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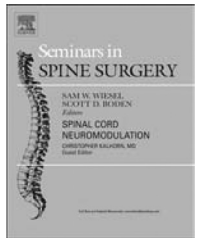

Update on lumbar stenosis and degenerative scoliosis: Deformity considerations when treating lumbar stenosis

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A B S T R A C T

Lumbar stenosis is often treated without consideration of the overall spinal alignment. However, surgery for stenosis in the presence of deformity should consider both pathologies. Attention to patient specific alignment parameters and neurologic symptoms should be a component of the preoperative plan for all lumbar spine surgeries. The ideal spinal alignment is still elusive, so a majority of research on spinal deformity in the past 10 years has focused on identifying target parameters of spinal balance to improve patient satisfaction, quality of life outcomes, and decrease failure rates. Here, the most current concepts in the application of balance and alignment in the treatment of degenerative scoliosis and lumbar spinal stenosis will be discussed.

1. Introduction

The primary clinical manifestations of lumbar spinal stenosis are neurogenic claudication and lumbar radiculopathy. Treatment of these conditions often requires decompression and fusion of the lumbar spine. Any fusion of the spine locks in alignment, even if only across two levels, that may have long term implications. This can affect patient function and future degeneration of the spine that may result in additional alignment changes. In many cases, spinal deformity exists in tandem with degenerative lumbar spinal stenosis. When this is the case, proper overall realignment of the spine along with decompression of neural elements is crucial for the long-term durability of the intervention.

2. Etiology and prevalence of disease

Lumbar spinal stenosis occurs with narrowing of the central spinal canal, foramina, or lateral recess causing compression of the neural elements, and is the most common indication for spine surgery in patients over 65 years of age.[1] Causes of stenosis within these regions consist of facet joint arthrosis, disc herniations, osteophyte formation, loss of disc height, and ligamentum flavum hypertrophy, or some combination of the above.[2] Stenosis is present in roughly 0.5% of the population older than age 50 and comprises the chief complaint of up to 14% of patients seeing a spinal specialist.[3]

It is important to consider deformity in conjunction with lumbar spinal stenosis, as up to 50% of patients with lumbar spinal stenosis have concomitant degenerative scoliosis.[4]

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Degenerative scoliosis may be the result of osteoporosis, vertebral body compression fractures, or the asymmetric degeneration of discs.[5] Not all patients with degenerative scoliosis necessarily have stenosis, however, as the prevalence of asymptomatic scoliosis has been shown to be as high as 68% in an elderly adult population.[2]

Degenerative scoliosis patterns often develop subluxation and instability at the lower lumbar segments.[2] Just as in isolated degenerative stenosis, the most common level for stenosis in the setting of deformity is at the L4/L5 level.[6] This can be visualized radiographically as lumbar spondylolisthesis or lateral listhesis. The instability can cause dynamic compression of the neural elements and claudicatory and/or radicular symptoms.[2] Traction on nerve roots through lateral listhesis is another common pattern of radiculopathy, as is foraminal stenosis due to the spinal curvature. Classically, radicular symptoms emanate from the concavity of the main curve contralateral to the apex and from the concavity of the fractional curve at the lumbosacral junction. The concavity of the lower fractional curve is the most common location for foraminal stenosis, and the L5 nerve root exiting from the L5/S1 neural foramen is often at risk. As is the case for most stenosis patients, the clinical exam is often benign, and resolution of neurologic symptoms can be achieved with sitting or lying down. This underscores the dynamic instability of degenerative scoliosis and the necessity to consider fusion in the surgical plan.

3. Treatment

Spinal intervention should be specifically tailored to the patient's primary complaints and goals for recovery. Neurologic symptoms must be fully understood via a thorough history and physical exam and must correlate clinically and radiographically. Electromyography can be helpful to determine the extent and chronicity of the neural compression.[7] It is very specific, but not sensitive, for the diagnosis for radiculopathy, but is probably most useful when determining the contribution of an underlying neuropathy, i.e. diabetes.[8] Epidural or transforaminal injections can also be useful adjuncts to determine the exact location and extent of the neural compression.[9] This can help guide surgical management and provide patients with surgical expectations.

