Review Article

An Approach to Lumbar Revision Spine Surgery in Adults

S. Samuel Bederman, MD, PhD, FRCSC

Vu H. Le, MD

Sohrab Pahlavan, MD

Abstract

Along with the increase in lifestyle expectations in the aging population, a dramatic rise in surgical rates has been observed over the past 2 decades. Consequently, the rate of revision spine surgery is expected to increase. A systematic approach to treatment is required for the adult patient presenting with late or chronic complications after spinal surgery. Patient assessment includes elucidating current symptoms and knowledge of the previous surgery, performing a detailed assessment, and obtaining appropriate studies. Subsequently, differential diagnoses are formulated based on whether the pathology arises from the same levels or adjacent levels of the spine and whether it relates to the previous decompression or fusion. Finally, familiarity with different surgical approaches is imperative in treating the common pathologies encountered in this patient population.

From the Texas Back Institute, Plano, TX (Dr. Bederman), the NewportCare Orthopaedic & Spine Center, Newport Beach, CA (Dr. Le), and the Department of Orthopaedic Surgery, University of California, Irvine, Orange, CA (Dr. Pahlavan).

Dr. Bederman or an immediate family member has received royalties from Spineart; is a member of a speakers' bureau or has made paid presentations on behalf of Mazor Robotics; serves as a paid consultant to Mazor Robotics, Spineart, and Vertebral Technologies; has stock or stock options held in Vertebral Technologies; and has received research or institutional support from NuVasive and Baxano Surgical. Neither of the following authors nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Le and Dr. Pahlavan.

J Am Acad Orthop Surg 2016;24: 433-442

http://dx.doi.org/10.5435/JAAOS-D-14-00181

Spinal surgery has been shown to be beneficial in reducing pain and improving function in patients with specific degenerative conditions. "Failed back surgery," "flatback syndrome," and "postlaminectomy syndrome" are terms used to describe the conditions of patients who have previously undergone spinal surgery and are currently symptomatic. Although these terms are in common use, they fail to convey any meaningful information to patients or treating physicians about the cause of the symptoms.

A considerable increase in spinal surgery rates has been observed over the past 2 decades. The rate of revision surgery is expected to increase[1] along with the number of patient visits to spine surgeons and generalists. Here, we provide the general orthopaedic surgeon with a systematic approach to the adult patient who presents with late complications after spine surgery. Unlike early complications occurring >90 days after surgery and intermediate complications seen 90 days to 2 years postoperatively, late complications that occur ≥2 years after surgery are more likely to be encountered by general orthopaedic surgeons.

Patient Assessment

Patients with degenerative lumbar conditions typically present to the spine surgeon with reports of pain, neurologic symptoms, spinal deformity, or a combination of the three. The pathology may be related to the previous surgical level, an adjacent level, or be remote from the previous level. The pathology also may vary depending on whether the patient has had an earlier decompression or fusion (Table 1).

An appropriate assessment of the symptomatic postsurgical spinal patient begins with a thorough history and physical examination followed by appropriate radiographic and laboratory investigations. Any

Table 1

Differential Diagnosis in Patients With Degenerative Lumbar Conditions

Procedure	Same Level	Adjacent Level
Decompression	Infection Stenosis Fracture Instability/deformity	Stenosis Instability/deformity
Fusion	Infection Stenosis Fracture Device irritation Pseudarthrosis Instability/deformity	Stenosis Fracture Instability/deformity

available surgical reports, imaging, and investigations from earlier surgery should be obtained.

The most common presenting symptom is pain. Patients may report pain in the back, in the lower extremities, or even in remote areas, such as headache caused by a cerebrospinal fluid leak. The pain may remain unchanged, may have recurred after successful treatment, may be in a completely different location, or may be of a different quality. It can occur immediately after surgery or after a long delay. Obtaining an accurate account of the location, timing, and inciting events of the pain is essential in elucidating the underlying etiology.

The physical examination starts with a full general examination of all organ systems. The inspection of prior incisions is necessary to plan future approaches and to ensure that the incisions have healed satisfactorily. Assessment of the patient's posture is required to evaluate spinal balance and alignment in the coronal and sagittal planes. Imaging obtained with the patient upright and bending can be used to distinguish a flexed forward posture, which can result from fixed spinal deformity, compensatory positioning to unload compressed nerve roots, weak trunk extensor muscles, or an underlying neurodegenerative disease.

Recurrent back pain after spinal surgery can result from pseudarthrosis, fracture, adjacent segment disease, infection, or painful instrumentation. It also can represent referred pain from the hip or sacroiliac joints. Radicular leg pain after spinal surgery could be attributed to recurrent or residual stenosis in the same dermatome or to adjacent segment stenosis affecting a different dermatome from the earlier surgery. Joints of the lower extremity should be examined to rule out other periarticular pathology.

A detailed evaluation of the neurologic status of the patient should include a complete assessment of motor and sensory function and an assessment of the reflexes, including long tract signs, to rule out more proximal neurologic lesions from compensatory cervical hyperlordosis causing myelopathy or other nonspinal neurologic pathologies, such as multiple sclerosis or stroke. Vascular claudication also should be ruled out as a source of symptoms.

As part of the radiographic assessment, plain radiographs are obtained with the patient in a standing or upright position. Dynamic views, including maximum traction, flexion, extension, and lateral flexion, are obtained to assess for spinal instability. In cases of spinal deformity, 36-inch radiographs are helpful to assess the overall spinal balance. Cross-sectional imaging is necessary to identify more subtle pathology not appreciated on plain radiography. CT without contrast is useful for evaluating the integrity of the existing instrumentation or any evidence of pseudarthrosis or fractures. MRI with gadolinium enhancement can be used to identify the locations of neural compression or ongoing infection in patients who have had prior surgery. In patients with existing instrumentation, however, artifact may interfere with the quality of the images. In such cases, postmyelographic CT can be invaluable to assess for ongoing neural compression. Technetium bone scans can identify areas of increased bone turnover, such as pseudarthroses, and gallium or white blood cell (WBC)-labeled indium scans can ascertain underlying infection.

