Pedicle-Lengthening Osteotomy for the Treatment of Lumbar Spinal Stenosis

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D. Greg Anderson

4.1 Introduction

Lumbar spinal stenosis (LSS) remains the most common indication for spinal surgery in the older adult population [1]. Degenerative changes in the vertebral column including the intervertebral disc, facet joints, and ligamentum flavum can lead to a reduction in the diameter of the spinal canal, causing compression of the neural elements and producing symptoms of pain or neurologic dysfunction [2, 3]. Although nonsurgical treatments are generally attempted for this patient population, many patients with severe symptoms may not achieve sufficient relief and therefore require surgical intervention [4]. The most common surgical approach for LSS has been the open lumbar laminectomy [5]. Patients with associated degenerative spondylolisthesis are often treated with arthrodesis in addition to a laminectomy decompression [6].

Open lumbar laminectomy is capable of reducing the symptoms of LSS but is moderately invasive and may not be tolerated by some older patients with significant medical comorbidities [5]. The initial favorable results of open lumbar laminectomy have been shown to deteriorate over time and, in some cases, require revision surgery [7]. Minimally invasive surgical approaches for LSS have been utilized; however these techniques have not gained wide acceptance due to concerns over the steep learning curve and/or the potential for an inadequate decompression or a technical complication [8–12]. Interspinous spacers have also been used in the subset of LSS patients who achieve good symptom relief while sitting [13]. Unfortunately, concerns over the durability of this approach have limited the popularity of interspinous spacers [14–16].

D.G. Anderson, M.D.
Departments of Orthopaedic and Neurological Surgery, Thomas Jefferson University
and Rothman Institute, 925 Chestnut St., 5th Floor, Philadelphia, PA 19107, USA
e-mail: greg.anderson@rothmaninstitute.com

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The pedicle-lengthening osteotomy procedure is a relatively new percutaneous surgical approach for LSS. To perform this procedure, the surgeon utilizes fluoroscopic guidance to cannulate the pedicles of the affected level(s). An internal passage is reamed through each pedicle into the vertebral body, leaving the cortical shell of the pedicle intact. A specialized handsaw is used to cut through the cortical shell of the pedicle (from inside the pedicle passage) at the junction of the pedicle and vertebral body. A specialized bone screw is threaded into the pedicle passage. The bone screw creates a gap (produces 4 mm of distraction) at the pedicle osteotomy site. The elongated pedicle heals, following the procedure, producing a permanent expansion of the spinal canal and neural foramina [17].

4.2 Surgical Technique

Pedicle-lengthening osteotomies are performed at lumbar levels requiring neural decompression. The selection of the surgical levels begins with a thorough history and physical examination of the patient. Advanced imaging studies (MRI or CT myelography) are always reviewed as part of the evaluation, and the location of nerve compression is correlated to the patient's clinical symptoms to determine the symptomatic levels of lumbar stenosis. All areas of clinically symptomatic nerve root compression should be included in the surgical plan.

To decompress a particular lumbar level, the pedicles above and below the symptomatic disc level are lengthened. For instance if the patient's symptoms are due to stenosis of the L4/L5 level, the surgeon should lengthen the L4 and L5 pedicles to correct the pathologic condition. The pedicle-lengthening osteotomy procedures may be performed under general anesthesia or local anesthesia and intravenous sedation. In either case, the patient is positioned prone on a radiolucent operating table with good access for fluoroscopic imaging. Surgeons may use either uniplanar or biplanar fluoroscopy during the pedicle-lengthening procedure, and some surgeons have utilized computer-assisted image guidance to perform the procedure.

After a sterile preparation and draping of the patient, fluoroscopic imaging is utilized to identify the pedicles to be lengthened. Using the *en face* fluoroscopic view, the site of the skin incision is demarcated directly in line with the central axis of the pedicle (Fig. 4.1). A 10 mm skin incision is made in line with the central axis of each pedicle. Next, a trochar-tipped reamer is utilized to cannulate the pedicle. It is important that the tip of the reamer be positioned within 2 mm of the center of the pedicle as seen on the *en face* view to ensure a well-centered passage through the pedicle is achieved. The reamer is passed down the center of the pedicle until the radiographic marker is positioned at the junction of the pedicle and vertebral body (Fig. 4.2). The reamer is then removed and the pedicle saw is placed into the pedicle passage (Fig. 4.3).