Adequate decompression at the concavity of the curve by either direct or indirect means is critical for the resolution of radicular symptoms. Of particular importance is decompression of the fractional lumbosacral curve which is the least obvious coronal plane deformity. However, it is a common source of radicular symptoms, most commonly the L5/S1 level, with compression of the L5 nerve root. When considering decompression alone, one must consider the location of stenosis and magnitude of the deformity. Decompression of central stenosis is more favorable than foraminal stenosis and is more durable long term in curves less than 20°.[10] The two options for decompression are direct decompression, either through and open or MIS approach without fusion, or indirect decompression through restoration of disc height through fusion, with a concomitant increase in foraminal height.

In the setting of isolated complaints of radicular or central stenosis symptoms without instability or prior lumbar surgery, isolated decompression without fusion can be considered (See Fig. 1 for an example). This can be accomplished with open or minimally invasive surgery (MIS) techniques. When either technique is employed, one must take care that isolated decompression without fusion does not cause instability.[11] Many studies have attempted to judge the merits of direct lumbar decompression through an open versus MIS approach. A recent meta-analysis and review found that MIS decompression without fusion takes approximately 11 minutes longer, but had less blood loss, shorter hospital stay, less back pain, and higher patient satisfaction then open techniques.[12] Indirect decompression of the neural foramen through increase of foraminal height can be accomplished through realignment of the spine via restoration of disc height through interbody placement and restoration of more normal coronal and sagittal alignment.[13]

Indications for fusion in the setting of lumbar stenosis have not been fully elucidated (See Fig. 2 for an example). Careful evaluation of a patients' symptomology and radiographic parameters is required to fully assess the source of discomfort and possible need for fusion. There is a spectrum of MIS and open options for lumbar stenosis in the setting of deformity. MIS fusion techniques are most effective for stenosis in the setting of mild deformity, whereas more significant deformity is more adequately addressed with open techniques. Minamide et al. found low progression of cobb angles and higher patient satisfaction when using MIS fusion techniques in patients with preoperative cobb angles less than 20° with low pelvic incidence (PI) to lumbar lordosis (LL) mismatch. These patients also had predominantly radicular or neurogenic claudication symptoms. MIS options can also provide some degree of deformity correction utilizing the lateral approach. MIS techniques with smaller incisions and less tissue disruption may have decreased morbidity compared to open treatment options, with lower blood loss through, fewer transfusions, cardiopulmonary complications, incision complications, and earlier mobility resulting in shorter hospital stays.[14]

MIS decompression can be combined with MIS fusion techniques through circumferential MIS (cMIS) surgery, consisting of an interbody fusion from a number of interbody fusion approaches (anterior (ALIF), lateral (LLIF), or posterior (TLIF)) along with posterior instrumentation. cMIS surgery without an open decompression has similar decrease in leg pain and correction of the fraction curve compared to open decompression for mild curves.[15] Finally, a hybrid approach can be undertaken, combining MIS approaches with open posterior techniques such as osteotomies when larger corrections are required. In summary, MIS approaches can be effective for addressing mild spinal deformity in the setting of lumbar stenosis, but overall these techniques should be limited to mild to moderate deformity, as the literature has suggested that severe deformity is best treated with open techniques.[16]

4. Role of balance

Spinal deformity was once thought to be predominantly a coronal plane abnormality. It is now been well established

