# Lumbar Spinal Stenosis

# 35

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**Learning Objectives**

- Patient selection for minimally invasive spine surgery (MISS) with spinal stenosis.
- The scientific basis supporting the benefits of MISS.
- Patient outcomes following treatment of lumbar spinal stenosis with MISS techniques.
- Complication profile associated with treating lumbar spinal stenosis with MISS techniques.
- MISS procedures available for lumbar spinal stenosis.
- MISS procedures available for lumbar spinal stenosis with instability.

## 35.1 Introduction

As the population ages, lumbar spinal stenosis (LSS) is becoming more prevalent and is the most frequent diagnosis in elderly patients undergoing spinal fusion [1]. Longer life expectancy and sustained interest in maintaining an active lifestyle makes treatment of LSS important for any individual providing spinal care. LSS typically manifests clinically with diminished walking tolerance accompanied by bilateral buttock and leg pain with or without back pain. Neurologic impairment may include pain, paresthesias, or weakness alone or in combination. Collectively, this constellation of symptoms is termed neurogenic claudication. The etiology of LSS may be congenital, iatrogenic, traumatic, or degenerative. This chapter will focus primarily on the latter. Anatomically, compression of neural elements by the bone and/or soft tissue may take place in various regions of the spinal segment including the central canal, the subarticular or lateral recess, and/or the neural foramen.

Conservative modalities are generally indicated as the first-line treatment and include oral analgesics, anti-inflammatories, activity modification, and physical therapy. Additionally, epidural and/or selective nerve root injections may be implemented, however, with variable results [2, 3]. Surgical treatment is reserved for patients who have exhausted all conservative measures and continue to be disabled by their symptoms. Traditional surgical options for LSS include laminectomy, foraminotomy, or fenestration laminotomy, with the primary goal of decompressing the neural elements. In cases where back pain is a predominant symptom and can be attributed to degenerative spondylolisthesis (DS) or a progressive degenerative scoliosis, a fusion procedure may be indicated.

Over the past several decades, the surgical treatment of LSS has trended toward less invasive techniques. Embrace of the surgical microscope and the development and utilization of tubular retractors have assisted in the evolution of minimally invasive techniques including spinous process osteotomies allowing muscular attachments to remain undisturbed and unilateral approach facilitating bilateral decompression [4, 5].

Traditional open techniques, while effective, inflict greater damage to the spinal musculature via soft tissue stripping and thermal injury that are further exacerbated by powerful self-retaining retractions that exert a tremendous amount of force, causing ischemia and subsequent necrosis, to a greater surface area of soft tissue [6]. Also, damage to

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the medial branch of the dorsal rami during a traditional open approach has been described to cause denervation of the paraspinal musculature further contributing to postoperative muscle dysfunction [7]. Conversely, decreased intraoperative blood loss and a shorter hospital stay without compromising the quality or extent of bony decompression have been shown with minimally invasive spine surgery (MISS) [8–10]. A variety of MISS techniques intended to treat LSS have been described.

## 35.2 Indications

For surgery to be considered, surgical candidates should exhibit neurogenic claudication and have completed a trial of conservative treatment. The desirable benefits of MISS treatment include decreased blood loss, smaller incisions, decreased infection rates, and shorter length of hospital stay. While these features are desirable for patients in general, they are particularly important for elderly patients or those with serious comorbidities or chronic diseases with little hope for optimization prior to surgical intervention [11].

Determining which patients are appropriate for MISS is as important as the performance of the procedure itself. Lumbar spinal stenosis and spondylosis are major causes of morbidity among the elderly. While surgical decompression may be effective for the elderly, many are not considered candidates for surgery based on their ages and/or comorbidities. In an effort to address these concerns, Rosen et al. found minimally invasive decompression for symptomatic LSS in patients over 75 years of age to be safe and effective [12].

Spine surgery has not been spared the challenges that arose with the obesity epidemic and its associated increased incidence of diabetes and other comorbidities. Increased surgical time, blood loss, perioperative surgical site infection (SSI), and other perioperative complications may be expected in these individuals. MISS provides for reduced soft tissue damage important in obese patients, thus minimizing infections and wound healing disorders. Additionally, deeper regions of wounds can be clearly visualized with the aid of tubular retractors [13].

Although the efficacy and safety of MISS for LSS have been documented in the elderly population, certain considerations should be made in younger patients. This cohort of patients often has less degenerative diseases, as well as more lax ligamentous structures, including the facet capsules that may predispose them to iatrogenic instability. In a cadaveric biomechanical study with finite element analysis, Ivanov et al. studied the effects of limited decompression on stresses of the remaining bone and showed that there were significant increases in stress at the pars and inferior facet. These effects were greatest in extension and rotation to the contralateral side, and the authors concluded that the surgeon should be aware of the possibilities of stress fractures in this patient group [14].

Neurogenic claudication due to LSS can be effectively addressed through decompression of the affected neural elements which can be performed directly or indirectly. An example of a MISS technique of indirect decompression is the interspinous process device (IPD). Historically, IPDs were indicated in patients over 50 years of age, with moderate cases of LSS, causing ambulatory limitations, and who had failed conservative treatment. Relief of symptoms when flexing the lumbar spine was a prerequisite for the use of these techniques [15, 16]. Similarly, radiographic evidence of distraction of the spinous processes of interest should have been observed [15]. Over time, these devices showed variable results in patients with spondylolisthesis and it was recommended to be used with caution in these instances. In addition, it was recommended to be limited to Meyerding grade I degenerative spondylolisthesis [17, 18]. Furthermore, the spinous process of S1 generally does not provide adequate bone stock to distract the L5–S1 segment, generally limiting the use of IPDs to the L4–5 level or cranial.

