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Adjacent Segment Disease after Lumbar Spine Surgery—Part 2: Prevention and Treatment

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Learning Objectives: *After participating in this CME activity, the neurosurgeon should be better able to:*

1. *Distinguish the pathophysiology of adjacent segment disease (ASD) and identify major ASD risk factors after lumbar spine surgery.*
2. *Analyze the impact of alignment (or malalignment) on ASD development after lumbar spinal operations and how short-segment fusion with proper alignment may reduce ASD.*
3. *Explain general management strategies for lumbar spine surgery patients with symptomatic ASD.*

This article is the second of 3 parts.

Adjacent Segment Disease and Proximal Junctional Kyphosis

Based on recently proposed terminology, degeneration that develops at mobile segments above or below a previously operated spinal level is known as adjacent segment pathology (ASP). Within the heading of ASP, radiologic ASP refers to the radiologic changes that occur at the adjacent segment, and clinical ASP refers to the clinical symptoms and signs that occur at the adjacent segment. ASP can occur after any spine surgery and in any region of the spine, including simple decompressions and short- or long-segment fusion surgical procedures. The development of ASP is problematic because it can necessitate further surgical intervention and adversely affect functional outcomes.

The first section of this 3-part series focused on description of the risk factors for development of ASP and proximal junctional kyphosis (PJK), and the classification systems that have been developed as a means of creating a more standardized approach for diagnosing and treating these conditions. In part 2 of this review, the focus is on important general concepts in the prevention and treatment of ASP after lumbar spine surgery. As a basis for understanding specific methods for prevention and treatment strategies, we also discuss important principles that underlie the pathologic processes involved in the development of these

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Category: Spine

Key Words: Adjacent level disease, Adolescent idiopathic scoliosis, Adult spinal deformity, Proximal junctional failure, Proximal junctional kyphosis, Scoliosis

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conditions, including the importance of global, regional, and junctional alignment.

Adjacent Segment Pathology in the Lumbar Spine

ASP after lumbar spine fusion surgery is likely a result of stress concentration and hypermobility at the junction of the mobile and fused segments. Iatrogenic disruption of the soft tissue and ligamentous structures may promote instability and accelerate degenerative processes at adjacent segments. With time, these forces can lead to premature degeneration of the facet joints. As the facets degenerate, translation of the adjacent segment may occur and may produce listhesis. The chronic segmental stress concentration and hypermobility can also lead to facet hypertrophy and thickening of the ligamentum flavum. Collectively, these changes can result in compression of the neural elements and the common clinical symptoms of ASP, including back pain, radiculopathy, and neurogenic claudication.

Radiographic ASP after lumbar spine surgery is a common occurrence. A recent meta-analysis reported a wide range of incidences, with up to 92% in some series. Reported rates for symptomatic ASP are also widely variable, with reports ranging from 2% to 30%. Risk factors for development of ASP include patient factors such as age, sex, obesity, preexisting degeneration, and facet tropism. A number of surgical risk factors have also been reported. For lumbar fusions the technique used, interbody versus posterolateral versus anterior/posterior surgery, has not been consistently shown to be associated with the occurrence of ASP, although some studies have reported a lower rate of degeneration with anterior lumbar interbody fusion alone. Increased number of laminectomy segments and laminectomy adjacent to a fusion has been reported to be a risk factor for development of ASP. It remains unsettled whether length of fusion is a risk factor for ASP, as some reports suggest that longer segment fusions are associated with increased incidence of ASP, whereas other studies, particularly in the adult deformity literature, suggest that fusion length and long spinal fusions are not necessarily associated with accelerated degeneration of the transitional level. Several retrospective studies and meta-analyses have shown that disruption of sagittal or coronal alignment and ligamentous disruption can accelerate degeneration of adjacent segments in the lumbar spine.

Impact of Alignment on Lumbar Adjacent Segment Pathology

Advances in our understanding of spinopelvic alignment, and reciprocal changes and compensatory mechanisms occurring in the unfused spine after spinal instrumentation for adult spinal deformity, have added further insights into understanding lumbar ASP. Duval-Beaupere and Boulay et al. described a chain of correlations between global and regional spinal alignment parameters with pelvic incidence (PI). They suggested that the PI (a fixed anatomic parameter) dictates the amount of lumbar lordosis (LL) required to assume a balanced sagittal posture using the equation $PI = LL \pm 9$ degrees. The importance of this relationship has been demonstrated in the adult spinal deformity literature. Schwab et al. reported that PI-LL mismatch was one of the strongest radiographic correlates with disability and lower quality-of-life scores in adult patients with spinal deformity. Smith et al. demonstrated that pathologic loss of LL with PI-LL mismatch can lead to significant pain and disability, even in the absence of global malalignment. They also showed that surgery to restore lordosis and reduce PI-LL mismatch can lead to significant improvement in pain and functional outcomes.