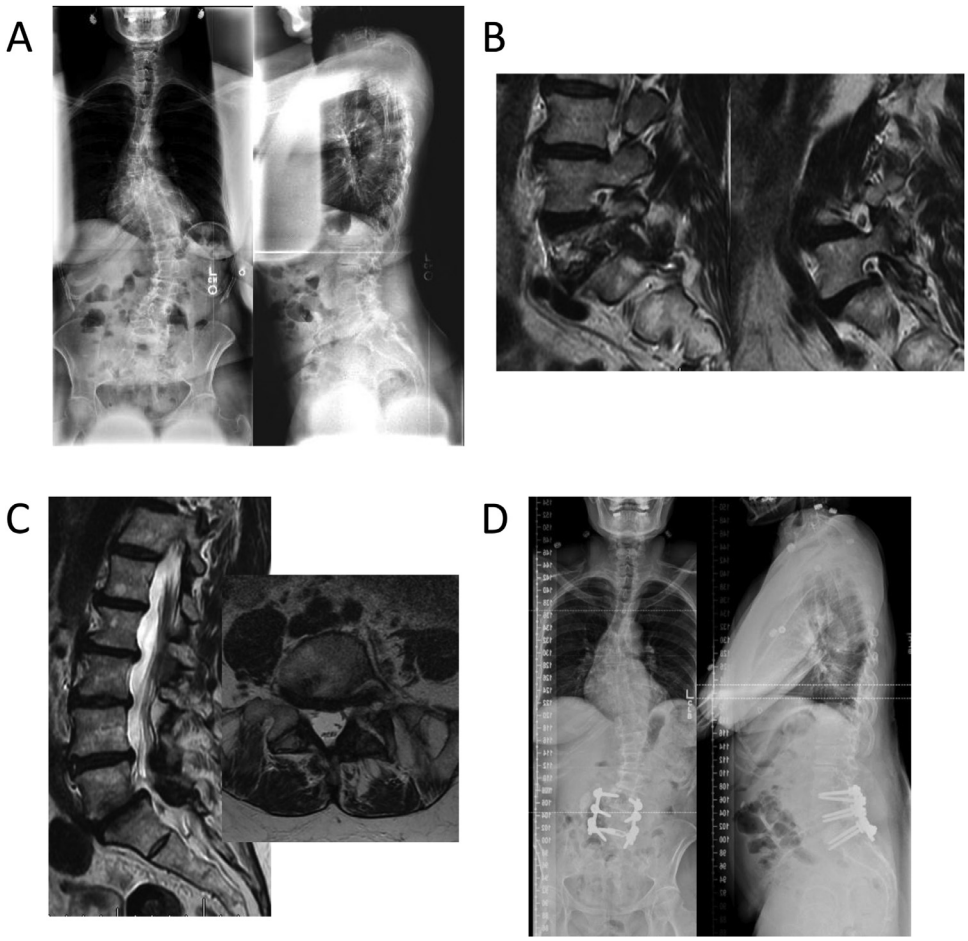

Fig. 1 – Preoperative standing scoliosis images (A) and the preoperative magnetic resonance imaging (B and C) of a 70 years old female with degenerative scoliosis with worsening back and left leg pain for 2 years. On exam, she had L5 distribution numbness and weakness. Magnetic resonance imaging showed severe stenosis of the left L5/S1 foramina in the concavity of the fractional curve and mild stenosis in the right L5 foramina (B and C). A transforaminal epidural steroid injection was performed at the L5/S1 level resulting in complete although temporary symptom relief. She underwent a limited posterior decompression and fusion with interbody placement (D). Post-operatively she did well with complete relief of her leg symptoms and improvement in her back pain. Clinical pearls: Limited coronal and minimal sagittal plane malalignment (Cobb angle 28° with minimal lateral listhesis, SVA 0 cm, PT 13°, LL 54°, PI 58°, PI-LL 4°). Given that symptoms were localized to the lumbosacral region, she was decompressed centrally with a laminectomy with direct and indirect decompression of her left sided nerve root through a foraminotomy and interbody placement at the L5/S1 level via left-sided TLIF (D).

that sagittal and rotational deformities are as important, if not more so, making spinal deformity a complex three-dimensional disease. The importance of assessing and achieving proper sagittal alignment in the treatment of lumbar stenosis and degenerative scoliosis cannot be overstated. Adequate decompression can be achieved in isolation, but if the overall spinal alignment and any concomitant deformity is not correctly addressed, then patients often have only short term relief.[17] Regional kyphosis is particularly poorly tolerated in the lumbar region, and pre-existing or iatrogenic deformity in this region influences the imbalance over the remainder of the spine.[18]

As described by Schwab et al., addressing spinal deformity is important because "ideal spinal alignment allows an individual to assume standing posture with minimal muscular energy expenditure."[19] A standing position that requires the lowest amount of energy to maintain is accomplished with balance in both the sagittal and coronal planes, resulting in balanced tension of the spinal ligaments and minimal activation of peri-spinal musculature to maintain balance. The "Cone of Economy" as described by Jean Dubousset demonstrates this concept.[20] As one leans further away from the center of the cone, a greater amount of energy is required to maintain balance. Once outside of the cone, a person becomes unstable and may require external support (i.e. assistive devices) to maintain an erect posture.