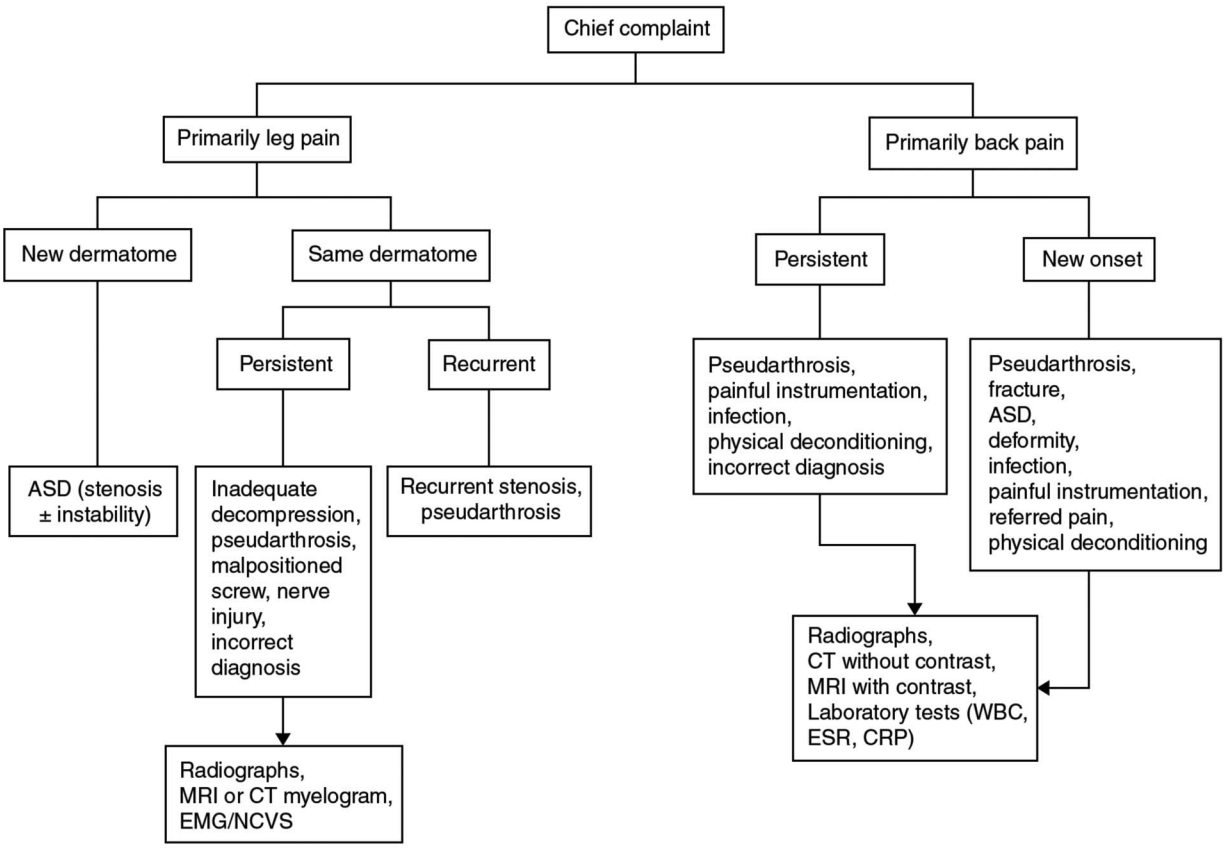
Laboratory studies should include a complete blood count with differential, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) level to rule out infection. The complete lymphocyte count and total serum protein and albumin levels are helpful in quantifying the nutritional status of the patient if future surgery is contemplated. Other diagnostic studies that can provide valuable information include electromyography and nerve conduction velocity studies for neurologic deficits and noninvasive vascular ultrasound studies or angiography if prior anterior surgery has been performed. An algorithm showing the management approach to revision lumbar spine surgery in adults is outlined in Figure 1.

Common Late-presenting Pathologies Requiring Revision Surgery

Infection

Infection following spinal surgery can be a devastating complication. As

Figure 1



Algorithm showing the management approach to revision lumbar spine surgery in adults. ASD = adjacent segment disease, CRP = C-reactive protein, EMG = electromyogram, ESR = erythrocyte sedimentation rate, NCVS = nerve conduction velocity studies, WBC = white blood cell count.

with most surgical procedures, the risk is related directly to the length and complexity of the primary procedure. Surgical risk factors include arthrodesis, especially with posterior instrumentation, longer surgical times, and greater blood loss.[2] Patient risk factors include diabetes mellitus, smoking, malnutrition, obesity, older age, corticosteroid use, and preoperative hospitalization >1 week.[3] The causative organism most often seen is *Staphylococcus aureus*, with methicillin-resistant *S aureus* reported in 34% of cultures. Other causative organisms may be *S epidermidis*, *Enterococcus faecalis*, *Pseudomonas*, and *Propionibacterium acnes*.