The importance of spinopelvic sagittal alignment and its implications for clinical outcomes after spinal fusion or decompression of the degenerative lumbar spine has been demonstrated in recent studies. Kumar et al. in a series of patients who underwent lumbar spine fusions

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for degenerative conditions reported that patients who had an abnormal C7 plumb-line position and/or high sacral slope had a significantly higher rate of ASP. Djurasovic et al. reported that patients with less lordosis across their fusion levels and through the entire lumbar spine developed ASP at a significantly greater rate than matched controls. A recent study by Rothenfluh et al. demonstrated that patients with PI-LL mismatch of more than 10 degrees after short-segment lumbar fusion had 10 times higher risk for undergoing revision surgery for ASP than did controls without such a PI-LL mismatch. These results are supported by biomechanical studies from Senteler et al. and Umehara et al., who provide a biomechanical explanation for the association between PI-LL mismatch and adjacent segment disease (ASD). Their studies suggest that hypolordosis across instrumented segments resulting in PI-LL mismatch increased the mechanical load on the posterior column of the adjacent unfused segments, which may accelerate the degenerative process (Figure 1).

Management of Lumbar Spine ASP

Based on radiographic evaluation, ASP appears to be quite common. Radiographic ASP, however, does not necessarily correlate with a poor prognosis. Most clinical studies show that functional outcomes are largely unaffected by asymptomatic ASP and that surgical intervention is therefore often not indicated. When patients present with symptoms referable to pathology at the adjacent segment, surgery can be considered as an option, particularly if nonoperative therapy has failed. The few clinical studies specifically addressing surgical management of lumbar ASP emphasize adequate decompression of neural elements and subsequent extension of the fusion if indicated for instability. Recent evidence suggests that identification and treatment of malalignment if present should be considered in any surgical intervention for ASP. Although simply extending the fusion to address the symptomatic level may be appropriate in certain instances, surgery for ASP that fails to address the underlying malalignment or fails to achieve an appropriate realignment may predispose to further ASP (Figure 2).

Treatment of symptomatic ASP has typically been decompression and stabilization, or extension of the existing construct. Traditionally, this is performed with posterior laminectomy and pedicle screw fusion. Other methods of spine stabilization and decompression have also been shown to be effective in the management of clinical ASD, including posterior lumbar interbody fusion, transforaminal lumbar interbody fusion (TLIF), anterior lumbar interbody fusion, and minimally invasive transpsoas lateral lumbar interbody fusion (LLIF). The next section discusses the various methods for management of lumbar ASD.