The pedicle saw is a hand-powered instrument that has a semiflexible saw blade that extends from the side of the saw shaft to cut the pedicle bone from inside the pedicle passage. The site of the pedicle osteotomy is located at the junction of the pedicle and vertebral body. With the pedicle saw positioned correctly, the surgeon

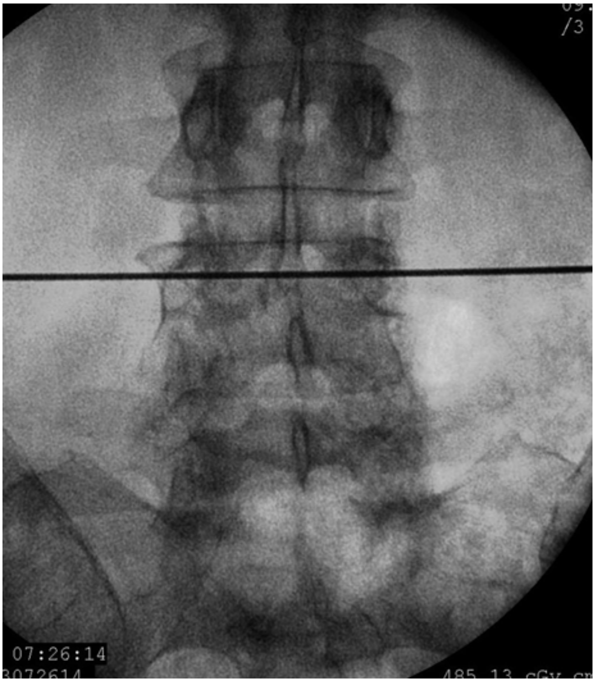

Fig. 4.1 An *en face* fluoroscopic view of the left L4 pedicle is shown with a Kirschner wire above the skin to demarcate the location of the pedicle for the planning of the skin incision

advances the blade in 1/8th mm increments by turning a knob on the upper portion of the saw. The saw is rotated within the pedicle passage to cut the pedicle bone at the site of the pedicle osteotomy. The initial 1–2 mm of the bone cut is performed with circumferential rotation of the pedicle saw. The remainder of the pedicle wall is cut with zonal cutting (Fig. 4.4). During zonal cutting, the pedicle is divided into four or more zones that are cut independently. This produces more accurate cutting of the uneven shape of the pedicle walls and reduces the risk of "past pointing" of the blade during the cutting procedure. As the pedicle saw blade is extended in 1/8th mm increments during cutting, the blade should be swept across the internal bony walls of the pedicle until the outer cortex of the pedicle wall has been breached. The blade is then retracted and the saw is adjusted to cut the next pedicle zone. Throughout the cutting procedure, the saw provides excellent tactile feedback allowing the surgeon to "feel" the sensation of the saw blade scraping away thin layers of bone. With experience, the surgeon will be able to detect the tactile sensation of the saw blade breaching the wall of the pedicle in a reliable fashion. Throughout the pedicle cutting process, periodic fluoroscopy images in the *en face* and lateral projections are obtained to check the position of the saw blade relative to the outer cortex of the pedicle (Fig. 4.5).