Positive sagittal balance is particularly poorly tolerated and can result in significant impairment and disability. With increased sagittal imbalance, energy expenditure is required to maintain a horizontal gaze and the center of mass over the feet.[21] With increasing imbalance, one can expect further disability as it will require increased energy expenditure to

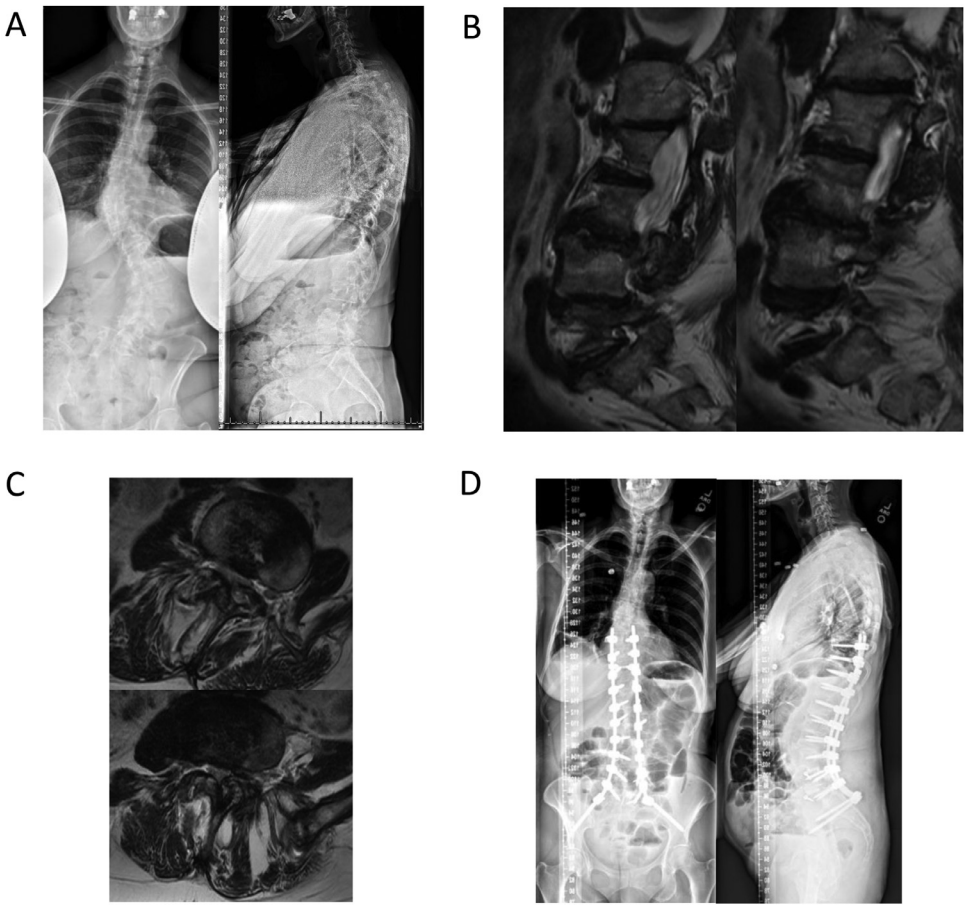

Fig. 2 – Preoperative standing scoliosis images (A) and preoperative magnetic resonance imaging (B and C) of a 64 years old female with degenerative scoliosis. In the year prior, she complained of debilitating leg pain which radiated down her bilateral legs (L >R) to the anterolateral thighs and great toe causing standing and walking intolerance. Magnetic resonance imaging demonstrated severe central stenosis at the L2/3 and L3/4 levels with severe multilevel foraminal stenosis at L4/5 and L5/S1 (B and C). She underwent a combined front-back approach to best correct her sagittal plane deformity, lumbar decompression, and fusion of the unstable segments (D). Postoperatively she noted complete relief of her back and leg symptoms. Clinical pearls: Significant coronal and sagittal plane malalignment (Cobb angle 75°, Coronal Imbalance 5 cm, SVA 0 cm, PT 26°, LL 26°, PI 54°, PI-LL 22°) with segmental instability with rotatory subluxation and lateral listhesis. This resulted in significant central and foraminal stenosis (B and C), Surgical goals are restoration of sagittal plane (20° lordosis) with additional correction of her PT due to a retroversion of her pelvis due to compensation. We chose an anterior releases and lumbar interbody fusion to restore lumbar lordosis, followed by direct decompression with laminectomy, foraminotomy and Ponte osteotomies to increase flexibility, with a final instrumented from T9-ilium(D). Final correction leads to a balance spine in the coronal and sagittal plane (CI 2.5 cm, SVA 0 cm, LL 48°, PT 20°, PI-LL 6°).