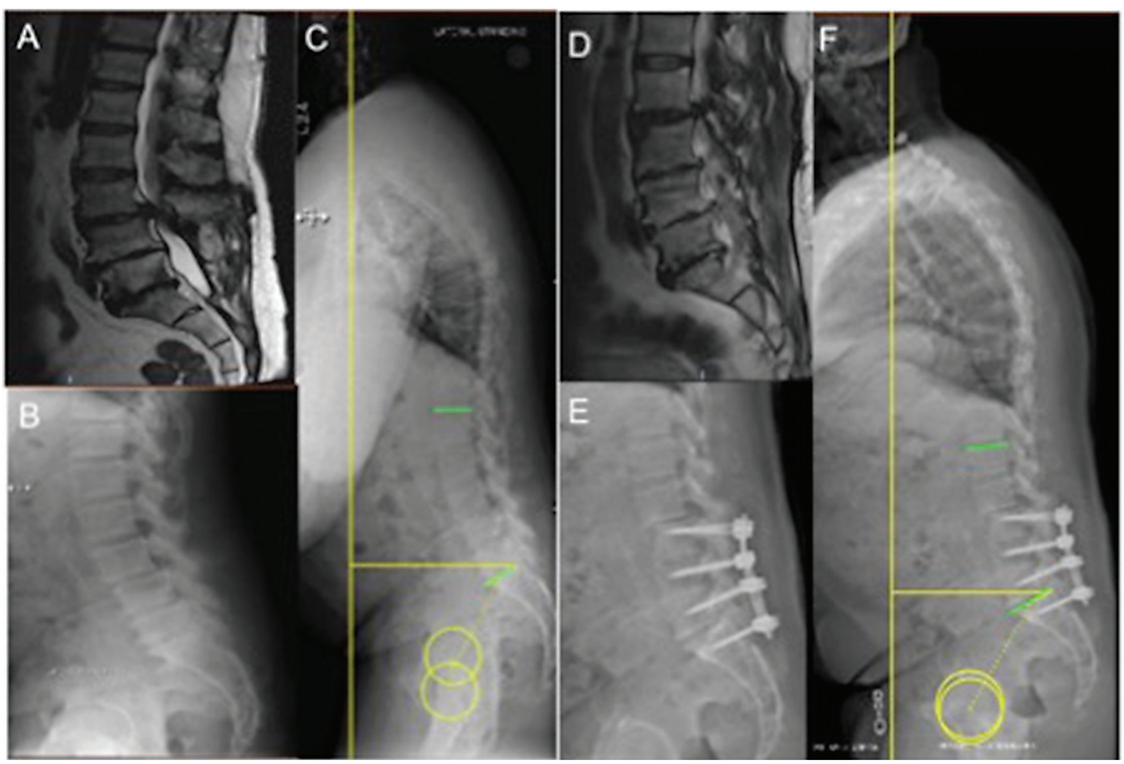


Figure 1. Case example 1. A 60-year-old man with back pain, neurogenic claudication, and radicular pain that was nonresponsive to multiple nonsurgical therapies. MRI demonstrated multiple levels of disc degeneration with significant central and foraminal stenosis at L3-L4 (***A***). Standing spine radiographs demonstrated a C7-S1 SVA of +13 cm (***B*** and ***C***). His PI and LL were 59 and 35 degrees, respectively, resulting in a PI-LL mismatch of 24 degrees. The patient underwent L3-S1 decompression and instrumented posterolateral fusion at an outside facility. The patient's symptoms improved after surgery. However, within 2 years of surgery, the patient developed progressive severe back pain and recurrent claudication symptoms. Imaging at follow-up demonstrated adjacent-level hypermobility with development of adjacent segment disc herniation and stenosis (***D*** and ***E***). Imaging demonstrated an SVA of +15 cm, an LL of 24 degrees, and a PI-LL mismatch of 35 degrees (***F***).