During pedicle cutting, the primary "at risk" structure is the traversing nerve root that courses along the medical and interior walls of the pedicle. The surgeon must use

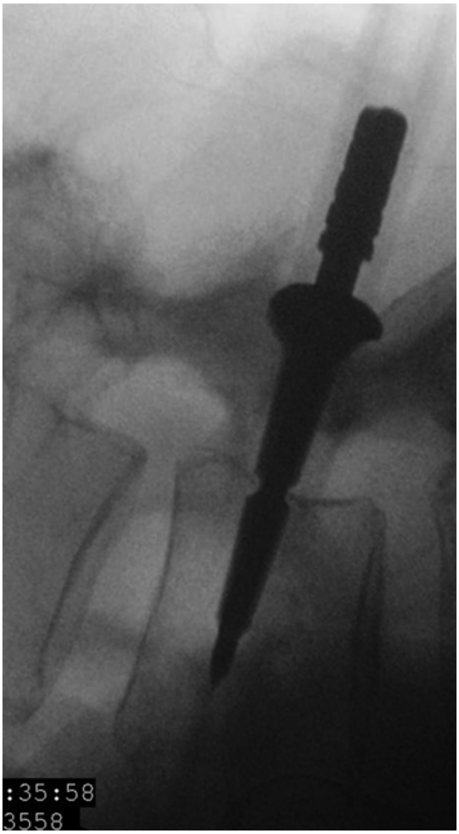

Fig. 4.2 A trochar-tipped bone reamer is passed through the central region of the pedicle until the radiographic marker (notch at the waist of the reamer) reaches the base of the pedicle

particular care in these regions to ensure that the blade of the saw does not project significantly beyond the walls of the pedicle. The geometry of the saw blade is designed to reduce the potential for nerve injury in the event of contact between the blade tip and nerve root. In addition, the surgeon may use stimulated EMG monitoring to assist in detecting any contact between the blade and nerve root.

After cutting the pedicles, an expandable bone screw is threaded into the pedicles and positioned utilizing the radiographic marker at the site of the pedicle cut (Fig. 4.6). A threaded mechanism is then used to lengthen the screw implant causing expansion of the gap at the base of the pedicle to 4 mm (Fig. 4.7). The bone screw locks in the expanded position to prevent loss of pedicle lengthening and maintain the lengthened position of the pedicle until bone healing across the osteotomy transpires (Fig. 4.8).

After completing the procedure, final fluoroscopic imaging is utilized to confirm position of the pedicle-lengthening devices. The surgical incisions are closed and local anesthetic is injected subcutaneously at the surgical sites for postoperative pain management. Patients are mobilized rapidly after recovery from anesthesia and encouraged to resume normal daily activities except for bending or twisting of the lumbar area for the first 6 weeks to allow bone healing at the osteotomy sites.

Fig. 4.3 A specialized hand-powered bone saw is placed into the pedicle passage and used to cut the pedicle at the junction of the pedicle and vertebral body

4.3 Discussion

Lumbar spinal stenosis is an increasingly common condition, due to aging of the population [2]. The rate of surgery for LSS varies widely in different regions of the world. Jansson and colleagues reported a rate of surgery for lumbar stenosis of 13.2 per 100,000 Swedish citizens in 1999 and noted a threefold increase between 1987 and 1999 [18]. In contrast, the rate of lumbar decompression surgery declined slightly between 2002 and 2007 for the US Medicare population [19].

The SPORT study provided multicentered, prospective outcome data on patients with LSS with and without a concomitant low-grade degenerative spondylolisthesis. In the SPORT study, patients with LSS were treated with a decompressive lumbar laminectomy, and lumbar fusion was added for the subset of patients with degenerative spondylolisthesis. Surgical care was also compared to a course of usual nonoperative care [20]. In the cohort without spondylolisthesis,