The incidence of late infections, which occur beyond 12 months after surgery, can range from 1% to 6.7%.[4] Although fusion without instrumentation has been associated with an infection rate ranging from 0.4% to 4.3%, the infection risk with spinal instrumentation is between 2.8% and 6%.[5,6] Late infections usually result from the hematogenous spread or intraoperative inoculation of low-virulence organisms and may present with a late onset of pain after a long asymptomatic period.[7] A recent history of infection or bacteremia may be present. The clinical assessment may yield a history of fever or chills or an elevated WBC count, ESR, or CRP level. Radiographic investigations may show a loosening of the instrumentation, increased gadolinium uptake on MRI, or a positive gallium-labeled or indium-labeled WBC bone scan. A blood culture and CT-guided biopsy may determine the type of bacteria and the sensitivities for appropriate antibiotic treatment. Cultures should be kept for at least 7 to 10 days because of the prolonged incubation of low-virulence skin organisms, such as *Propionibacterium*.[4,8] Because late infections normally are associated with low-virulence organisms, culture examination also should include fungus and acid-fast bacilli, in addition to aerobic and anaerobic specimens.

The general indications for surgery include the progression of infection despite antibiotic therapy, epidural abscesses causing pain and/or neurologic symptoms, and progressive collapse of the vertebral bodies or disks, leading to spinal deformity. Treatment usually involves the surgical débridement of infected and necrotic tissues and intravenous antibiotic therapy for 4 to 9 weeks.[9] When instrumentation is present, removal is recommended if no sign of pseudarthrosis or instability exists. The need for repeat débridement within 48 to 72 hours depends on the extent of the infection during the initial surgery. Maruo and Berven[10] described high rates of treatment failure in cases with late infection, long instrumented fusions, polymicrobial infections, and *P acnes* infection. Therefore, the removal of implants and direct or staged reimplantation may be useful in these cases.

If instability following implant removal is anticipated, retention or immediate exchange to titanium instrumentation should be considered to eradicate the infection. Titanium implants have been shown to have less bacterial glycocalyx adherence than stainless steel.[11] If additional bone graft is needed, autogenous graft may be used because it has been shown to be effective for fusion and eradicates infection.[12] The placement of antibiotic beads also should be considered during the initial débridement if a staged procedure is contemplated. The addition of intrawound vancomycin powder before closure has conferred considerable benefit, according to a recent meta-analysis.[13] Continual postoperative drainage or persistently high ESR and CRP levels also should warrant repeat débridement.

Stenosis

Patients with radicular pain after lumbar decompression represent a diagnostic challenge. Up to 20% of patients undergoing primary surgery for spinal stenosis do not experience sustained pain relief because of recurrence or residual stenosis.[14] In cases of recurrent stenosis, the patient typically experiences a resolution of the symptoms after the initial surgery, and then recurrent symptoms begin to develop in the same distribution as before. In residual stenosis, persistent radicular symptoms without resolution may indicate an inadequate decompression, surgery at the wrong level, or a wrong diagnosis for the index procedure. In the case of a prior fusion, recurrent stenosis would not be expected in an area of solid arthrodesis. Recurrent stenosis can occur easily at the index fusion level in the setting of pseudarthrosis, however, as a result of the persistent motion. Symptoms in a new distribution may represent adjacent-level stenosis. In patients with instrumentation, an MRI with contrast or a CT myelogram can show ongoing areas of stenosis. Electromyography and nerve conduction velocity studies may help to document neurologic dysfunction and may support the diagnosis. Treatment should start with nonsurgical modalities, such as physical therapy, anti-inflammatory medications, and injections, but revision decompression with or without fusion may be necessary if these modalities fail.

Fractures

Fractures after spinal surgery typically involve the pars interarticularis because of aggressive decompression or compression fractures of the vertebral bodies adjacent to the upper or lower instrumented level. Iatrogenic fractures of the pars interarticularis that occur after spinal surgery and give rise to acquired spinal instability were first recognized by Marchetti and Bartolozzi,[15] who surmised that the pathology was caused by overly wide decompressions or as a result of subsequent trauma following thinning of the pars.[16] The rate of spondylolysis after posterior lumbar decompression can be as high as 28%.[17] Direct surgical repair becomes technically difficult because of the narrow bridge of bone and poor vascular supply. Thus, symptomatic patients typically require a fusion of that motion segment.

Proximal junctional failure (PJF) most commonly occurs at or above the upper instrumented vertebrae (UIV) after long-segment instrumentation. Hostin et al[18] examined 1,218 patients who underwent adult spinal deformity surgery and found a PJF rate of 5.6%; fracture was the most common mode of failure. Risk factors for PJF include low bone density, a large preoperative sagittal imbalance, a large curve correction, disruption of the posterior tension band, and ending the UIV at a kyphotic junction.[19] Fractures causing intractable pain and instability or progressive deformity may require stabilization and correction of the focal deformity after a careful assessment of global balance.[20] Otherwise, they can be treated nonsurgically with bracing. In a study of patients who had vertebral cement augmentation at the UIV and supra-adjacent vertebrae, Hart et al[21] found that none had PJF compared with 15% of patients in the nonaugmented group. The placement of hooks instead of pedicle screws at the UIV also may reduce the risk of PJF by providing a less stiff transition while avoiding possible facet violation.[22] Ohtori et al[23] reported that patients with osteoporosis who received teriparatide injections before and after lumbar surgery had less pedicle screw loosening than did the risedronate and control groups, suggesting that increasing bone density may prevent PJF.

Painful Instrumentation

Implant-related pain in the setting of a solid fusion can be related to the formation of bursae about the implants in prominent areas. Alanay et al[24] found that patients who responded well to local anesthetic injection into the inflamed bursa had pain relief equivalent to that of implant removal. Prominent instrumentation commonly is encountered at the top or bottom of the segmental construct.

Iliac screws inserted with a Galveston technique may be bothersome over the posterior superior iliac crest.[25] This problem can be avoided with the use of an inside-out iliac screw technique in which the screw head is buried into the medial cortex of the posterior iliac spine. Techniques that may prevent this complication include burying iliac screws or adopting the S2-alar-iliac (S2AI) trajectory, which can prevent symptomatic iliac screws, and ensuring that the screw heads are as close to the bone as possible. Chang et al[26] performed a three-dimensional radiographic analysis using CT to analyze the anatomic advantage of the S2AI screw placement over the conventional iliac screw placement into the posterior superior iliac spine. They found that S2AI screws sit approximately 15 mm deeper than typical iliac screws and are more in line with S1 screws.