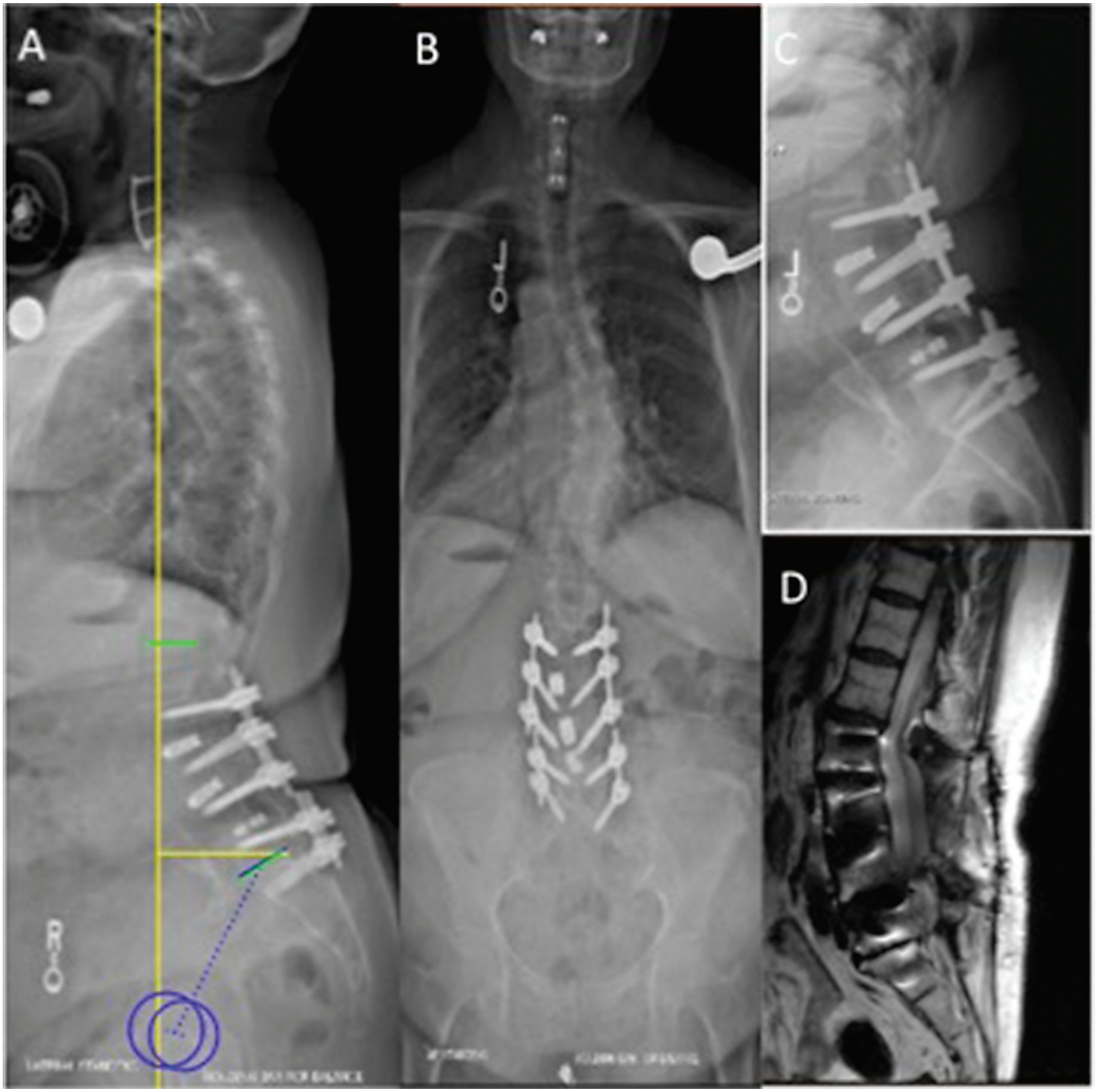


Figure 2. Case example 2. A 50-year-old woman with a history of multiple prior spine surgical procedures. The initial treatment was an L5-S1 posterolateral fusion. Subsequently, she underwent a stand-alone L4-L5 LLIF for ASP. She subsequently developed ASP at L3-4 and was treated with extension of fusion and L2-3 and L3-4 TLIFs. She ultimately presented with back pain and recurrent claudication symptoms. Full-length standing films (***A***–***C***) demonstrated a C7-S1 SVA of +7 cm. Her PI was 58 degrees and her LL was 34 degrees, resulting in a PI-LL mismatch of 24 degrees. MRI demonstrated adjacent segment stenosis at L1-2 (***D***).

Decompression Without Fusion for Lumbar ASP

Symptoms of radiculopathy and neurogenic claudication are commonly the result of hypertrophic facet joints and hypertrophied ligamentum flavum. In patients without overt instability and preserved alignment, a simple decompression may provide adequate symptom relief. Series reported by both Phillips et al. and Schlegel et al. reported greater than 50% improvement in back and leg pain after decompression alone without additional extension of fusion. Despite the positive results of some studies, it has been shown in other studies that laminectomy alone, adjacent to a previous fusion segment, increases the risk of recurrent ASP. This is presumably secondary to destabilization adjacent to a fused construct. In general, adjacent noninstrumented decompression should be only considered in those patients with a low likelihood of developing instability (no spondylolisthesis, no significant coronal or sagittal malalignment). Even then, patients should be counseled about the risks of instability, potentially requiring future surgery for stabilization.

Posterior Instrumentation and Fusion for Lumbar ASP

Decompressive laminectomy and extension of the previous fusion construct from a posterior approach remains the mainstay of treatment for symptomatic ASP of the lumbar spine. In the setting of symptomatic ASP with radiographic evidence of dynamic instability, spondylolisthesis, and/or stenosis, several studies report significant improvement in pain and quality of life after revision surgery. In a series of patients treated for adjacent segment instability and stenosis, Chen et al. reported 77% of the patients had good results after a 5-year follow-up period. In that series revision surgery consisted of aggressive decompression involving extensive removal of the medial facets and foraminotomies followed by extension of the previous fusion.

A modified TLIF technique described by Jagnnathan et al. has been shown to be a powerful technique for restoring LL from a posterior approach and is an effective technique for the treatment of ASP. This procedure involves a full posterior column osteotomy with bilateral facetectomies and placement of a large lordotic cage in a horizontal position at the anterior aspect of the disc space. With the horizontal placement at the anterior one-third of the disc space, subsequent compression allows a cantilever effect resulting in significant segmental lordosis restoration. This enables correction of both focal and segmental lordosis using a short-segment extension of a prior fusion. In the setting of postsurgical PI-LL mismatch, this technique may be used to revise a previously fused segment