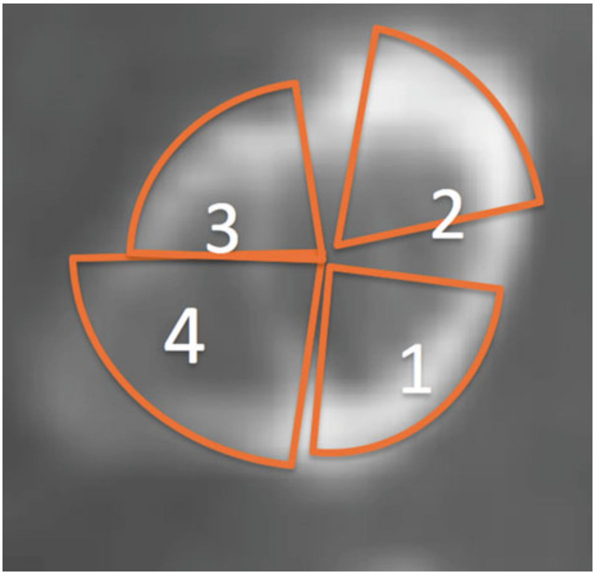

Fig. 4.4 Coronal reconstruction of a pedicle demonstrates an asymmetric pedicle shape. The pedicle is cut in zones (orange pie-shaped regions) to reduce "past pointing" of the bone saw blade

the 24-month as-treated analysis demonstrated a mean improvement of 16.1 (±1.9) points compared to the mean baseline Oswestry Disability Index (ODI) scores. This was statistically superior to the improvement of 12.7 (±1.8) points on

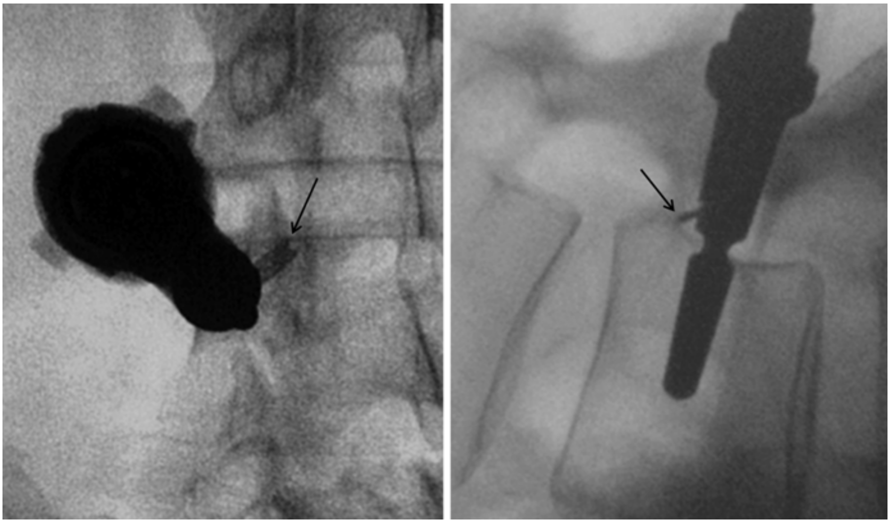

Fig. 4.5 *En face* and lateral fluoroscopic images of the pedicle saw during pedicle cutting. Note the location of the saw blade (*arrows*) is easily seen relative to the margins of the pedicle wall

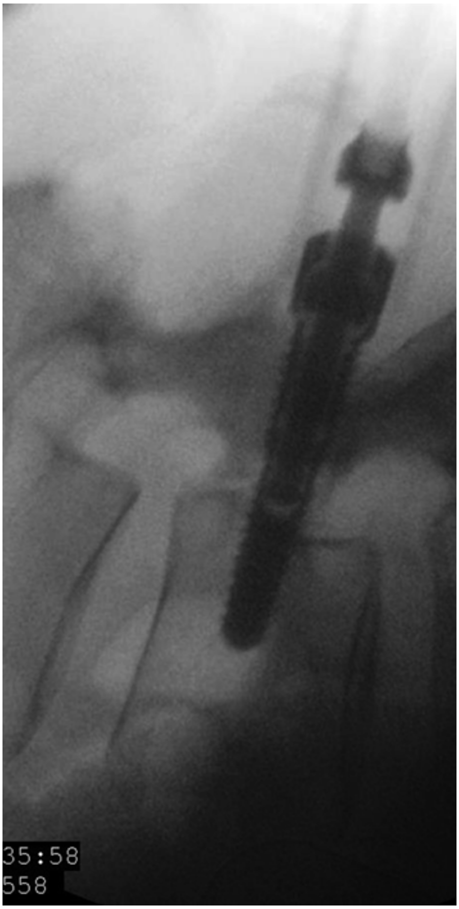

Fig. 4.6 Bone screw in place in the pedicle before expansion of the bone screw. Notice the slight gap where the pedicle cut has been performed

