate was low in the endoscopic group. Wada *et al*. also reported improvement in the mean Japanese Orthopaedic Association score from 17.0 before operation to 23.3 after surgery. The clinical results were excellent in Xu *et al*. series with 65.6% and 34.4% patients had excellent and good pain relief respectively according to the Macnab scale. Endoscopic technique can be as effectively as an open technique with the additional benefit of decreased complications and morbidity. Bilateral decompression with a unilateral approach can increase the area of the dural tube up to 408.0% after the surgery. Guiot *et al*. used one of the four procedures (unilateral microendoscopic laminotomy, bilateral microendoscopic laminotomy, unilateral open laminotomy and bilateral open laminotomy) in cadavers. CT was performed before and after each procedure to establish the extent of decompression of the spinal canal. Measurements of the midsagittal, interpedicular and decompression diameters were recorded. Satisfactory decompression of the spinal canal was achieved in all the four procedures. The exiting nerve roots were well visualized when any one of these techniques was used. Complications, including dural tears and facet complex instability, were also same in all the procedures.

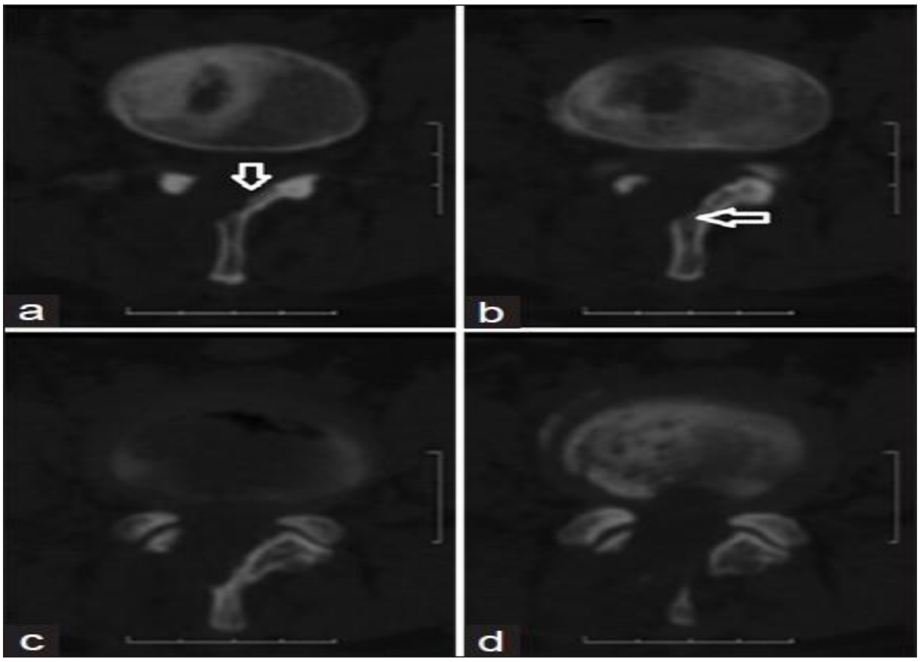

Figure 1a,b,c,d: *Postoperative computed tomography scan showing bilateral sufficient decompression by a minimal invasive technique.*

The operative time was short and the blood loss was also less in the endoscopic technique. The result of endoscopic decompression is usually poor if back pain is out of proportion to the leg symptoms, such patients should be investigated for instability (21, 22).

Main advantages of minimal invasive methods for LSS:

1. Less invasive
2. Easier access to opposite side from same side, by tilting 30-45^{0}
3. Stability maintained
4. Multiple level canal decompression possible
5. Less complication such as epidural fibrosis, infection, laminectomy membrane and CSF leakage.

DISCUSSION

The formerly standard of treatment for symptomatic LSS is a wide decompression via a bilateral paraspinal muscle stripping exposure. Although this traditional technique allows maximal neural decompression, there is morbidity related to stripping the paraspinal muscles and resection of stabilizing ligaments like interspinous and supraspinous. An alternative is a less invasive microsurgical technique of unilateral hemi-laminotomy for bilateral decompression. Commonly known as lumbar segmental sublaminoplasty, the technique was developed by John A. McCulloch and Paul H. Young over 20 years ago (13). This technique enables bilateral central and foraminal neural decompression of one or two levels while limiting muscle stripping to one side and preserving the stabilizing midline ligamentous structures.