mobilize and accomplish activities of daily living.[22] This can have a significant social impact on a patient and their family as the majority of patients with these pathologies have limited functional reserve. This can result in a loss of independence, necessitating additional caretakers or moving to assisted living facilities.

Just as the foundation of a building, the morphology of the pelvis is the foundation of the spine that defines a unique patient-specific spinal architecture.[21] The inherent anatomic based pelvic incidence (PI) drives the spinopelvic compensatory mechanism altering pelvic tilt (PT) and sacral slope (SS) to maintain overall sagittal alignment. Roussouly demonstrated the correlation between pelvic incidence and sacral slope with its effect on lumbar lordosis and thoracic kyphosis.[23] He described two arcs of lumbar lordosis, superior and inferior, that are equal to thoracic kyphosis and sacral slope, respectively. Using a population of asymptomatic adult volunteers, he described four types of lumbar lordosis subtended according to their progressive SS and increasing PI.[24] In short, a Type 1 is an imbalanced spine with thoracolumbar kyphosis and a short hyperlordotic segment at the lumbopelvic junction. The remained types are considered harmonious curves: Type 2—a harmonious flat back, Type 3—a well-balanced proximal and distal arch, and Type 4—a large distal arch in both magnitude and length (Fig. 3). These subtypes are useful in assessing ideal spinopelvic alignment in addressing spinal deformity in conjunction with lumbar spinal stenosis.

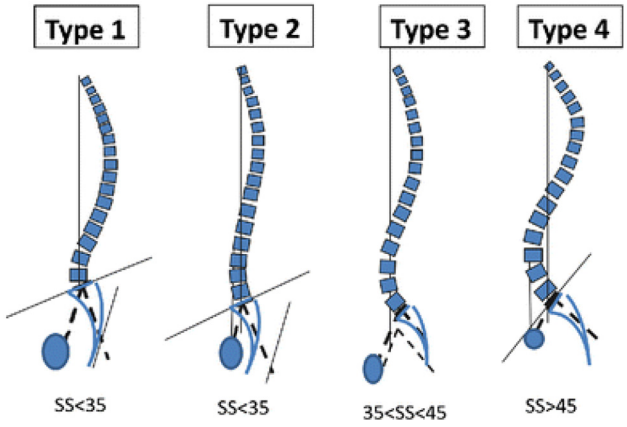

Fig. 3 – Graphic representation of the Roussouly classification of asymptomatic spinal shapes based on sacral slope and corresponding compensatory thoracolumbar alignment. Type 1 demonstrates a low SS with a long thoracolumbar kyphosis and small, low lumbar lordosis. Type 2, again, demonstrates a low SS with a harmonious flatback. Type 3 demonstrates an increased SS with a larger lumbar lordosis and long thoracolumbar kyphosis. Type 4 demonstrates a very large SS with a correlated hypercurved lumbar lordosis and thoracic kyphosis.[36]