Other indirect decompressive techniques include interbody fusion procedures. Oliveira et al. reported a 41.9% increase in average disc height, 24.7% increase in foraminal area, and a 33.1% increase in central canal diameter [19]. Kepler et al. demonstrated a significantly increased average lumbar foraminal area following lateral lumbar interbody fusions (LLIFs) [20]. Elowitz et al. reported significantly increased dural sac/bony canal ratio in the anterior–posterior and lateral axis following lateral transpoas interbody fusion (LTIF) using the extreme lateral interbody fusion (XLIF) technique. This was associated with improved low back and leg pain intensity and frequency [21]. In addition, Alimi et al. reported a significant improvement in ODI that was sustained following LLIF [22]. Indirect decompression via interbody fusion does have its limitations. For example, Malham et al. found 11 failures in a prospective cohort study of 122 patients that underwent stand-alone LLIF without posterior instrumentation. Seven were due to underappreciated pathology. Of those, three had high-grade facet arthropathy with associated dynamic instability, three had bony lateral recess stenosis, and one had congenital stenosis with dynamic instability [23]. In another multi-institutional prospective study, Wang et al. reported on radiographic predictors of failed indirect decompression via XLIF supplemented with pedicle screw fixation and found bony subarticular recess stenosis to be the sole independent risk factor [24]. Hence, when considering indirect decompression via an interbody device, radiographs and MRI should be closely scrutinized to prevent a poor outcome. CT scan may also be helpful to rule out bony stenosis in the canal and/or neural foramen.

Direct decompression for LSS has traditionally been accomplished through a decompressive open laminectomy via a midline incision and subperiosteal dissection from the spinous processes centrally to the lateral aspect of the pars laterally. However, direct decompression may also be accomplished with MISS via a mini-open incision or with the use of a tubular retractor. The procedure may be performed with or without the use of an operating microscope or endoscope. In keeping with MISS philosophy of muscle preservation, a muscle-splitting approach is preferred. In cases of unilateral radicular symptoms, decompression is typically performed from the ipsilateral side, although a contralateral approach may facilitate foraminal decompression while undercutting the facets. In cases of bilateral radicular symptoms, a unilateral approach with bilateral decompression has been shown to be safe and effective [9]. Although Asgarzadie et al. reported acceptable results for the treatment of central, lateral recess and foraminal disease via this technique, other authors have observed limitations to the extent of lateral recess decompression achieved from the unilateral microendoscopic technique [25]. Furthermore, patients with arachnoiditis, tumor, infection, high-grade spondylolisthesis, or pseudomeningocele are generally not candidates for such sublaminar microendoscopic approaches. Likewise, patients who have had prior surgery at the level of interest require caution due to the presence of adhesions and its associated intra- and postoperative sequelae including thecal sac violation and nerve root injuries, although these complications are generally not higher when comparing revision MISS to open revision surgery [26]. Nevertheless, if revision cases are to be attempted, they should be performed by surgeons thoroughly experienced with the technique in primary settings [9]. Minimally invasive techniques have overall been successfully employed for treating central and lateral recess stenosis; however, the neural foramen can be difficult to access to address foraminal stenosis via these techniques, given a relatively confined space bordered by the cephalad and caudal pedicles and the dural sac medially. Nevertheless, Yoshimoto et al. recently described the successful treatment of foraminal stenosis with a minimally invasive technique, indicating that further advancements in treating this condition, without fusion, may be on the horizon [27]. In cases of neural foramen or subarticular recess stenosis from facet cysts, Deinsberger et al. demonstrated successful treatment by direct decompression through MISS techniques [28].

Although decompression of the affected neural elements remains the priority of either minimally invasive or open surgical treatment of LSS, care must be taken to maintain spinal stability. Decompression alone without fusion should be contemplated with caution in patients with spondylolisthesis and those with coronal or sagittal plane spinal deformities [29]. In fact, Yamada et al. cautioned against the use of decompressive foraminotomy alone in deformities with Cobb angles measuring as little as 3° in the coronal plane [9, 29].

> Appropriately indicating MISS is as important as performing the surgery itself. Elderly and obese patients are often good candidates for MISS to mitigate associated complication risks. MISS in a younger cohort may reduce the risk of postoperative instability. These procedures can be technically challenging; hence, caution should be exercised when performing revision MISS.

## 35.3 Outcomes

Most spine surgeons care for patients with LSS and, likewise, are familiar with the benefits and shortcomings associated with open techniques for treating this disorder. Thus, establishing benefits and shortcomings of MISS will be the focus of this section. Additionally, safety and efficacy profiles for new procedures will be reviewed.