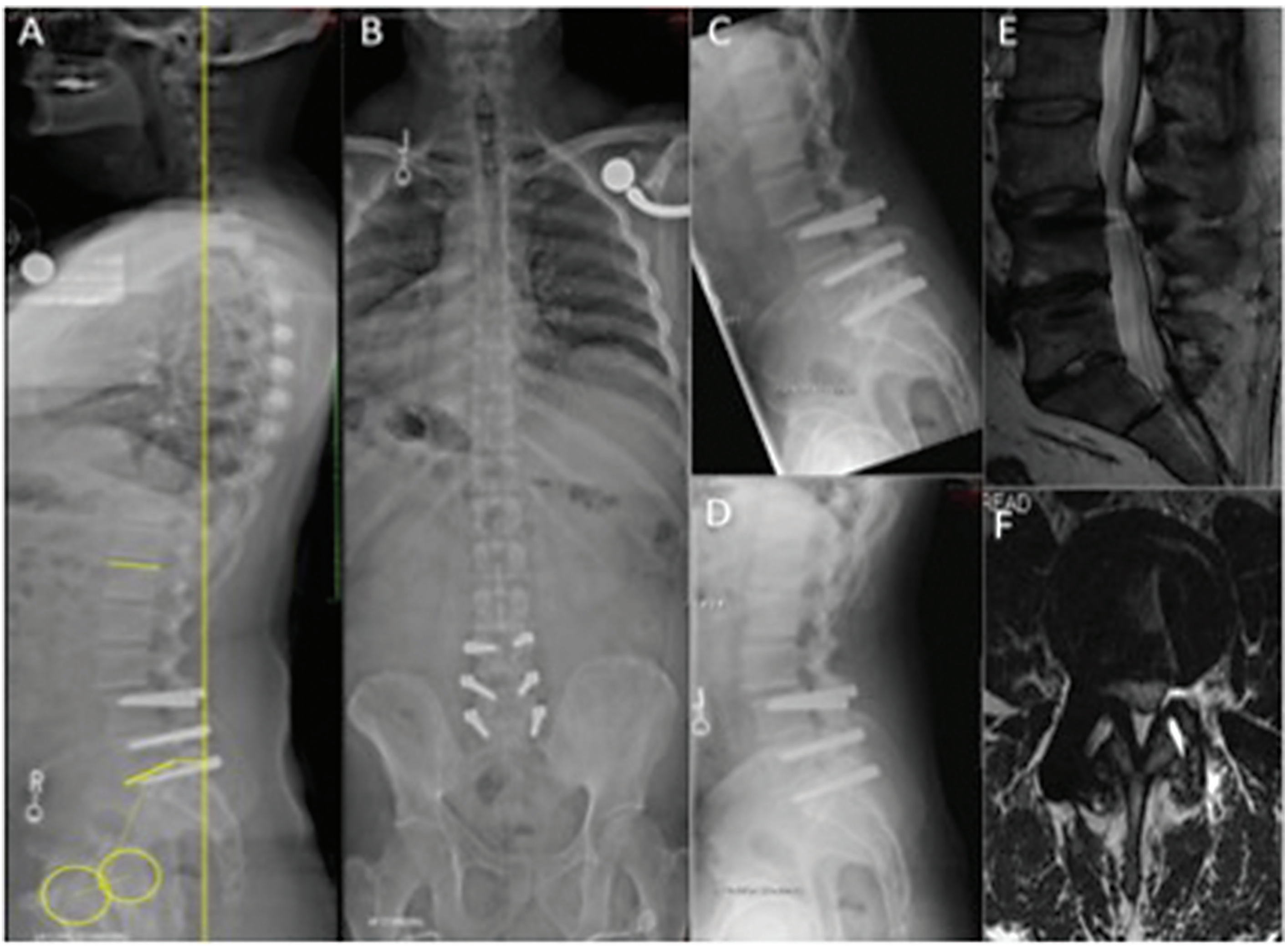


Figure 3. Case example 3. A 54-year-old man with back pain and lower extremity radicular pain. The patient underwent an L4-S1 dynamic stabilization 6 years prior. At that time, the patient had been experiencing primarily leg pain. After the surgery, the patient's symptoms improved; however, over the past few years he developed significant back pain and new right leg radicular pain. He states the leg pain radiates from the right hip, across the right thigh, to the medial aspect of the right knee. In addition, he describes significant back pain particularly when standing. He has undergone extensive nonoperative management, including facet injections, epidural injections, and sacral-iliac joint injections without durable benefit. Notably, he underwent an L3-4 epidural corticosteroid injection 2 weeks before presentation, which provided approximately 1 week of relief and since then his symptoms have recurred. He states that the back pain is significant, but the right leg pain and weakness is worse than the back pain. Full-length standing films demonstrate an SVA of −1 cm. His PI and LL were 46 and 32 degrees, respectively, for a PI-LL mismatch of 14 degrees (***A*** and ***B***). Flexion and extension lumbar radiographs demonstrate a grade I L3-4 spondylolisthesis (***C*** and ***D***). MRI demonstrates adjacent segment stenosis at L3-L4 with degenerative changes in the L3-4 facet joints (***E*** and ***F***).