Pseudarthrosis

Pseudarthrosis following attempted fusion commonly is diagnosed at least 12 months after the index procedure.[27] In a meta-analysis, Bono and Lee[28] showed higher fusion rates with instrumentation (89%) than without (84%) and with single-level fusion (89%) rather than with multilevel fusion (71%). Patient risk factors for pseudarthrosis include nicotine use, poor bone quality, medical comorbidities (eg, diabetes mellitus, collagen vascular disease), the use of such medications as NSAIDs and corticosteroids, and even genetic predisposition. Risk factors related to the surgical technique include fusion at the lumbosacral level, the number of levels fused, the use of instrumentation, and the materials used for grafting.[29]

Prevention strategies include smoking cessation, nutrition optimization, and blood glucose control for patients with diabetes mellitus who are undergoing fusion. During the index surgery, a meticulous preparation of the posterior fusion bed with decortication or combined with a concurrent anterior fusion can increase the likelihood of fusion. A variety of biologic graft materials are available, including autograft, allograft, demineralized bone matrix, synthetic scaffolds, and osteoinductive biologics. The ideal material should combine the properties of osteoconduction and osteoinduction for satisfactory fusion. A commonly used osteoinductive graft is recombinant human bone morphogenetic protein (rhBMP)-2, which currently is approved by the FDA only for anterior lumbar interbody fusion. Despite this declaration, rhBMP-2 is widely used posteriorly on an off-label basis because of its equivalency with autogenous bone graft.[30] Although it has been shown to be an effective alternative to iliac crest autograft bone as measured by fusion rate and donor site morbidity, some concerns have arisen regarding possible adverse effects, such as inflammation, heterotopic ossification, and malignancy.[31] A recent study of the incidence of cancer in Medicare patients after exposure to a high dose of rhBMP-2 showed no increase in the risk of malignancy, however.[32]

The standard of care for the diagnosis of pseudarthrosis remains the reexploration of the surgical site. A more practical approach involves initial imaging with CT or a technetium bone scan; however, these modalities have high rates of inaccuracy.[33] CT and dynamic radiographs may show evidence of instability or loose or broken instrumentation, indicating inadequate fusion. Nonetheless, broken implants have been seen in cases of solid fusion. Before embarking on any revision surgery, an occult infection also must be ruled out. We recommend obtaining deep cultures during surgery to help rule out the presence of infection.

Although not every pseudarthrosis is symptomatic, approximately 23% of revisions were performed for this pathology.[34] The treatment of symptomatic pseudarthrosis presents a challenge to the treating surgeon. As in general orthopaedic principles, atrophic pseudarthrosis denotes the need for bone graft and stabilization, whereas hypertrophic pseudarthrosis tends to respond to stabilization. An inadequate fusion technique or inadequate fixation may be treated with a revision procedure, with careful attention to detail and attempted interbody, intertransverse, facet, or central interlaminar fusion across all locations possible. If the description of the technique and the graft material were deemed adequate, then an alternative approach, such as an anterior/lateral interbody fusion in the case of a stand-alone posterior technique, may be necessary with or without a revision of the index procedure. Optimizing patient-related factors is essential before embarking on revision surgery for pseudarthrosis.

Adjacent Segment Pathology

Adjacent segment degeneration (ASDg) is defined as degeneration above or below a prior fusion seen on

Figure 2

Preoperative upright full scoliosis PA (**A**) and lateral (**B**) radiographs showing the coronal and sagittal imbalance after multiple surgeries. Note the failure of instrumentation at multiple levels, corresponding to pseudarthroses. The black arrow in panel A points to failure in one of the rods. **C**, Postoperative axial CT demonstrating the position of the posterior lumbar interbody fusion cage at L5-S1 and the transsacral screw positioned in the vertebral body of L5. Postoperative standing PA (**D**) and lateral (**E**) radiographs of the entire spine showing the restoration of normal coronal and sagittal balance through osteotomy and extension of fusion and instrumentation.

radiographs. The etiology of ASDg still is debated because distinguishing this entity from the natural history of the degenerative process remains controversial. The reported prevalence of ASDg following lumbar fusion surgery has ranged between 5% and 43%, whereas the prevalence of surgical interventions has ranged between 2% and 15%.[35]