Defining outcomes of MISS for LSS is difficult due to a lack of level I studies addressing this question and the lack of randomization and a control group in prospective studies. Furthermore, although open decompressive laminectomy is generally considered the standard in comparing the results of MISS, there is considerable variability in open techniques (i.e., the frequency and extent to which medial facetectomy or foraminotomy is performed). Within the current literature evaluating MISS, patient cohorts are often heterogeneous with regard to demographics, procedures performed, or diagnoses. Another difficulty in interpreting the MISS literature is in the parameters used to measure outcomes. For example, when examining interventions for DS, changes in preoperative to postoperative scores on patient-reported outcome measurement instruments such as the Oswestry Disability Index (ODI) or Short Form 36 (SF-36) may be used. Alternatively, others may define success based on radiographic parameters such as progression of DS slip. Finally, as evident in the Spine Patient Outcomes Research Trial (SPORT), the time at which outcomes are measured can have a great impact on the benefits and value of decompressive spinal surgery. Within MISS literature, there is a spectrum of time points at which outcome data is gathered; this may be as short as weeks or, more typically, midterm results [30, 31]. Most MISS techniques have been described within the past two to three decades, some much more recently, and procedures continue to be developed currently. Hence, as a result of the innovation in this field, long-term data tends to be less common.

Nearly 100 years after the first description of open laminectomy, Young et al. described bilateral decompression of the thecal sac from a unilateral approach in 1988 [32]. Many of these early MISS techniques still included bilateral dissection of paraspinous muscles and were plagued by complications, over 20% in Young's initial series, including a 6% incidence of dural tears. Nevertheless, patients responded favorably clinically, and no patients developed instability or required revision to traditional laminectomy. By the end of the 1990s, endoscopic techniques had been introduced, yet they also experienced a high rate of incidental durotomy [33]. Although enthusiasm for the endoscopic technique waned in general, orthopedic surgeons continued the practice, perhaps at an advantage by familiarity with arthroscopic procedures [33]. The use of an operating microscope proved very important in the evolution of the MISS, and with the addition of tubular retractor systems in early 2000, these techniques became much more prevalent in the field of spine surgery [8, 34, 35].

Fessler first demonstrated the feasibility of bilateral decompression from a unilateral approach in a cadaver model and showed adequate decompression and complication rates independent of approach [8]. In Palmer's early experience treating LSS with decompression through tubular retractors, he prospectively followed 135 patients, measuring visual analog scale (VAS), the Oswestry Disability Index (ODI), and the Short Form-36 (SF-36) [34]. Follow-up data was collected in 129 of 135 patients. Improvement was seen on the VAS (scores 7–2), ODI (scores 57–16), and SF-36 scales (bodily pain scores 20–60). Patient satisfaction with results was 94% at a minimum follow-up of 1 year. Complications included one superficial wound infection, one case of discitis, three durotomies, and three cases of excessive bleeding (>100 ml). There were five reoperations for recurrent disc herniations and one for recurrent spinal stenosis contralateral to the index site. Of note, the rate of dural tears had decreased to less than 3%, from over 6% in early studies. Unfortunately, patients were not randomized, and there was no control group. Palmer also demonstrated the feasibility for performing bilateral laminar decompression from a unilateral approach in the setting of LSS with DS [34]. Mobbs et al. followed this up with a head-to-head comparison of patients with LSS who underwent a standard "open" laminectomy versus those who underwent a unilateral laminectomy for bilateral decompression (ULBD). This was a prospective randomized study. Patients from both groups experienced improved function and pain. However, those patient randomized to ULBD treatment experienced significantly improved VAS scores and shorter length of hospital stay and time to mobilization and were less likely to use opioids for pain postoperatively, compared to patients randomized to "open" laminectomy [36]. Other authors have shown favorable results for microendoscopic posterior decompression for LSS but have observed a tendency toward medial encroachment of the facet complex as observed on postoperative axial imaging. These authors found a 2% incidence of postoperative instability after this procedure. Interestingly, the trends of medial facet encroachment and instability occurred earlier in the course of the study, implying there may be a learning curve associated with this phenomenon [37]. A large retrospective case series of 374 patients reported by Costa et al. demonstrated 87.9% clinically significant improvement in VAS and Prolo scores with a 0.08% rate of postsurgical instability demonstrated on radiography [38].

Other major benefit of minimally invasive techniques includes soft tissue preservation through muscle-splitting approaches. This was quantified by postoperative measurement of inflammatory markers as well as markers of muscle necrosis such as creatine kinase and aldolase. Kim et al. studied the tissue damage inflicted by open and mini-open lumbar fusions by measuring creatine kinase, aldolase, pro-inflammatory cytokines (IL-6, IL-8), and anti-inflammatory cytokines (IL-10, IL-1 receptor antagonist) with ELISA techniques. Values were checked preoperatively and 1, 3, 7, and 14 days after operation. Serum creatine kinase and most of the inflammatory cytokines were significantly high in the "open" group compared to the "mini-open" group on postoperative days 1 and 3 but returned to equal and normal levels by postoperative day 7. The authors concluded that mini-open lumbar fusion may significantly contribute to the reduction of muscle injury and systemic inflammatory reactions during the acute postoperative period [6]. In a different study, Kim et al. demonstrated a 50% improvement in low back muscle extension strength with MISS compared to conventional open techniques. This was corroborated by MRI findings that revealed significantly higher cross-sectional area of the multifidus muscle following MISS [39]. Again, in a different study, Kim et al. reported that damage to the medial branch of the dorsal rami may contribute significantly to the aforementioned impaired function [7].

In addition to minimizing soft tissue trauma intraoperatively, MISS is an excellent alternative to open surgery in elderly patients or those with chronic illnesses [12]. Fifty patients over the age of 75 who underwent minimally invasive lumbar spinal surgery were reviewed by Rosen et al. who noted statistically significant improvements in VAS, ODI, and SF-36 scores. This study was not randomized, there was no control group, and follow-up averaged only 10 months. However, it is one of the few studies that focus on the outcome of MISS in this elderly population—a group which is frequently referenced as one which would benefit from minimally invasive techniques.

