Semin Spine Surg 31 (2019) 44–52

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Evaluation and workup in revision spine surgery

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ABSTRACT

The incidence of spine surgeries performed annually continues to rise and despite advances in instrumentation and surgical techniques, reoperation rates are still high. Common reasons for revision surgery include an incorrect preoperative diagnosis, technical error, complications of procedure or implants, or a poor surgical candidate for the index procedure. Identifying the source of symptoms can present a diagnostic challenge and requires a careful and strategic approach. Given that outcomes lessen with each subsequent spine surgery, spine surgeons must be cautious and meticulous when considering a revision spine surgery. This article will review a general diagnostic approach when evaluating a patient with persistent symptoms, along with a review of the more common indications for revision spine surgery.

1. Introduction

Despite advances in surgical technique and fusion technology, the rate of revision spine surgery has increased.[1–3] In 2009, the rate of revision spine fusion procedures had risen to 7.2 per 100,000 adults in the US.[4] Reoperation rates following spine surgery vary by level and type of procedure. Lumbar 5-year overall reoperation rate (fusion and non-fusion) has been reported at 15% with only slightly higher rate in fusion surgery.[5] Reoperation rates after cervical spine surgery have been reported up to 9% for single-level anterior cervical discectomy and fusion (ACDF), up to 10% for multilevel ACDF, 5% at 31.7 months for cervical foraminotomy and as high as 27% at 41 months after laminectomy and fusion.[6–10] In an analysis of trends of revision spine surgery in the US, complication or failure of surgical implant was the most common indication for revision spine surgery, accounting for over 50% of cervical, thoracic, and lumbar revision surgeries.[4] Other common diagnosis included degeneration or displacement of intervertebral disc, stenosis, kyphosis, and spondylosis.

Given the high prevalence of failed spine surgery and revision spine surgery, it is inevitable that spine practitioners will encounter patients presenting for revision spine surgery. The lack of descriptive or clinically meaningful terminology in diagnosis such as “failed back surgery syndrome” highlight the diagnostic challenge in the postoperative symptomatic spine patient.[11] Thus, it is crucial that a careful, systematic evaluation and diagnostic workup be performed in all patients presenting for revision spine surgery. Establishing a detailed timeline from the index surgery to onset or recurrence of symptoms is critical in developing a differential diagnosis. A patient’s symptoms should be categorized as axial back/neck pain or radicular arm/leg pain. These details should then be correlated with diagnostic laboratory and imaging evaluation to ultimately guide an effective treatment plan.

The first section of this article will review the patient evaluation including key portions of the history, exam, and diagnostic tests in developing a differential diagnosis and treatment plan when evaluating a symptomatic patient with prior spine surgery. The second section will review the incidence and diagnostic workup for the most common indications for revision surgery.

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https://doi.org/10.1053/j.semss.2019.03.002
1040-7383/

2. Patient evaluation and developing a differential diagnosis

2.1. Patient history

A detailed patient history is critical to establish an appropriate diagnosis and treatment plan for symptomatic patients with a prior spine surgery. Patients should be asked to recall what symptoms they were having prior to the index procedure, who performed the procedure, how much relief the procedure provided, how long that relief was experienced, and if there was an inciting event that caused the pain to recur. Supplementing this history with preoperative notes and imaging from the index procedure can be helpful. Unfortunately, patients do not always recall preoperative symptoms, often discounting the extremity pain for which they underwent surgery.[12] It is helpful to consider a differential based on the patient's response to their index procedure. Patients can often be placed into 1 of 3 categories: 1) no clinical response after surgery; 2) a brief period of improvement but become symptomatic by 1 year; or 3) symptom free for an extended period (>1 year) before becoming symptomatic. By combining the presenting symptoms and response to index procedure, a working differential diagnosis can be developed.

2.1.1. No symptom improvement after index procedure

If an indicated surgery was performed, the patient should experience at least partial relief of their initial symptoms following their initial procedure. Failure to achieve any pain-free interval is likely related to an unindicated surgery (including an incorrect preoperative diagnosis or surgery directed at asymptomatic imaging findings), technically flawed procedure (e.g. unrecognized pathology, hardware malposition, and wrong-level surgery), or negative patient characteristics (high preoperative opioid burden, psychiatric distress, poorly controlled diabetes to name a few). A patient's failed outcome can be a combination of any of these factors. Identifying the specific reasons and risk factors that contributed to the poor outcome is essential to preventing a repeat failure.

Evaluation should begin with a detailed review of imaging obtained (and attention to imaging not obtained) prior to surgery and postoperative imaging provides insight into whether all areas of correlative pathology were addressed, if the intended level was decompressed, and if a diagnosis was potentially missed. Failure to recognize far lateral disc herniations or foraminal/recess stenosis in the setting of central stenosis can also lead to inadequate decompressions and persistent pain following spine surgery.[13] The incidence of concurrent (tandem) cervical and lumbar stenosis range from less than 1% up to 20% of patients with stenosis.[14] Thus, more proximal stenosis should also be considered if upper motor neuron signs exist and or imaging appears to demonstrate that a technically well done surgery was performed at the index level with no clear explanation of persistent symptoms. The incidence of wrong level spine surgery is low relative to other spine related complications, but still responsible for nearly half of the reported wrong site surgeries and occur at least once in approximately 50% of spine surgeons at some point in their career.[15,16] Unaddressed instability can be an additional source of worsening pain after the index procedure. Without assessing dynamic X-rays and for fluid in the facet joints on axial imaging, incidence rates up to 28% have been reported for missed degenerative spondylolisthesis.[17]