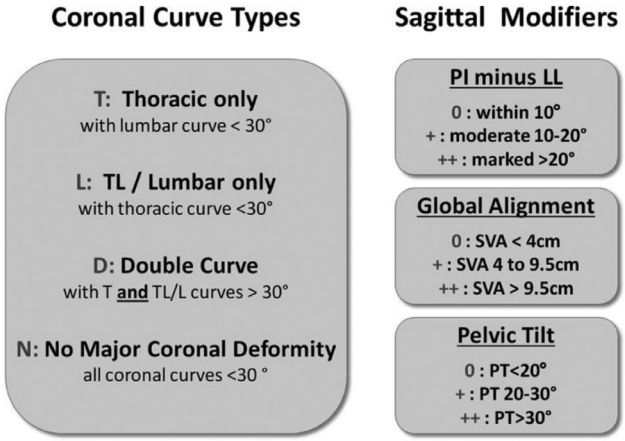

Fig. 4 – Scoliosis Research Society (SRS)—Schwab adult spinal deformity classification system with coronal curve types and sagittal modifiers including PI-LL mismatch, global alignment, and pelvic tilt.[25]

The current understanding ideal spinal alignment is the result of the efforts by the Scoliosis Research Society (SRS), European Spine Study Group (ESSG), and International Spine Study Group (ISSG), as large sample sizes are needed to power these studies.[19,25–27] Schwab et al. have established PT <20°, PI-LL <10°, and SVA <4 cm as target sagittal alignment goals.[25] Not meeting these parameters were determined to be highly correlated with severe pain and disability as measured by the Oswestry Disability Index (ODI).[28,29] The Scoliosis Research Society (SRS)—Schwab adult spinal deformity classification system utilizes parameters highly associated with HRQOL outcome scores with strong clinical relevance from frontal and sagittal plane radiographs (Fig. 4).[25] A unique and commonly used measure of sagittal alignment to simultaneously account for spinal inclination and pelvic retroversion is the T1-pelvis angle (TPA) proposed by Protopsaltis and the ISSG.[30] It is a measurement that takes into account both SVA and PT, and is the angle formed by a line from the center of the femoral heads to the center of the T1 vertebral body and a line from the center of the femoral heads to the center of the superior sacral end plate. With a normal value of <10° with three subsequent categories characterized by 10° of increasing divergence, increasing severity was shown to correlate with ODI, SVA, PT, and PI-LL.[30]

In an effort to develop patient specific optimal spinal alignment, the global alignment and proportion (GAP) score was developed in an attempt to predict failure of adult spinal deformity surgery.[27] It is composed of the PI, from which the GAP score predicts the optimal pelvic version, magnitude, and distribution of lumbar lordosis, and global spinopelvic alignment. There is also an age factor, as an age greater than or equal to 60 was found to significantly increase the risk of mechanical complications. This is in corroboration with recently proposed age adjusted goals of deformity correction,[31] which have been shown to correlate with improved outcomes, and lower complication rates (Fig. 5).[32,33] The GAP score is still controversial, as a recent study was unable to reproduce the results of the original GAP paper as they found no significant association between postoperative GAP score and mechanical failure or revision surgery.[34]

Determining the ideal spinal alignment following surgery, if one exists, is complex. Ideally, defining patient specific alignment goals related to a patient's intrinsic alignment based on their pelvic incidence may improve outcomes and reduce post-operative construct failure.[35] Predictive analytics and patient specific metrics will likely play a larger role in predicting ideal alignment in the future.

Age Group (yr)	PT (°)	PI–LL (°)	SVA (mm)
<35	11.0	−10.5	−30.5
35–44	15.4	−4.6	−5.5
45–54	18.8	0.5	15.1
55–64	22.0	5.8	35.8
65–74	25.1	10.5	54.5
≥74	28.8	17.0	79.3
LL indicates lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis.			

Fig. 5 – Age-specific sagittal spino-pelvic alignment parameters as defined by Lafage et al.[31]

5. Conclusion

In treating lumbar stenosis, assessment of spinal alignment is critical. If there is little to no spinal deformity or instability, surgical decompression alone may be adequate. If deformity is present and contributing to neural compression, decompression in the concavity of the main and fractional curves along with correction of the deformity should be considered using either direct or indirect surgical techniques. Decompression alone in this setting can lead to progression of the deformity, incomplete neural decompression, or both. Spinal realignment surgery requires an understanding of sagittal alignment parameters to determine the goals of surgical correction. Research in this arena has advanced our understanding of ideal spinal sagittal alignment, but it is still not completely understood. Surgical correction of deformity with decompression of the neural elements can lead to high patient and surgeon satisfaction.

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