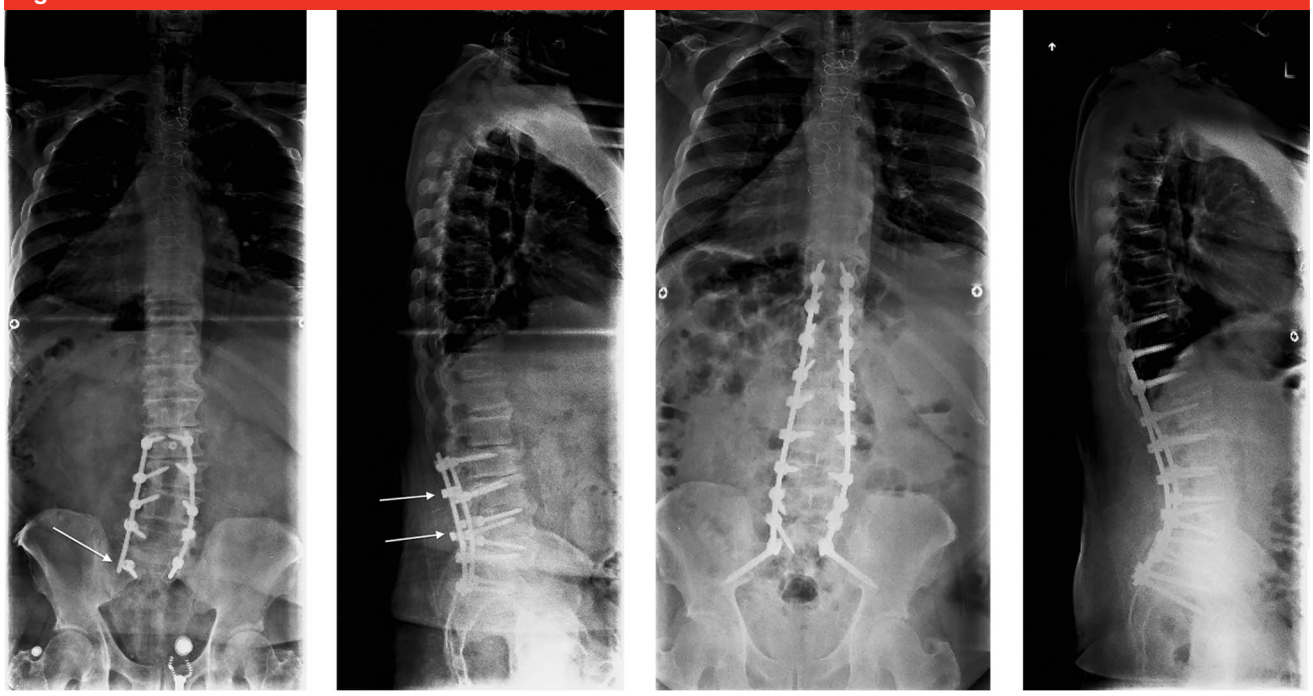
When ASDg becomes symptomatic, it is termed adjacent segment disease and may manifest as back pain or radicular pain or may be associated with degenerative instability patterns, such as spondylolisthesis, scoliosis, kyphosis, or retrolisthesis. Many cases can be treated nonsurgically as primary degenerative conditions. For patients in whom nonsurgical measures have failed, extension of the decompression or decompression with fusion may be necessary. In general, patients with adjacent segment stenosis associated with spondylolisthesis, retrolisthesis, or rotatory olisthesis, or patients who need a wide decompression, should be treated with extension of the arthrodesis. In most cases requiring surgery, it may be possible to extend the fusion up by just one or two levels. However, it is essential to confirm adequate spinal balance with a clinical assessment and full-length radiographs to avoid "topping off" syndrome, whereby the fusion becomes extended on several occasions. Addressing this problem, however, can be performed using a variety of approaches, such as revision posterior, direct anterior, or transpsoas lateral interbody approaches.

Postoperative Deformity

The loss of normal lumbar lordosis following fusion commonly is referred to as flatback syndrome, resulting in a positive sagittal imbalance. Common causes include hypolordotic lumbar fusion for degenerative spondylosis, pseudarthrosis leading to progression of deformity, and kyphosis at the thoracolumbar junction. One unique etiology of this condition is distraction instrumentation (eg, Harrington distraction rods) extending into the lumbosacral spine.[36] Patients with flatback deformity typically present with pain and an inability to stand upright. On physical examination, a decompensated positive sagittal imbalance can be observed. The following conditions also may be present: compensatory hypokyphosis of the thoracic spine, hyperlordosis of the cervical spine, and pelvic retroversion and knee flexion to compensate for the flattening of the lumbar spine, all in the setting of a reasonably compensated clinical sagittal balance.[37]

Full-length standing radiographs of the spine are necessary to quantify the degree of imbalance properly and to measure the radiographic pelvic parameters and their relationships. If the condition is symptomatic, correction of the flatback and restoration of normal lordosis may be required.[38] For mobile disks, multiple posterior spinal osteotomies (ie, Ponte osteotomies) can restore lordosis. If the spine is fused with a fixed deformity, a three-column pedicle subtraction osteotomy may be necessary. A more detailed approach to treating symptomatic

Figure 3



A B C D

Preoperative standing PA (**A**) and lateral (**B**) radiographs of the entire spine showing multilevel pseudarthroses and failure of instrumentation (arrows). Note the relative loss of normal lordosis or flatback deformity. Postoperative standing PA (**C**) and lateral (**D**) radiographs of the entire spine showing multilevel anterior interbody grafting and extension of instrumented fusion.

spinal deformities is beyond the scope of this article.