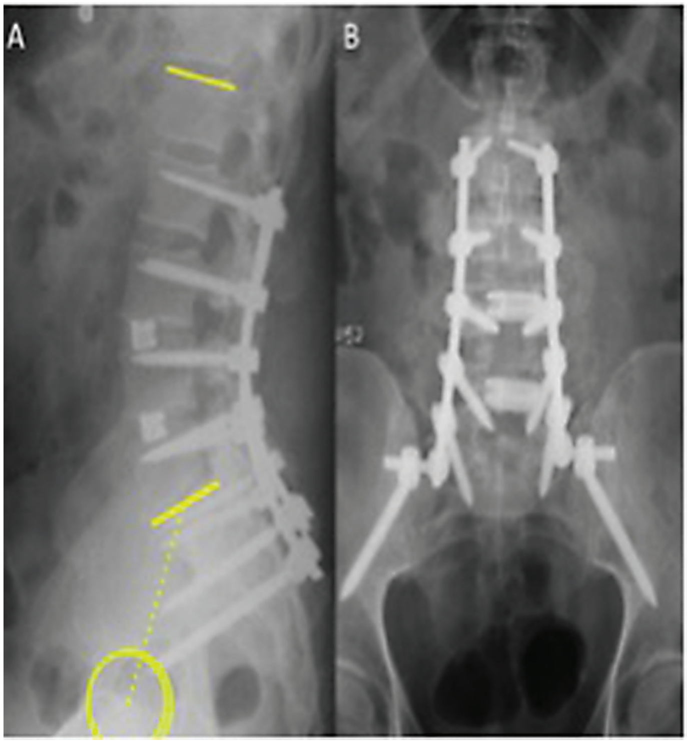


Figure 4. Case example 3. The patient underwent a revision fusion with removal of the dynamic stabilization device and L2 to iliac instrumentation with L3-L4, L4-L5 TLIF. Postoperative radiographs demonstrate restoration of an LL of 40 degrees with improvement of PI-LL mismatch (now 6 degrees) (***A*** and ***B***).

if no interbody fusion had been performed. It is also a useful technique for maximizing segmental lordosis at the lumbosacral junction after long-segment fusions (Figures 3 and 4).

Lateral Lumbar Interbody Fusion for Lumbar ASP

The LLIF is a minimally invasive procedure that has been shown to be effective in the treatment of ASP. With an LLIF, interbody fusion is achieved through a transpsoas approach and achieves indirect decompression through restoration of disc height. One of the benefits of the LLIF in the treatment of ASP is the ability to avoid traversing scar tissue and to avoid disruption of the posterior tension band and the anterior and posterior longitudinal ligaments, which may help to prevent further ASP. A recent study by Aichmair et al. reported on the outcomes of single-level LLIF for treatment of lumbar ASP. In their series of 52 patients, the authors reported a significant reduction in back and leg pain and improvement in segmental lordosis. Although LLIF seems to be advantageous in the setting of ASP, there is much debate regarding the efficacy of treatment with stand-alone LLIF. There are also conflicting reports on the ability of LLIF to restore segmental lordosis.

Nonfusion Techniques

Motion preservation technologies, including lumbar disc arthroplasty and dynamic posterior instrumentation, have been described as potential solutions for preventing ASP. To date, multiple studies have not shown significant differences in adjacent segment reoperation rates after lumbar total disc replacement versus fusion control groups, although longer follow-up and larger studies will be necessary to determine whether motion preservation will ultimately result in lower ASP rates.

Posterior dynamic stabilization devices have been designed that provide segmental stability with reduced rigidity compared with pedicle screw fixation, with the goal of reducing biomechanical stress at the junctional level compared with rigid fusion techniques. Results of several series, however, suggest that lumbar dynamic stabilization may not be effective in preventing adjacent segment degeneration. Kanayama et al. reported no reduction in ASP with posterior-based motion-preserving technology over fusion in a retrospective study comparing dynamic stabilization, posterolateral fusion, and posterolateral interbody fusion for patients with lumbar spinal stenosis. In a prospective study of patients treated with dynamic stabilization, Schaeren et al. showed a 47% rate of adjacent segment breakdown at average 52 months' follow-up. In another similar prospective cohort study of patients treated with a Nitinol spring rod system, Heo et al. reported 12% proximal and 16% distal segment degeneration after dynamic stabilization. Other studies have also demonstrated progression of degeneration at bridged and adjacent segments after dynamic stabilization system after 2-year follow-up.