the ODI scale for the nonoperative cohort. The SPORT study reported blood transfusions in 15 % and dural tears in 9 % of patients treated by lumbar laminectomy. Patients undergoing a concomitant lumbar fusion had a higher rate of complications including blood transfusion (35 % intraoperative and 16 % postoperative), dural tears (12 %), wound infection (5 %), and additional surgery within 12 months (8 %) [20].

Complication rates and clinical outcome following lumbar laminectomy surgery have been reported by other authors. Deyo et al. studied Medicare claims and reported life-threatening complications in 2.3–5.6 % of patients undergoing surgery for LSS depending on the invasiveness of the surgical approach. An additional 7.8–13 % of the LSS cases required hospital readmission within the first 30 days of surgery [19]. Reoperation rates following laminectomy for LSS were reported to be 23 % within 8–10 years in the prospective, observational Maine cohort study [21]. In a 7–10 year follow-up study, Katz et al. reported a 33 % rate of severe back pain following open lumbar decompression [7].

Fig. 4.7 The bone screw after expansion showing lengthening of the pedicle and enlargement of the spinal canal

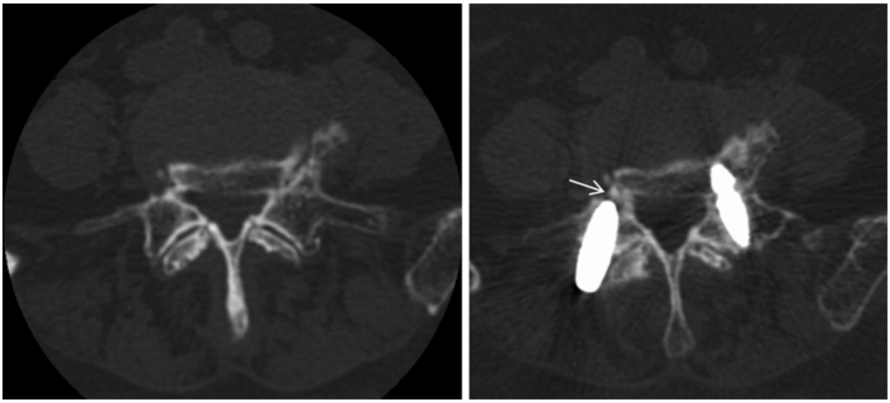

Fig. 4.8 Computed tomography scan of the L5 level before and after pedicle lengthening. Notice the increase space in the lateral recess of the spinal canal. Also notice, the healing of the pedicle osteotomy (*arrow*)

Minimally invasive techniques for lumbar decompression have become increasingly popular in recent years. These procedures often employ a tubular retractor system which limits the soft tissue disruption of the surgical approach [8]. Rahman et al. reported less blood loss, reduced operating times, shorter hospital stays, and a lower rate of complications in a cohort of patients following minimally invasive decompression when compared to open decompression [22]. Rigorous prospective studies comparing the outcome of open laminectomy to minimally invasive decompression are currently lacking [23, 24]. Only two small studies could be found which prospectively compare minimally invasive surgical decompression to open decompression [25, 26]. In a retrospective data mining study, Fu et al. reported lower rates of death and neurological complications among enrollees of the Scoliosis Research Society database treated with a minimally invasive approach as compared to open surgery [27]. Despite these encouraging reports, concerns persist among many surgeons regarding the steep learning curve and risk of technical complication due to inadequate visualization with minimally invasive techniques. [26] These concerns have currently limited the adoption of minimally invasive decompression techniques.