Nonspinal Etiology

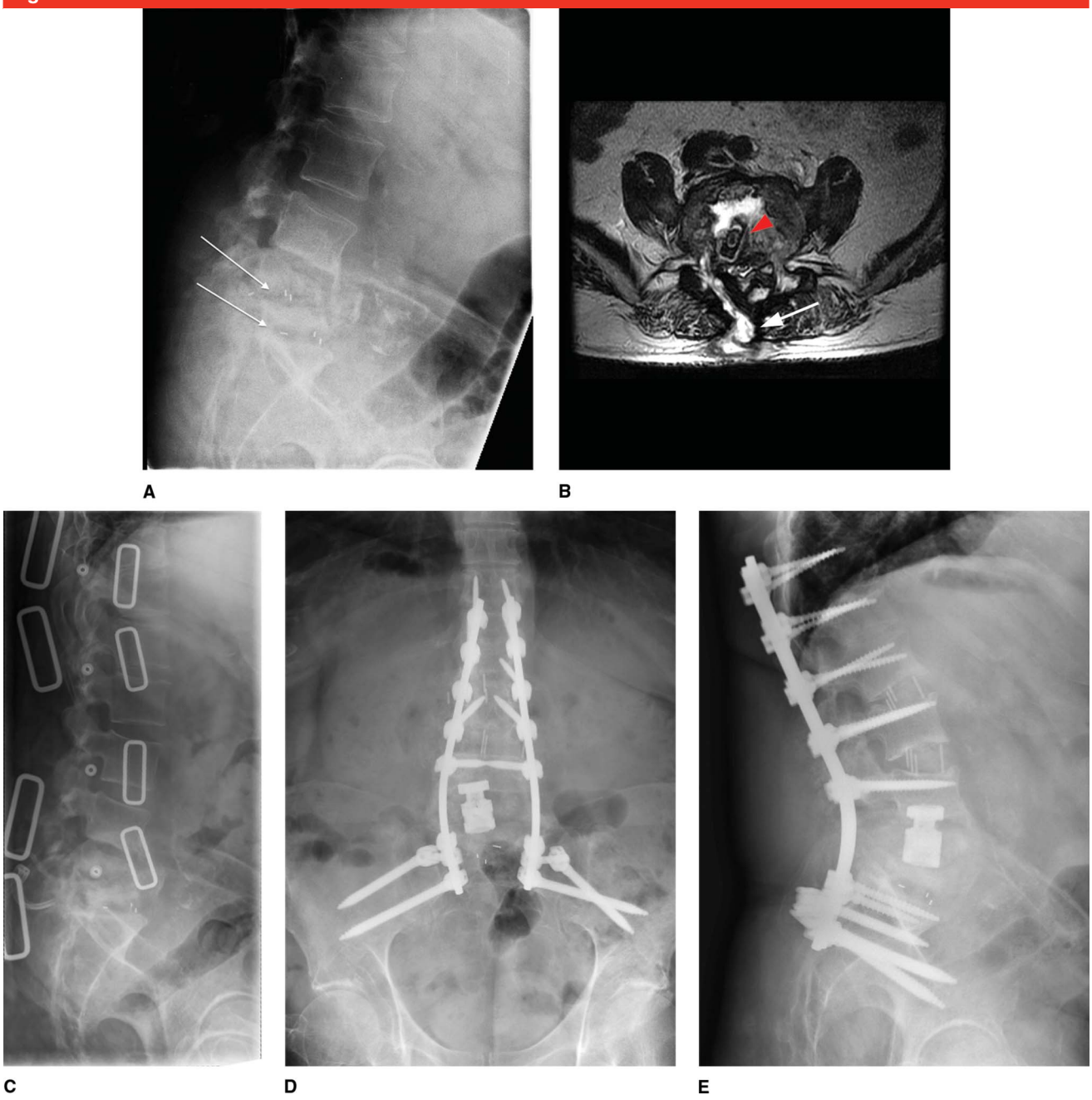
Back pain after spinal surgery without an identifiable cause poses a major challenge to the treating surgeon. Persistent pain after spinal surgery without a clear pathologic process may be a result of an incorrect initial diagnosis, with pain arising from a nonspinal etiology. In these patients, the initial clinical evaluation must be comprehensive. Back pain may arise from a disease of the adjacent organs or joints. Visceral etiologies may include malignancies, such as pancreatic cancer. Low back pain and lower-extremity pain can be mistaken for severe sacroiliac, hip, or knee arthritis; therefore, these joints must be assessed thoroughly. Joint injections can be helpful in the diagnosis and in providing therapeutic results. Peripheral nerve disorders, which typically are treated medically, also could present as recurrent or residual stenosis. Neurophysiologic testing, such as a nerve conduction velocity test and electromyography, may elicit the source of leg pain. Abdominal or pelvic conditions, such as kidney stones, pyelonephritis, pancreatitis, and aortic aneurysm symptoms, can manifest as referred pain to the back. Affective disorders (eg, depression, anxiety) can be associated with functional disability and poorer improvement after revision lumbar surgery.[39] Referral of these patients to psychiatry before surgical treatment should be contemplated. Likewise, preoperative opioid users tend to have worse patient-reported outcomes and therefore would benefit from psychological and opioid screening using a multidisciplinary approach.[40] Deconditioning also can mimic back and leg pain and typically responds to physical therapy. Thus, attention should be paid to the review of systems during an appropriate physical examination.

Case Histories

Case 1

A woman in her 70s presented with severe and worsening back and leg pain after multiple surgeries for adult scoliosis performed at outside institutions. After an extensive work-up that included laboratory studies, plain radiographs, and CT myelography, she was found to have multiple pseudarthroses (without evidence of infection) with sagittal and coronal imbalance following a

Figure 4



A, Standing lateral radiograph of the spine showing the destruction of the L4 and L5 vertebral bodies with intact interbody cages at L4-L5 and L5-S1 as demonstrated by cage markers (arrows). Note the kyphotic deformity with destruction of the vertebral bodies. **B,** Axial T1-weighted magnetic resonance image showing the sinus tract (red arrowhead) and the retention of the intervertebral cage (arrow). **C,** Standing lateral radiograph demonstrating the spine after device removal. Postoperative standing AP (**D**) and lateral (**E**) radiographs of the spine showing anterior column reconstruction with an expandable cage from L3-5, interbody fusions at L1-2 and L2-3, and posterior fusion and instrumentation from T11 to the pelvis.

prior partial pedicle subtraction osteotomy and presacral lumbosacral screw insertion (Figure 2, A and B). She underwent revision pedicle subtraction osteotomy at L3, posterior lumbar interbody fusion cages around the presacral lumbosacral screw at L5-S1 (Figure 2, C), transforaminal lumbar interbody

fusion (TLIF) at L2-3 for pseudarthrosis, and extension of fusion to T4 above the apex of the thoracic kyphosis (Figure 2, D and E).

Case 2

A man in his 70s presented with back and leg pain 5 years after an earlier L2-S1 posterior instrumented fusion performed at an outside institution. His work-up revealed multilevel pseudarthroses with failure of instrumentation, including screw fracture, rod dislodgement, and set cap backout (Figure 3, A and B). He underwent revision circumferential fusion using a lateral transpsoas approach from L1 to L5 because the instrumentation was not fixed rigidly. On the posterior approach, a TLIF at L5 to S1 was performed. Replacement and extension of the instrumentation up to T10 with pelvic fixation also was performed using the S2AI technique (Figure 3, C and D).