Providing results from somewhat longer follow-up, Asgarzadie retrospectively reviewed patients undergoing MISS utilizing a tubular retractor system [9]. Compared to a historical control of 32 patients undergoing open laminectomy, 48 patients who underwent MISS left the hospital sooner (36 h vs. 94 h) and maintained patient satisfaction and improvement in ODI and SF-36 equivalent to controls at an average of 38 months' follow-up. Also, no cases of instability were noted; other authors have shown slightly higher recurrence rates requiring reoperation, but no higher than that for open treatment of LSS [40]. In a prospective randomized study, 41 patients were randomly assigned either minimally invasive microendoscopic decompression or conventional open laminectomy to be performed by the same surgeon. With a mean follow-up of 18 months, 90% of the patients treated with MISS decompression had satisfactory symptom relief. Compared to the open group, the MISS decompression cohort had a shorter hospital stay, lower mean blood loss, and lower VAS scores for back pain [41].

A little over a decade ago, interspinous process devices (IPDs) were introduced as a minimally invasive method for treating LSS in patients who were poor surgical candidates and whose symptoms abated with forward flexion [15, 16]. The biomechanical rationale behind these devices is fairly intuitive. These devices act to limit extension at the treated level, thereby widening the space available for the neural elements and resultant symptom relief similarly achieved with leaning over a shopping cart (i.e., the shopping cart sign). Goyal et al. performed a biomechanical study to evaluate if the distraction achieved with IPDs results in radiographic increase in the spinal canal and neuroforamen, as well as whether the devices stabilized the motion segment. The authors found that canal area was minimally altered and foramen height, width, and area increased with extension and were statistically significant as compared to specimens without devices in place. Furthermore, there was no device subsidence or migration after cyclic loading [42].

In a 2005 multicenter, prospective, controlled, randomized study of 100 patients undergoing placement of the X-STOP IPD compared to 91 patients treated non-surgically, Zucherman et al. showed significant improvement in neurogenic claudication symptoms at all time points when treated with the X-STOP IPD versus non-surgically [43]. Zurich Claudication Questionnaire (ZCQ) values were assessed at all follow-up visits, and at 2-year follow-up, those who were treated with IPDs were 45% improved compared to those who were treated nonoperatively. Of note, in this and many studies looking at the efficacy of IPDs, the control groups were composed of patients treated conservatively rather than those undergoing traditional decompressive laminectomy. Only 6% of patients in Zucherman's study arm had undergone decompressive surgery at 2 years, whereas 26% in the control had undergone surgical decompression. In 2015, a randomized, controlled, multicenter study comparing MISS decompression to X-STOP reported a significantly improved functional and disability outcomes in both groups. Between-group difference was not statistically significant [44]. One retrospective review of 46 patients undergoing IPD implantation at a mean follow-up of 34 months showed a rather high revision rate of 30.4% with most cases requiring revision within a year [45]. Also, although Verhoof et al. reported a mean surgical time for MISS decompression and X-STOP was 113 and 47 min, respectively, reoperation rates due to recurrent symptoms were significantly higher in patients who underwent X-STOP [17]. However, next-generation technologies have shown more promise, most notably the Coflex interlaminar stabilizing system (ILS). Ultimately, the role of IPDs is still being defined in the spectrum of surgical treatment options for LSS.

Recently, entirely percutaneous procedures performed under fluoroscopic guidance, dubbed "MILD," percutaneous remodeling of the ligamentum flavum, and lamina (PRLL), have been described utilizing epidurograms to assess the adequacy of decompression. Although preliminary data showed improvement in symptoms, the follow-up period was only weeks in these studies, and other investigators have shown an unacceptably high failure rate of this procedure [30, 31, 46]. With the dearth of supporting evidence, this procedure does not currently have a place in the surgical treatment of lumbar spinal stenosis.

> The quality of research assessing outcomes following MISS is low, although there is a consistent trend toward lower operative time, blood loss, and infection rates, less muscle damage; shorter hospital stay, and an improved short-term pain and functional outcome following MISS compared to traditional open techniques. Outcomes following IPD implantation are controversial.

## 35.4 Outcomes in Cases of Spinal Instability

Spinal instability is frequently associated with and can contribute to LSS. This instability typically takes place in the form of degenerative spondylolisthesis (DS). Although an arthrodesis is generally performed for LSS with DS, there may still be a role for stability-preserving decompression alone in this condition. The primary concern in performing decompression alone in LSS for DS is the additional iatrogenic instability and hastening of slip progression by disrupting the existing anatomy, including inter-/supraspinous ligaments and the facet complexes. Sasai et al. investigated risk of progression of spondylolisthesis after minimally invasive decompression without fusion in 23 patients with DS and 25 patients with LSS without DS. The average follow-up in this study was 46 months. No patient in either group required fusion procedures or other additional surgery. Clinical improvement in the form of the Neurogenic Claudication Outcome Score, back pain score, and ODI had significantly improved at the last follow-up in both groups, although there were no significant differences between those with DS and LSS without DS. However, there was a trend toward inferior clinical outcome in the DS group, and there was a significantly increased slip percentage on radiographs postoperatively. The authors concluded that this less invasive procedure was not likely to result in postoperative dynamic instability at the affected level [47]. Biomechanical studies investigating instability produced by standard open laminectomy with bilateral soft tissue and bony dissection, compared to MISS involving unilateral approach for bilateral decompression (preserving the contralateral bone and soft tissue), confirm these clinical findings. This study demonstrated less segmental motion in extension and rotation for the minimally invasive unilateral approach [48].