Conclusion

ASD may occur after any lumbar spine surgery because of the combined effect of several postoperative mechanical factors and the normal aging process of the spine. The development of ASD may become problematic and adversely impact functional outcomes. Surgical revision may be warranted in more severe cases of ASD that involve refractory back pain or neurological deficit. The technical factors that are most reliably associated with ASD include laminectomy adjacent to a fusion and failure to restore appropriate segmental lordosis. When planning a surgical intervention for the treatment of ASD, restoration of global, regional, and segmental alignment should be considered in addition to neural decompression and stabilization. New technologies, including minimally invasive techniques and motion preservation, have not yet been proven to reduce the rate of ASD.

Readings

Bridwell KH, Lenke LG, Cho SK, et al. Proximal junctional kyphosis in primary adult deformity surgery: evaluation of 20 degrees as a critical angle. *Neurosurgery*. 2013;72(6):899-906.

Buell TJ, Buchholz AL, Quinn JC, et al. A pilot study on posterior polyethylene tethers to prevent proximal junctional kyphosis after multilevel spinal instrumentation for adult spinal deformity. *Oper Neurosurg (Hagerstown)*. 2018 Apr 24 (Epub ahead of print).

Buell TJ, Chen CJ, Quinn JC, et al. Alignment risk factors for proximal junctional kyphosis and the effect of lower thoracic junctional tethers for adult spinal deformity. *World Neurosurg*. 2018;Sept 11 (Epub ahead of print).

Carman DL, Browne RH, Birch JG. Measurement of scoliosis and kyphosis radiographs: Intraobserver and interobserver variation. *J Bone Joint Surg Am*. 1990;72(3):328-333.

Glattes RC, Bridwell KH, Lenke LG, et al. Proximal junctional kyphosis in adult spinal deformity following long instrumented posterior spinal fusion: incidence, outcomes, and risk factor analysis. *Spine (Phila Pa 1976)*. 2005;30(14):1643-1649.

Hart RBS, Burton DC, Shaffrey CI, et al. Study Group, International Spine. Proximal Junctional Failure (PJF) Classification and Severity Scale: Development and Validation of a Standardized System. 2013 Annual Meeting of the AANS/CNS Section on Disorders of the Spine and Peripheral Nerves; Phoenix, Arizona, 2013.

Helgeson MD, Shah SA, Newton PO, et al, Harms Study Group. Evaluation of proximal junctional kyphosis in adolescent idiopathic scoliosis following pedicle screw, hook, or hybrid instrumentation. *Spine (Phila Pa 1976)*. 2010;35(2):177-181.

Hilibrand AS, Tannenbaum DA, Graziano GP, et al. The sagittal alignment of the cervical spine in adolescent idiopathic scoliosis. *J Pediatr Orthop*. 1995;15:627-632.

Hostin R, McCarthy I, O'Brien M, et al. Incidence, mode, and location of acute proximal junctional failures after surgical treatment of adult spinal deformity. *Spine (Phila Pa 1976)*. 2013;38(12):1008-1015.

Lafage R, Schwab F, Challier V, et al. Defining age-specific sagittal alignment thresholds. *Spine*. 2016;41:62-68.

Lafage V, Ames C, Schwab F, et al. Changes in thoracic kyphosis negatively impact sagittal alignment after lumbar pedicle subtraction osteotomy: a comprehensive radiographic analysis. *Spine (Phila Pa 1976)*. 2012;37(3):E180-E187.

Lau D, Clark AJ, Scheer JK, et al. Proximal junctional kyphosis and failure after spinal deformity surgery: a systematic review of the literature as a background to classification development. *Spine (Phila Pa 1976)*. 2014;39(25):2093-2102.

Lee GA, Betz RR, Clements DH 3rd, Huss GK. Proximal kyphosis after posterior spinal fusion in patients with idiopathic scoliosis. *Spine (Phila Pa 1976)*. 1999;24(8):795-799.

Maruo K, Ha Y, Inoue S, et al. Predictive factors for proximal junctional kyphosis in long fusions to the sacrum in adult spinal deformity. *Spine (Phila Pa 1976)*. 2013;38(23):E1469-E1476.

McClendon J, Jr, O'Shaughnessy BA, Sugrue PA, et al. Techniques for operative correction of proximal junctional kyphosis of the upper thoracic spine. *Spine (Phila Pa 1976)*. 2012;37(4):292-303.

Mummaneni PV, Park P, Fu KM, et al., International Spine Study Group. Does minimally invasive percutaneous posterior instrumentation reduce risk of proximal junctional kyphosis in adult spinal deformity? A propensity-matched cohort analysis. *Neurosurgery*. 2016;78(1):101-108.