Interspinous spacers have been studied for selected cases of LSS. In the United States, the X-Stop device (Medtronic Spine, Sunnyvale, California) was approved by the Food and Drug Administration in 2005 for the treatment of LSS and has achieved mixed results. Although one large trial showed the X-Stop to be superior to nonoperative care [28], others have reported problems with the device. For instance, Brussee et al. found that only 31 % of their patient cohort achieved a good result following X-Stop implantation [14]. Tuschel et al. reported a 30 % revision rate, mostly in the first year after implantation, due to inadequate relief from the symptoms of stenosis [29]. Kim et al. found spinous process fractures in 29 % of the cases in their series [15]. Bowers et al. reported complications in 38 % of patients and performed revision surgery in 85 % of the patients in their series [16]. Because of these concerns, intraspinous spacers have not replaced open lumbar decompression as the predominant method of treatment for LSS at the current time.

The pedicle-lengthening osteotomy procedure provides a novel surgical strategy for enlarging the spinal canal and neural foramen using a percutaneous approach. The theoretical advantages of this procedure include the lack of removal of normal anatomic structures and the reduced risk of major bleeding, infection, and medical complications compared to traditional open lumbar decompression. A compelling aspect of pedicle lengthening is the lack of removal of normal anatomic structures which should limit the risks of postoperative instability. Mlyavykh et al. reported the results of a pilot study for pedicle lengthening which demonstrated favorable clinical results and a low perioperative complication rate [30]. Further study of this technique and a more direct comparison to alternative treatment strategies for lumbar spinal stenosis will be needed in the future to define the ultimate role of this procedure for the treatment of lumbar spinal stenosis.

References

1. Atlas SJ, Keller RB, Robson D, et al. Surgical and nonsurgical management of lumbar spinal stenosis: four-year outcomes from the maine lumbar spine study. Spine. 2000;25:556–62.
2. Siebert E, Pruss H, Klingebiel R, et al. Lumber spinal stenosis: syndrome, diagnostics and treatment. Nat Rev Neurol. 2009;5:392–403.
3. Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonsurgical therapy for lumbar spinal stenosis. N Engl J Med. 2008;358:794–810.
4. Yuan PS, Albert TJ. Nonsurgical and surgical management of lumbar spinal stenosis. J Bone Joint Surg Am. 2004;86:2320–30.
5. Fredman B, Arinzon Z, Zohar E, et al. Observations on the safety and efficacy of surgical decompression for lumbar spinal stenosis in geriatric patients. Eur Spine J: Off Publ Eur Spine Soc, Eur Spinal Deformity Soc, Eur Sect Cervical Spine Res Soc. 2002;11(6):571–4.
6. Herkowitz HN, Kurz LT. Degenerative lumbar spondylolisthesis with spinal stenosis: a prospective study comparing decompression with decompression and intertransverse process arthrodesis. J Bone Joint Surg Am. 1991;73:802–8.
7. Katz JN, Lipson SJ, Chang LC, et al. Seven to 10-year outcome of decompressive surgery for degenerative lumbar spinal stenosis. Spine. 1996;21(1):92–8.
8. Asgarzadie F, Khoo LT. Minimally invasive operative management for lumbar spinal stenosis: overview of early and long-term outcomes. Orthop Clin North Am. 2007;38(3):387–99.
9. Hamasaki T, Tanaka N, Kim J, et al. Biomechanical assessment of minimally invasive decompression for lumbar spinal canal stenosis: a cadaver study. J Spinal Disord Tech. 2009;22(7):486–91.
10. Podichetty VK, Spears J, Isaacs RE, et al. Complications associated with minimally invasive decompression for lumbar spinal stenosis. J Spinal Disord Tech. 2006;19(3):161–6.
11. Rahimi-Movaghar V, Rasouli MR, Vaccaro AR. Patient outcomes vs a minimally invasive approach in lumbar spinal stenosis: which is more important? Neurosurgery. 2010;67(4):E1180.
12. Yoshimoto M, Takebayashi T, Kawaguchi S, et al. Minimally invasive technique for decompression of lumbar foraminal stenosis using a spinal microendoscope: technical note. Minim Invasive Neurosurg: MIN. 2011;54(3):142–6.
13. Kondrashov DG, Hannibal M, Hsu KY, Zucherman JF. Interspinous process decompression with the X-STOP device for lumbar spinal stenosis: a 4-year follow-up study. J Spinal Disord Tech. 2006;19(5):323–7.
14. Brussee P, Hauth J, Donk RD, et al. Self-rated evaluation of outcome of the implantation of interspinous process distraction (X-Stop) for neurogenic claudication. Eur Spine J: Off Publ Eur Spine Soc, Eur Spinal Deformity Soc, Eur Sect Cervical Spine Res Soc. 2008;17(2):200–3.
15. Kim DH, Tantorski M, Shaw J, et al. Occult spinous process fractures associated with interspinous process spacers. Spine. 2011;36(16):E1080–5.
16. Bowers C, Amini A, Dailey AT, et al. Dynamic interspinous process stabilization: review of complications associated with the X-Stop device. Neurosurg Focus. 2010;28(6):E8.
17. Kiapour A, Anderson DG, Spenciner DB, et al. Kinematic effects of a pedicle-lengthening osteotomy for the treatment of lumbar spinal stenosis. J Neurosurg Spine. 2012;17(4):314–20.
18. Jansson KA, Blomqvist P, Granath F, Nemeth G. Spinal stenosis surgery in Sweden 1987–1999. Eur Spine J: Off Publ Eur Spine Soc, Eur Spinal Deformity Soc, Eur Sect Cervical Spine Res Soc. 2003;12(5):535–41.
19. Deyo RA, Mirza SK, Martin BI, Kreuter W, Goodman DC, Jarvik JG. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. JAMA. 2010;303(13):1259–65.
20. Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonoperative treatment for lumbar spinal stenosis four-year results of the spine patient outcomes research trial. Spine. 2010;35(14):1329–38.