Contrary to purported benefits of maintained spinal stability in patients with LSS and DS treated with direct minimally invasive decompression, IPDs in this population have shown unacceptable failure rates. In their small cohort of 12 patients undergoing placement of X-STOP IPD for LSS with DS, Verhoof et al. reported failure to relieve symptoms in 58% of individuals. Interestingly, those failing treatment with X-STOP, and undergoing open decompression and posterolateral fusion, showed no progression of slip. Nevertheless, the authors recommended against the use of IPDs in cases of LSS with DS [17]. Still, other authors have reported favorable outcomes using IPDs in these patients [49]. Hence, there may be a role for the use of IPDs to treat DS, provided it is done on a case-to-case basis with the understanding that their performance is variable (see Figs. 35.1, 35.2, and 35.3). Conversely, Coflex ILS has been shown to adequately stabilize adjacent vertebrae while preserving both flexion and extension in LSS patients. Outcomes utilizing this device have been shown to be superior to that of patients undergoing standard decompression only, and equivalent to patients undergoing decompression and fusion [50, 51]. Adverse event rates have been shown to be equivalent as well.

Although a paramedian, muscle-splitting approach is among the most common minimally invasive approaches to the posterior spine, a recent description of a midline muscle-sparing approach has been reported [52]. This procedure involves limited spinous process burring from a midline approach to allow the supra−/intraspinous ligaments to be split, allowing access to the interlaminar space and performance of neural decompression. Hatta et al. demonstrated this procedure to be safe and noted a 64% increase in the Japanese Orthopedic Association (JOA) scores from pre- to postoperative.

> MISS appears to have a lower rate of progressive segmental instability in patients with LSS with DS compared to traditional open techniques. X-STOP IPD is associated with unacceptable failure rates in this patient cohort. Conversely, Coflex ILS is promising.

## 35.5 Complications

With new technology, there is often a learning curve to overcome and a potential for a new set of complications. MISS for LSS is no exception [53, 54]. Initial efforts to implement minimally invasive techniques in the surgical treatment of degenerative spinal conditions were limited by a lack of visualization, and techniques such as spinous process osteotomies were used to remedy this dilemma while avoiding interruptions to muscular attachments [4]. Advances in instrumentation including tubular retractor systems and the increased use of the operating microscope and endoscope has allowed improved visualization with muscle preservation via a muscle-splitting approach. The smaller operating corridors which are a fundamental tenet of MISS may present unfamiliar territory to a surgeon inexperienced in these techniques. However, MISS was shown to have statistically fewer complications than that of open procedures in a review of over 10,000 patients treated surgically for symptomatic LSS [55]. In addition, one study reported that there was no increase in complication rates attributable to their body mass index [13]. Complications experienced in open surgical treatment of LSS are similar to those experienced in MISS for LSS. The complications of incidental durotomies, excessive bleeding requiring transfusion, and surgical site infection, as well as pseudarthrosis and iatrogenic instability, will be discussed in this section.

Because of the largely percutaneous nature of MISS, intraoperative imaging is heavily relied upon. This is a particularly critical step in identifying the correct level identified preoperatively. Becoming disoriented in this regard may easily occur with MISS as illustrated by two cases in a prospective study evaluating the microendoscopic treatment of LSS [56]. Such occurrences can prove devastating to both the patient and surgeon.

### 35.5.1 Interspinous Process Device Unique Complications

One major complication of IPDs is a fracture of the spinous process (SP). Although this can happen during or after surgery, intraoperative fractures make proceeding with the procedure impossible as the fractured SP is no longer able to distract the stenotic segment. Cadaveric studies have showed the average force of 317 N required to fracture an SP is significantly greater than that of 55 N required to implant an IPD [57]. However, there was an overlap between the ranges of the groups, which was correlated with bone mineral density. This may be a concerning finding if many of the patients undergoing this procedure have compromised bone mineral density [58]. Additionally, the use of Coflex ILS has been noted to erode bone that is immediately in contact with the device, which is associated