Case 3

A man in his 60s presented with back pain and a stooped posture. At an outside institution, the patient underwent an earlier L4-S1 fusion with TLIF cages and posterior instrumentation, which was complicated by early postoperative infection (Figure 4, A). The original surgeon removed the posterior instrumentation. On presentation, the patient was found to have persistent active infection, based on laboratory studies and contrast MRI, with a sinus tract arising from the retained L4-5 TLIF cage and a solidly fused L5-S1 level (Figure 4, B). He underwent removal of the L4-5 cage followed by 3 months of intravenous and oral antibiotics (Figure 4, C). After the course was completed and his infectious blood markers normalized, the patient underwent a staged revision surgery involving posterior transpedicular resection of L4 and part of L5 with insertion of an expandable cage through the posterior approach, posterior instrumentation from T11 to the pelvis, and transpsoas lateral interbody fusions from L1-3 (Figure 4, D and E).

Summary

Managing patients with recurrent or persistent pain following earlier spinal surgery remains a challenge for the spine surgeon. Diagnostic terms, such as "failed back surgery" and "postlaminectomy syndrome," fail to convey any meaningful information about the underlying problem or potential treatment options.

The differential diagnosis is informed by the earlier procedure and the current symptoms. Patient evaluation requires a thorough history and physical examination, a review of earlier records and imaging, and a thoughtful use of appropriate imaging and laboratory studies. The most frequent late-presenting conditions encountered by the general orthopaedic surgeon include infection, stenosis, fracture, instability/deformity, painful instrumentation, pseudarthrosis, or adjacent segment pathology.

Treatment is individualized for each patient based on the severity of the symptoms and the underlying pathology. Nonsurgical treatment may yield functional improvement in some patients. Surgical treatment is reserved for patients in whom nonsurgical treatment has failed and who possess structural pathology that can be corrected with well-defined surgical objectives. Only with a more systematic approach to the evaluation and treatment of these patients will orthopaedic surgeons be able to improve the quality of life and restore acceptable function in these patients.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 2 and 40 are level II studies. References 1, 3, 20, 21, 23, 31, 32, and 34 are level III studies. References 4-7, 10, 12, 14, 17-19, 22, 24, 25, 33, 35, 38, and 39 are level IV studies.

References printed in **bold type** are those published within the past 5 years.

1. **Rajaee SS, Kanim LE, Bae HW: National trends in revision spinal fusion in the USA: Patient characteristics and complications. *Bone Joint J* 2014;96-B (6):807-816.**
2. Koutsoumbelis S, Hughes AP, Girardi FP, et al: Risk factors for postoperative infection following posterior lumbar instrumented arthrodesis. *J Bone Joint Surg Am* 2011;93(17):1627-1633.
3. **Meredith DS, Kepler CK, Huang RC, Brause BD, Boachie-Adjei O: Postoperative infections of the lumbar spine: Presentation and management. *Int Orthop* 2012;36(2): 439-444.**
4. Clark CE, Shufflebarger HL: Late-developing infection in instrumented idiopathic scoliosis. *Spine (Phila Pa 1976)* 1999;24(18):1909-1912.
5. Rechtine GR, Bono PL, Cahill D, Bolesta MJ, Chrin AM: Postoperative wound infection after instrumentation of thoracic and lumbar fractures. *J Orthop Trauma* 2001;15(8):566-569.
6. Massie JB, Heller JG, Abitbol JJ, McPherson D, Garfin SR: Postoperative posterior spinal wound infections. *Clin Orthop Relat Res* 1992;284:99-108.
7. Heggeness MH, Esses SI, Errico T, Yuan HA: Late infection of spinal instrumentation by hematogenous seeding. *Spine (Phila Pa 1976)* 1993;18(4):492-496.
8. Weinstein MA, McCabe JP, Cammisa FP Jr: Postoperative spinal wound infection: A review of 2,391 consecutive index procedures. *J Spinal Disord* 2000;13(5): 422-426.
9. **Bas T, Bas P, Blasco A, Bas JL: Chronic infections of the spine. *Eur J Orthop Surg Traumatol* 2013;23(suppl 1):S35-S40.**
10. **Maruo K, Berven SH: Outcome and treatment of postoperative spine surgical site infections: Predictors of treatment success and failure. *J Orthop Sci* 2014;19 (3):398-404.**
11. Sheehan E, McKenna J, Mulhall KJ, Marks P, McCormack D: Adhesion of Staphylococcus to orthopaedic metals, an in vivo study. *J Orthop Res* 2004;22(1): 39-43.
12. McGuire RA, Eismont FJ: The fate of autogenous bone graft in surgically treated

pyogenic vertebral osteomyelitis. *J Spinal Disord* 1994;7(3):206-215.

13. **Khan NR, Thompson CJ, DeCuypere M, et al: A meta-analysis of spinal surgical site infection and vancomycin powder. *J Neurosurg Spine* 2014;21(6):974-983.**

14. Airaksinen O, Herno A, Turunen V, Saari T, Suomlainen O: Surgical outcome of 438 patients treated surgically for lumbar spinal stenosis. *Spine (Phila Pa 1976)* 1997; 22(19):2278-2282.

15. Marchetti PG, Bartolozzi P: Classification of spondylolisthesis as a guideline for treatment, in Bridwell K, DeWald R, eds: *The Textbook of Spinal Surgery*. Philadelphia, PA, Lippincott-Raven, 1997, pp 1211-1254.