21. Atlas SJ, Keller RB, Wu YA, et al. Long-term outcomes of surgical and nonsurgical management of lumbar spinal stenosis: 8 to 10 year results from the maine lumbar spine study. Spine. 2005;30(8):936–43.
22. Rahman M, Summers LE, Richter B, et al. Comparison of techniques for lumbar laminectomy: the minimally invasive versus the "classic" open approach. Minim Invasive Neurosurg. 2008; 51:100–5.
23. Fu KM, Smith JS, Polly Jr DW, et al. Morbidity and mortality in the surgical treatment of 10,329 adults with degenerative lumbar stenosis. J Neurosurg Spine. 2010;12(5):443–6.
24. Mannion RJ, Guilfoyle MR, Efendy J, et al. Minimally invasive lumbar decompression: long-term outcome, morbidity, and the learning curve from the first 50 cases. J Spinal Disord Tech. 2012;25(1):47–51.
25. Rosen DS, O'Toole JE, Eichholz KM, et al. Minimally invasive lumbar spinal decompression in the elderly: outcomes of 50 patients aged 75 years and older. Neurosurgery. 2007; 60(3):503–9.
26. Lauryssen C. Technical advances in minimally invasive surgery: direct decompression for lumbar spinal stenosis. Spine. 2010;35(26):S287–93.
27. Stucki G, Daltroy L, Liang MH, et al. Measurement properties of a self-administered outcome measure in lumbar spinal stenosis. Spine. 1996;21(7):796–803.
28. Zucherman JF, Hsu KY, Hartjen CA, et al. A prospective randomized multi-center study for the treatment of lumbar spinal stenosis with the X STOP interspinous implant: 1-year results. Eur Spine J. 2004;13(1):22–31.
29. Tuschel A, Chavanne A, Eder C, Meissl M, Becker P, Ogon M. Implant survival analysis and failure modes of the X-Stop interspinous distraction device. Spine (Phila Pa 1976). 2013;1;38(21):1826–31.
30. Mlyavykh S, Ludwig SC, Mobasser JP, Kepler CK, Anderson DG. Twelve-month results of a clinical pilot study utilizing pedicle-lengthening osteotomy for the treatment of lumbar spinal stenosis. J Neurosurg Spine. 2013;18(4):347–55.