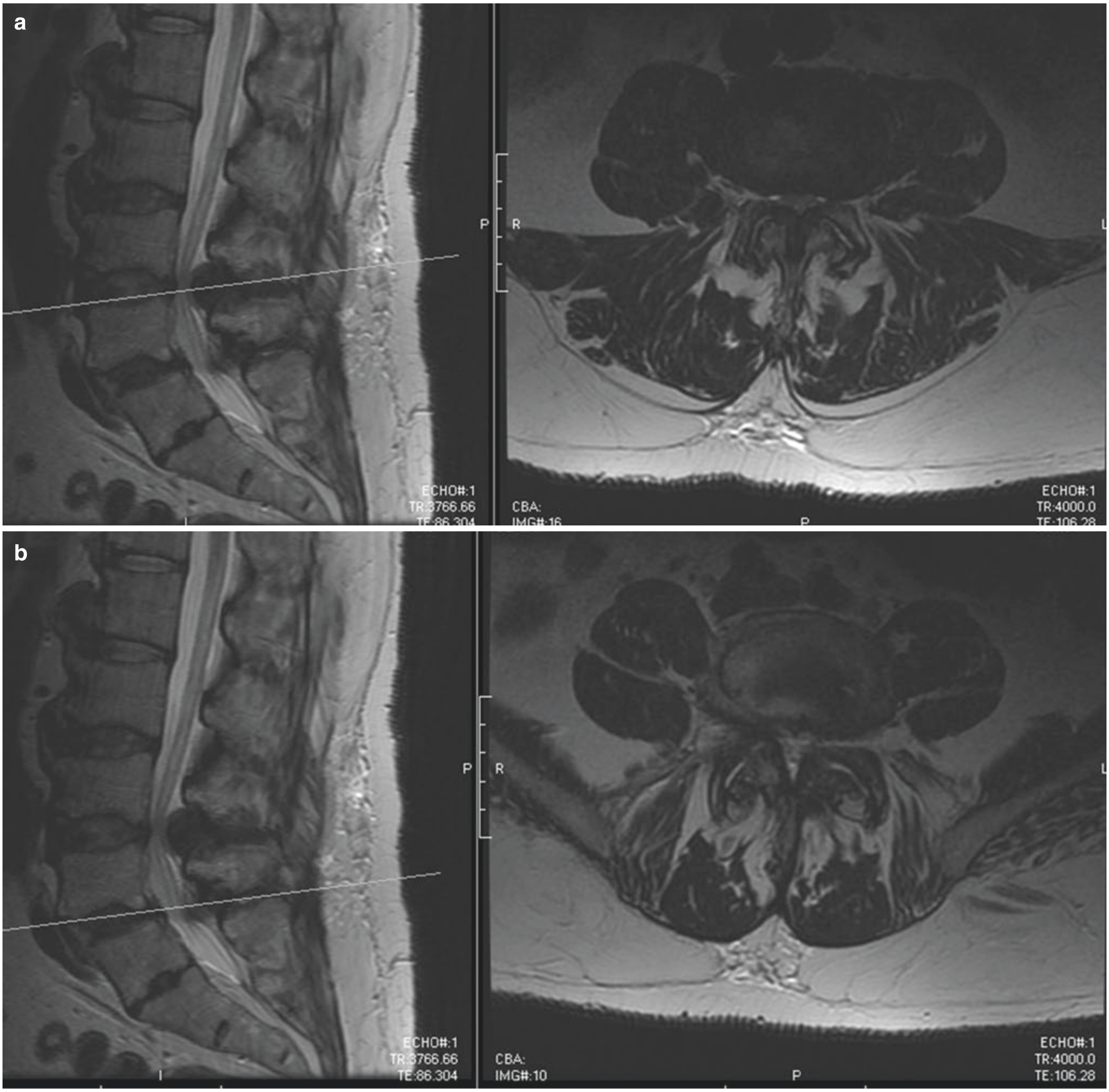


**Fig. 35.1** A 66-year-old male presenting with neurogenic claudication with good relief of his symptoms upon forward flexion. His radiographic studies demonstrate a degenerative spondylolisthesis at L4–5 with advanced imaging showing concomitant spinal stenosis at (**a**) sagittal and axial image at L4–5 and (**b**) L5–S1

with decreased ROM and is considered a failure. One study reported that this phenomenon occurred in 14 out of 30 patients treated with the Coflex ILS [59].

### 35.5.2 Wound Problems

A prospective study using tubular retractors reported a 0.8% rate of infection [37]. A somewhat higher incidence of 4.5% was seen for wound hematomas or delayed healing in 222 patients studied retrospectively. More concerning was the 4.5% rate of infection reported in this series, including one case of discitis and one case of epidural abscess [60].

### 35.5.3 Excessive Bleeding

This complication is difficult to define as there is not a standard blood loss (EBL) for any given procedure, and intraoperative blood loss for different procedures may vary dramatically. Palmer et al. considered EBL >100 cc to be