Nguyen NL, Kong CY, Hart RA. Proximal junctional kyphosis and failure-diagnosis, prevention, and treatment. *Curr Rev Musculoskelet Med*. 2016;9(3):299-308.

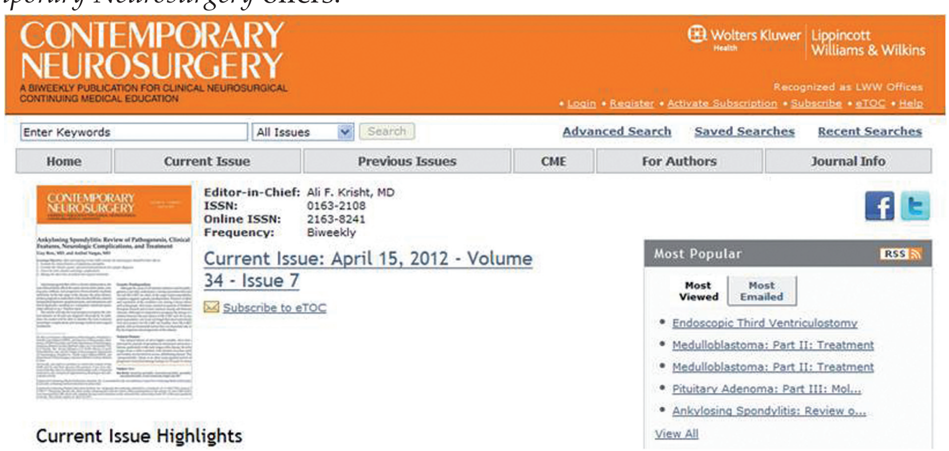
Radcliff KE, Kepler CK, Jakoi A, et al. Adjacent segment disease in the lumbar spine following different treatment interventions. *Spine J*. 2013;13(10):1339-1349.

Rothenfluh DA, Mueller DA, Rothenfluh E, et al. Pelvic incidence-lumbar lordosis mismatch predisposes to adjacent segment disease after lumbar spinal fusion. *Eur Spine J*. 2015;24(6):1251-1258.

Smith JS, Singh M, Klineberg E, et al. Surgical treatment of pathological loss of lumbar lordosis (flatback) in patients with normal sagittal vertical axis achieves similar clinical improvement as surgical treatment of elevated sagittal vertical axis: clinical article. *J Neurosurg Spine*. 2014;21(2):160-170.

Yagi M, Akilah KB, Boachie-Adjei O. Incidence, risk factors and classification of proximal junctional kyphosis: surgical outcomes review of adult idiopathic scoliosis. *Spine (Phila Pa 1976)*. 2011;36(1):E60-E68.

Yagi M, Rahm M, Gaines R, et al. Characterization and surgical outcomes of proximal junctional failure in surgically treated patients with adult spinal deformity. *Spine (Phila Pa 1976)*. 2014;39(10):E607-E614.



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1. The development of adjacent segment disease may be problematic because in severe cases it can warrant further surgical intervention.

   True or False?

2. A spine surgeon performs L4-L5 decompression and posterior fusion with transpedicular instrumentation. Postoperatively, there will likely be decreased stress concentration and hypermobility at the adjacent L3-L4 level.

   True or False?

3. During lumbar spine surgery, iatrogenic disruption of the soft tissue and ligamentous structures may promote instability and accelerate degenerative processes at adjacent segments. With the goal of reducing severe ASP, the lumbar spine surgeon should attempt to limit posterior dissection and preserve ligamentous structures (facets and posterior ligaments) at the adjacent segments.

   True or False?

4. Radiographic ASP after lumbar spine surgery is common; however, symptomatic ASP may be variable and occur with less frequency.

   True or False?

5. Patients with PI-LL mismatch of more than 10 degrees after short-segment lumbar fusion do not have higher risk for undergoing revision surgery for ASP compared with patients without such a PI-LL mismatch.

   True or False?

6. In general, adjacent noninstrumented decompression should be only considered in those patients with a low likelihood of developing instability (no spondylolisthesis, no significant coronal or sagittal malalignment).

   True or False?

7. A posterior approach and performing a decompressive laminectomy and extension of the previous fusion construct remains the mainstay of treatment for symptomatic lumbar ASP.

   True or False?

8. A possible benefit of LLIF in the treatment of ASP is avoiding disruption of the posterior tension band, which may help prevent further ASP.

   True or False?

9. Motion preservation technologies, including lumbar disc arthroplasty and dynamic posterior instrumentation, have been proven to prevent ASP.

   True or False?

10. When planning a surgical intervention for the treatment of ASP restoration of global, regional, and segmental alignment should be considered in addition to neural decompression and stabilization.

    True or False?