16. Maurer SG, Wright KE, Bendo JA: Iatrogenic spondylolysis leading to contralateral pedicular stress fracture and unstable spondylolisthesis: A case report. *Spine (Phila Pa 1976)* 2000;25(7):895-898.

17. Suzuki K, Ishida Y, Ohmori K: Spondylolysis after posterior decompression of the lumbar spine: 35 patients followed for 3-9 years. *Acta Orthop Scand* 1993;64(1):17-21.

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

19. **Lau D, Clark AJ, Scheer JK, et al; SRS Adult Spinal Deformity Committee: 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.**

20. **Lewis SJ, Abbas H, Chua S, et al: Upper instrumented vertebral fractures in long lumbar fusions: What are the associated risk factors? *Spine (Phila Pa 1976)* 2012;37 (16):1407-1414.**

21. Hart RA, Prendergast MA, Roberts WG, Nesbit GM, Barnwell SL: Proximal junctional acute collapse cranial to multi-level lumbar fusion: A cost analysis of prophylactic vertebral augmentation. *Spine J* 2008;8(6):875-881.

22. **Hassanzadeh H, Gupta S, Jain A, El Dafrawy MH, Skolasky RL, Kebaish KM: Type of anchor at the proximal fusion level has a significant effect on the incidence of proximal junctional kyphosis and outcome in adults after long posterior spinal fusion. *Spine Deform* 2013;1(4):299-305.**

23. **Ohtori S, Inoue G, Orita S, et al: Comparison of teriparatide and bisphosphonate treatment to reduce pedicle screw loosening after lumbar spinal fusion surgery in postmenopausal women with osteoporosis from a bone quality perspective. *Spine (Phila Pa 1976)* 2013;38 (8):E487-E492.**

24. Alanay A, Vyas R, Shamie AN, Sciocia T, Randolph G, Wang JC: Safety and efficacy of implant removal for patients with recurrent back pain after a failed degenerative lumbar spine surgery. *J Spinal Disord Tech* 2007;20(4):271-277.

25. Martin CT, Witham TF, Kebaish KM: Sacropelvic fixation: Two case reports of a new percutaneous technique. *Spine (Phila Pa 1976)* 2011;36(9):E618-E621.

26. Chang TL, Sponseller PD, Kebaish KM, Fishman EK: Low profile pelvic fixation: Anatomic parameters for sacral alar-iliac fixation versus traditional iliac fixation. *Spine (Phila Pa 1976)* 2009;34(5):436-440.

27. Raizman NM, O'Brien JR, Poehling-Monaghan KL, Yu WD: Pseudarthrosis of the spine. *J Am Acad Orthop Surg* 2009;17 (8):494-503.

28. Bono CM, Lee CK: Critical analysis of trends in fusion for degenerative disc disease over the past 20 years: Influence of technique on fusion rate and clinical outcome. *Spine (Phila Pa 1976)* 2004;29 (4):455-463, discussion Z5.

29. Arnold PM, Klemp JA: Assessment of malunion in spinal fusion. *Neurosurg Q* 2005;15(4):239-247.

30. **Kaiser MG, Groff MW, Watters WC III, et al: Guideline update for the performance of fusion procedures for degenerative disease of the lumbar spine: Part 16. Bone graft extenders and substitutes as an adjunct for lumbar fusion. *J Neurosurg Spine* 2014;21(1):106-132.**

31. **Kim HJ, Buchowski JM, Zebala LP, Dickson DD, Koester L, Bridwell KH: RhBMP-2 is superior to iliac crest bone graft for long fusions to the sacrum in adult spinal deformity: 4- to 14-year follow-up. *Spine (Phila Pa 1976)* 2013;38(14): 1209-1215.**

32. **Kelly MP, Savage JW, Bentzen SM, Hsu WK, Ellison SA, Anderson PA: Cancer risk from bone morphogenetic protein exposure in spinal arthrodesis. *J Bone Joint Surg Am* 2014;96(17):1417-1422.**

33. Brodsky AE, Kovalsky ES, Khalil MA: Correlation of radiologic assessment of lumbar spine fusions with surgical exploration. *Spine (Phila Pa 1976)* 1991;16 (6 suppl):S261-S265.

34. Martin BI, Mirza SK, Comstock BA, Gray DT, Kreuter W, Deyo RA: Reoperation rates following lumbar spine surgery and the influence of spinal fusion procedures. *Spine (Phila Pa 1976)* 2007;32 (3):382-387.

35. Ghiselli G, Wang JC, Bhatia NN, Hsu WK, Dawson EG: Adjacent segment degeneration in the lumbar spine. *J Bone Joint Surg Am* 2004;86-A(7):1497-1503.

36. Potter BK, Lenke LG, Kuklo TR: Prevention and management of iatrogenic flatback deformity. *J Bone Joint Surg Am* 2004;86-A(8):1793-1808.

37. **Ames CP, Smith JS, Scheer JK, et al: Impact of spinopelvic alignment on decision making in deformity surgery in adults: A review. *J Neurosurg Spine* 2012;16(6): 547-564.**

38. Lagrone MO, Bradford DS, Moe JH, Lonstein JE, Winter RB, Ogilvie JW: Treatment of symptomatic flatback after spinal fusion. *J Bone Joint Surg Am* 1988; 70(4):569-580.

39. **Adogwa O, Verla T, Thompson P, et al: Affective disorders influence clinical outcomes after revision lumbar surgery in elderly patients with symptomatic adjacent-segment disease, recurrent stenosis, or pseudarthrosis: Clinical article. *J Neurosurg Spine* 2014;21(2):153-159.**

40. **Lee D, Armaghani S, Archer KR, et al: Preoperative opioid use as a predictor of adverse postoperative self-reported outcomes in patients undergoing spine surgery. *J Bone Joint Surg Am* 2014;96 (11):e89.**