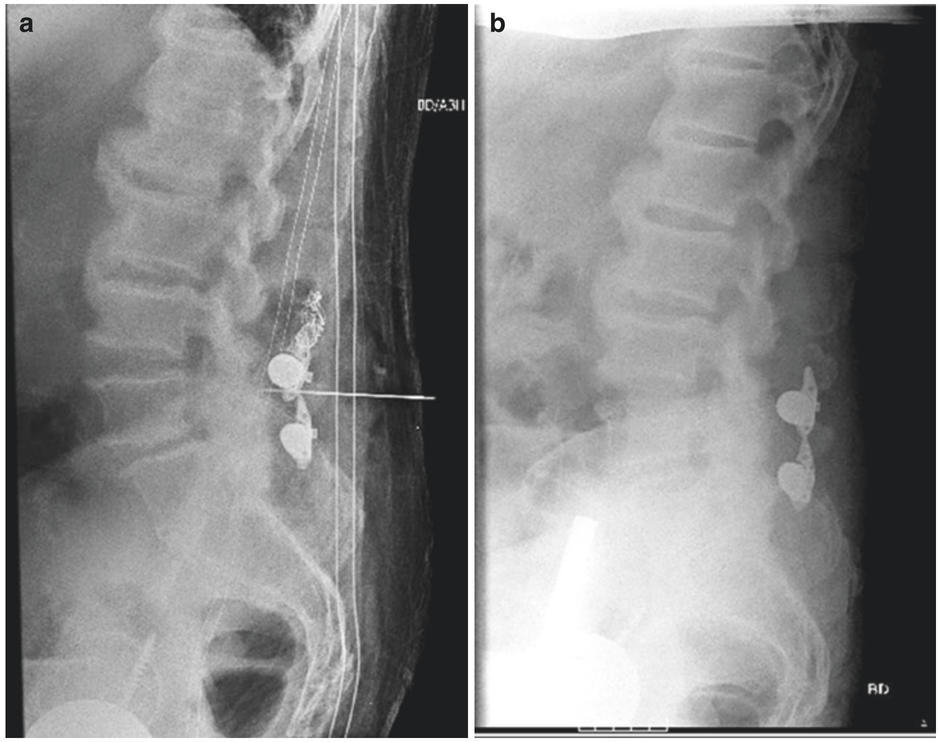


**Fig. 35.2** Same patient from Fig. 35.1. Patient underwent a two-level X-STOP procedure seen on (**a**) intraoperative lateral radiograph. At 2 years, the patient continued to have very good relief of his symptoms with (**b**) radiographs showing maintained position of the X-STOP device

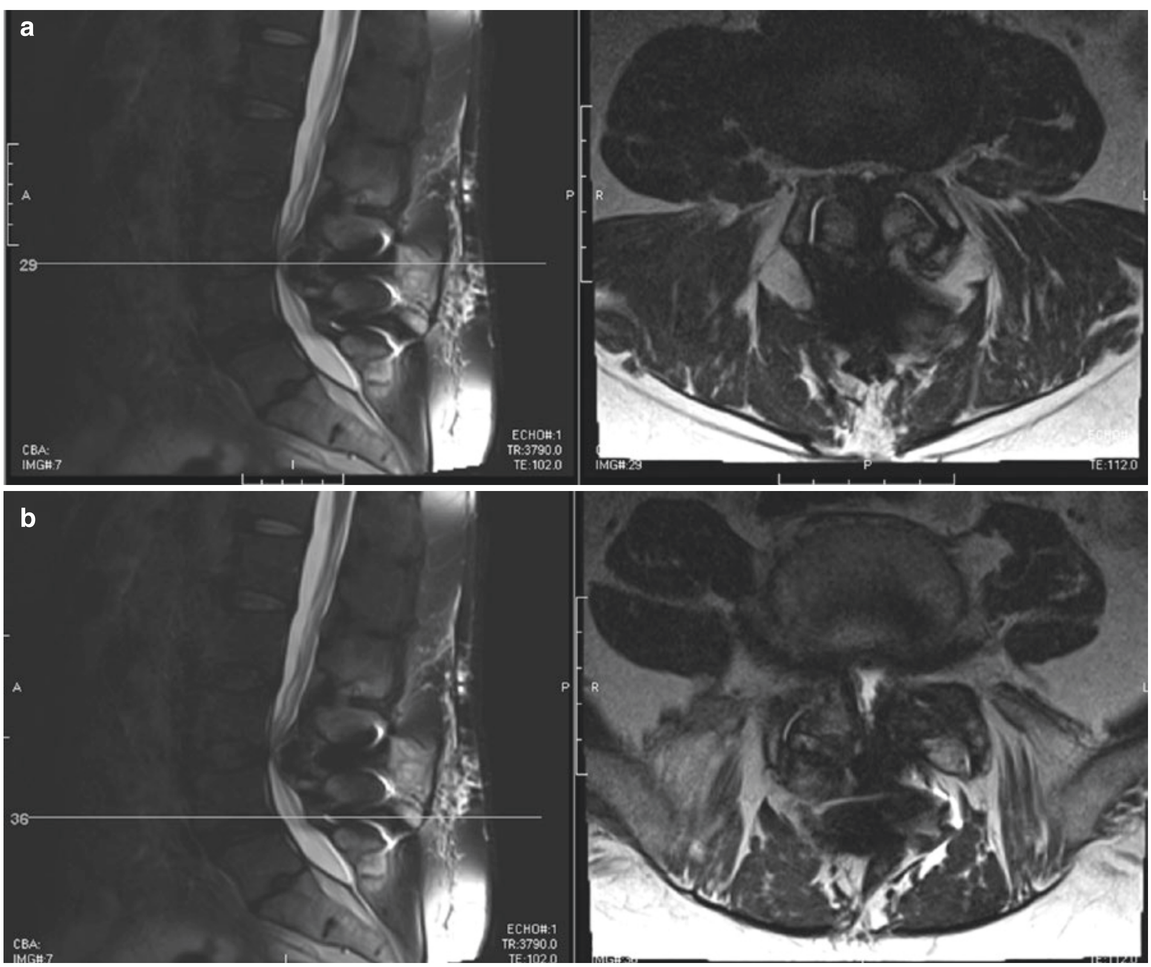


**Fig. 35.3** Same patient from Fig. 35.1. Eventually patient symptoms returned to the original severity with repeat advanced imaging showing advanced spinal stenosis at the two X-STOP levels (**a**) L4–5 and (**b**) L5–S1. At 3 years postoperative from the index procedure, he underwent an open laminectomy along with X-STOP removal

excessive in the minimally invasive treatment of lumbar disc herniations and found an incidence of 2.1% in his review of 135 patients [35].