Other minimally invasive lumbar decompression (presented here as the *mild*® procedure) is indicated for those LSS patients exhibiting neurogenic claudication with hypertrophic lig. flavum. The *mild* procedure is similar to standard open or endoscopic lumbar laminotomy in terms of the anatomic structures undergoing decompression. The most significant difference between these procedures is that *mild* is a minimally invasive therapy that relies on fluoroscopic guidance, thus providing a clear procedural safety margin. Typically performed with local anesthesia and conscious sedation, the *mild* procedure can also be performed in the outpatient setting. In multiple studies, patients reported significant improvements in all clinical outcomes without any reported safety issues. The results of these studies compare favorably when contrasted to the Medicare database, which indicates that 2.1% of patients undergoing simple decompression experience medical complications and 7.8% are re-hospitalized within 30 days (23).

LSS is generally described as compression of the neural elements related to a variety of degenerative changes including: facet hypertrophy, hypertrophic lig. flavum, and bulging of the intervertebral disc. In LSS, the space within the spinal canal narrows, which leads to asymptomatic compression of nerves and ultimately symptomatic neurogenic claudication. The goal of any surgical treatment of LSS is relief of symptoms by adequate neural decompression while preserving as much of the anatomy, stability, and biomechanics of the lumbar spine as possible. Traditional open surgical treatment of LSS may not only require the large incisions, but also involve a wide laminectomy and undercutting of the medial facet with foraminotomy; leading to local tissue trauma, scarring, and potential postoperative spinal instability. The goal of any surgical treatment of spinal stenosis is to decrease pain and increase the functional capacity of the patient while limiting surgery-related morbidity and mortality. Limiting the extent of surgical invasiveness with the preservation of preexisting spinal elements has been utilized to try and optimize the clinical benefit of surgery. This may limit the risk of iatrogenic spondylolisthesis, postoperative pain and disability, and hospital and rehabilitation costs, and thereby improve patient outcomes.

Lumbar spinal stenosis is not commonly a disease of younger patients. Surgery in an older patient is commonly complicated by multiple comorbidities. It is particularly attractive to have a minimally invasive surgical treatment option for this older group. This allows for early consideration of surgical options without waiting for potentially irreversible neurological morbidity before entertaining fusion surgery. This also allows for an earlier return to an active lifestyle, often limited by the symptoms of lumbar spinal stenosis. Rehabilitation is quicker with minimally invasive surgery with the avoidance of the complications related to postoperative immobility of more extensive procedures. We utilized general anesthesia in all patients, but spinal or epidural anesthesia has been utilized successfully by others. The surgery can be performed with the patient as an in-patient or an outpatient depending on medical, social, and economic factors.

Although the list of potential complications with tubular decompression is no different from traditional open surgery, the rate of certain complications is significantly reduced. For instance, blood loss, wound infection, iatrogenic instability, and medical deterioration following lumbar decompression using a tubular retractor system are lower compared to open laminectoms. Dural laceration (incidental durotomy) may be managed with either suture repair or dural sealants depending on the location, size, and severity of the durotomy. One report found the incidence of durotomy to be 16%, although no long-term sequelae were noted. Because exposure with the tubular retractor systems produces minimal “dead space,” the risk of postoperative dura-cutaneous fistula is reduced with tubular retractor-based surgery in comparison to traditional laminectomy. Small, stable tears may be successfully managed with a small pledget of a hemostatic agent followed by a dural sealant (e.g., fibrin glue). Larger tears or tears with exposed nerve root should be treated with direct suture repair. Although technically demanding, this can be achieved using a small needle and micropituitary instrument as the needle driver and an arthroscopic knot pusher to assist with knot typing. In most cases, prolonged bed rest is not required for patients after a satisfactory dural repair (16).

Infection rates following tubular access surgery are low. In the rare event of a wound infection, treatment with debridement and antibiotic therapy should be instituted. Due to the lack of prolonged anesthesia, heavy blood loss and prolonged bed rest, medical complications after tubular access decompression, are uncommon even in the elderly population (18).

CONCLUSION

Minimally invasive bilateral decompression of acquired spinal stenosis from a unilateral approach can be successfully accomplished with reasonable operative times, minimal blood loss, and acceptable morbidity. Using a minimally invasive lumbar decompression for spinal stenosis, one can safely, and effectively reduce pain, improve functionality, and minimally change spinal biomechanics and stability in LSS patients who have failed conservative treatment and who are not yet in need of, or who do not desire more invasive open surgical decompression procedures.

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