### 35.5.4 Recurrence

Recurrence of LSS, especially requiring reoperation, while not necessarily a complication of treatment, is an undesired outcome. Recurrence rates of LSS after surgical treatment through minimally invasive techniques have been reported to be as low as 0.8% or as high as 58% [17, 34]. A more moderate, yet still relatively high, rate of recurrence was seen in patients with degenerative lumbar scoliosis who underwent minimally invasive foraminotomy for foraminal stenosis [29]. These patients were shown to have recurrence of symptoms in 19.6% of cases.

### 35.5.5 Aborting Miss

Abandoning minimally invasive efforts and converting to open techniques may not represent a complication and may not compromise a patient's outcome; however, it is an important metric and one unique to MISS. Rate of conversion to open surgery is not routinely reported in the literature. Greiner-Perth et al. reported a rate of 5% conversion to open treatment in their prospective study of 38 individuals undergoing minimally invasive decompression for LSS [40]. It should be noted that these authors were using muscle dilators providing an 11 mm portal as opposed to portals 18 mm or larger which are more commonly used.

### 35.5.6 Iatrogenic Instability

Iatrogenic instability is a concern when employing minimally invasive techniques with their smaller operating corridors in the treatment of LSS. A clinical situation particularly concerning for development of iatrogenic instability is the surgical treatment of a facet cyst. However, Deinsberger et al. reported no postoperative instability at an average of 35-month follow-up with minimally invasive decompression of facet cysts without fusion [28]. Of note, nearly half of these patients had degenerative spondylolisthesis preoperatively. Other authors have reported cases of instability requiring reoperation due to iatrogenic facet fracture during a tubular MISS for LSS, a facet fracture after a fall, and an unidentified DS [60]. All of the combined cases of instability resulted in an incidence of only 1.4%, and only one of these cases required arthrodesis. Over 30% of patients in this series had spondylolisthesis; however, there was no mention whether those patients experiencing instability postoperatively had spondylolisthesis preoperatively. In patients with no DS preoperatively, Musluman et al. recently showed only one patient (1.2%) who required fusion after bilateral microdecompression from a unilateral approach [61]. Using microendoscopic techniques for bilateral decompression for LSS, Ikuta et al. similarly observed 2.6% patients with inferior facet fractures [53].

As mentioned earlier, biomechanical investigation of stress at the bony elements after both traditional and minimally invasive decompressive techniques showed greater stress at the remaining bony elements in the latter [14]. This was particularly the case in younger patient populations and specifically increased stress at the pars and inferior facets. Specifically evaluating progression of spondylolisthesis, Sasai et al. retrospectively reviewed patients undergoing minimally invasive decompression for LSS both with and without DS and found no difference between the groups, with no patients undergoing additional lumbar surgery at 2-year follow-up [47]. These results were not duplicated when attempting indirect decompression with the X-STOP IPD for patients with LSS due to DS. One-third of patients experienced no improvement in symptoms, and three of the remaining eight patients had symptoms which recurred by 2 years. Ultimately, over half of these patients underwent revision posterolateral fusion at the previously operated level [17].

### 35.5.7 Neurologic Deficits

A retrospective review of 220 consecutive patients undergoing microscopic or microendoscopic decompression reported one foot drop lasting at least 6 months [60]. Transient neurologic deficits were also observed in 10.5% of patients undergoing microendoscopic decompression for LSS; however, this did not appear to impact the clinical outcome of these patients at 28-month follow-up [53].

### 35.5.8 Dural Tear

When evaluating a large series of minimally invasive decompression, reported rates of dural tears vary from 4.5% to 10% [53, 56, 60].

> Complication rates following MISS are likely lower but at worst equivalent to complication rates following open techniques. Unique complications include spinous process fractures that may occur intra- or postoperatively following IPD implantation and a 5% abortion rate with MISS requiring conversion to an open technique.

## 35.6 Conclusion

Minimally invasive decompression procedures for the surgical treatment of lumbar spinal stenosis were developed to limit perioperative morbidity and expediate recovery compared to traditional open surgical approaches. Advances in retractor technology, instruments, and visualization enhancement have contributed to the evolution of MISS with good results seen in clinical studies with midterm follow-up.

The complication profile of MISS is favorable compared to historically reported complication rates of open surgery; however, there is a clear learning curve for the individual surgeon. The role of interspinous process devices for decompression alone is plausible; however, it's use for decompression and stabilization of an unstable motion segment is still to be determined.

**Summary**

- Lumbar spinal stenosis that is recalcitrant to conservative treatment is becoming more prevalent, primarily due to the aging population
- Less invasive surgical techniques may minimize soft tissue injury and, hence, improve morbidity associated with lumbar stenosis decompression, especially in the elderly and overweight patients
- Minimally invasive surgical decompression for lumbar spinal stenosis is effective and safe relative to open methods
- Interlaminar stabilizing systems such as Coflex may be a good MISS alternative for degenerative spondylolisthesis and lumbar spinal stenosis
- The keys to success with MISS include careful patient selection, meticulous surgical planning, and regular practice

## Quiz Questions

1. What outcome(s) is MISS associated with?
   (a) Less blood loss
   (b) Decreased infection rate
   (c) Shorter hospital stay
   (d) All of the above
   (e) None of the above
2. What MISS group of implants have been shown to be motion preserving, while adequately stabilizing the spinal segment, with minimal complications?
   (a) Interspinous process devices (e.g., X-STOP)
   (b) Interlaminar stabilizing system (e.g., Coflex)
   (c) Segmental pedicular stabilization
   (d) Segmental pars screw stabilization
   (e) None of the above

## Answers

1. d
2. b

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