Patients presenting with worsening or different pain since surgery should be evaluated for implant malposition, whereby iatrogenic neural injury or impingement occurs. A CT scan can better assess for malpositioned pedicle screws causing nerve root irritation (Fig. 1). The reported incidence of malpositioned pedicle screws is widely variable.[18,19] However, it seems that the incidence of symptomatic pedicle screw breach is low, as one review reported only 2 of 45 malpositioned pedicle screws were symptomatic causing radiculopathy.[20]

Surgery to address axial spine pain, in the absence of instability, has a higher likelihood of not responding to the intervention. Preoperative expectations certainly affect how patients perceive their response to surgery. Finally, even if indicated pathology was addressed and the procedure performed technically well, certain patient characteristics can lead to a poor response immediately following surgery. The characteristics (modifiable and not) that seem to affect immediate postoperative outcomes include a high preoperative opioid burden, poorly controlled diabetes, psychiatric disorders such as anxiety or depression, and workers' compensation status.[21–26] Assessing a patient's psychosocial history is just as crucial as assessing spine pathology and symptoms and these characteristics should be carefully screened for and optimized before considering revision surgery.

2.1.2. Brief period of improvement, symptomatic by 1 year

The differential for patients that initially respond but become symptomatic by 1 year broadens substantially. Potential diagnoses include recurrent disc herniation, instrumentation failure and or proximal junctional kyphosis, surgical site infection, and pseudarthrosis if a fusion surgery was performed (discussed further below).[13] The evaluation is similar to the index procedure, including a detailed documentation of the patients symptoms and exam findings, along with imaging and laboratory diagnostic workup.

2.1.3. Improvement beyond 1 year before becoming symptomatic

Patients that are over a year out from surgery prior to experiencing recurrence of symptoms can include diagnosis already discussed but is the minimum time frame needed for adjacent-level degeneration (ALD), which can present a complex diagnostic and treatment challenge. Differentiating adjacent level degeneration (radiographic findings) from adjacent level disease (symptomatic adjacent disease) is important, as radiographic findings do not necessarily correlate with clinically relevant adjacent level disease.[27]

2.2. Presenting symptoms

A detailed discussion of the patient's symptoms is essential in developing an effective treatment plan. Differentiating axial back and neck pain from radicular arm or leg pain is critical in identifying the pain generators. Failure to carefully review the patient's symptoms risks treating asymptomatic imaging findings and another poor outcome. Patients presenting with continuing or new radicular arm or leg pain may be suffering from either inadequate initial decompression or recurrent pathology such as a repeat disc herniation. Axial back or neck pain presents a less clear picture and could be related to physical deconditioning after surgery or the surgery itself. Axial pain may also be related to either facet arthropathy, discogenic pain, or even instability in those who present on a delayed basis.[13] Other causes of pain that mimic spinal pathology must also be considered based on a patient's medical history including diabetic neuropathies, vascular claudication, systemic inflammatory conditions, and shoulder or hip osteoarthritis (OA). There are also reports of complex regional pain syndrome following spine surgery, which must also be considered.[28]

2.3. *Physical exam*

In addition to the physical exam that should be performed during an initial evaluation, examination of patients with recurrent symptoms should pay special attention to seek out sources of pain unrelated to their spine pathology. Concurrent hip OA and degenerative lumbar spinal stenosis (DLSS), otherwise known as hip-spine syndrome, can present a challenging clinical picture. Many symptoms of hip OA and DLSS overlap including groin pain or pain radiating beyond the knee.[29] On exam, reproduction of symptoms with weight-bearing or hip manipulation is more consistent with hip OA. Groin pain elicited by hip internal rotation has been shown to be sensitive and specific for hip pathology.[30] Similarly, considerable overlap exists in symptoms of shoulder pathology and cervical spine disease. A careful shoulder exam in conjunction with adjunctive tests including selective corticosteroid injections will assist in establishing a diagnosis.[31] When exam findings are inconsistent with anatomy, Waddell signs should be elicited, as these are known to be poor predictors of outcome regardless of pathology.[32] Finally, the surgical wound should always be evaluated for drainage, dehiscence, swelling, or erythema that may be suggestive for a post-operative infection. However, lack of these findings does not rule out infection to any degree.

2.4. *Laboratory evaluation*

Laboratory studies may be necessary especially in those with concern for a postoperative spinal wound infection. Initial infection workup includes white blood cell count (WBC) with differential, C-reactive protein (CRP), and erythrocyte sedimentation rate. Following spine surgery, CRP typically returns to normal within 14 days, while ESR can take 6 weeks or more.[33] Thus, CRP has largely replaced ESR due to its superior sensitivity in assessing for infection and monitoring treatment response.[34] While WBC in general has low sensitivity for detecting postoperative spine infection, lymphopenia in the immediate post-op period (day 4) can represent an increased susceptibility to infection.[35] In the setting of pseudarthrosis, a more comprehensive metabolic laboratory workup should be performed (see below).

2.5. *Imaging evaluation*

Imaging studies typically should begin with plain radiographs of the prior surgical site as well as site of any axial back or neck pain. Flexion-extension radiographs may provide valuable evidence in assessment of instability and to assess a prior fusion mass.[36] Implants should be carefully scrutinized for malpositioning, broken or loosening, and subsidence. Hardware loosening may be indicative of pseudarthrosis or hardware infection. The presence of instability as noted by haloing about the screws or movement between vertebrae (dynamic

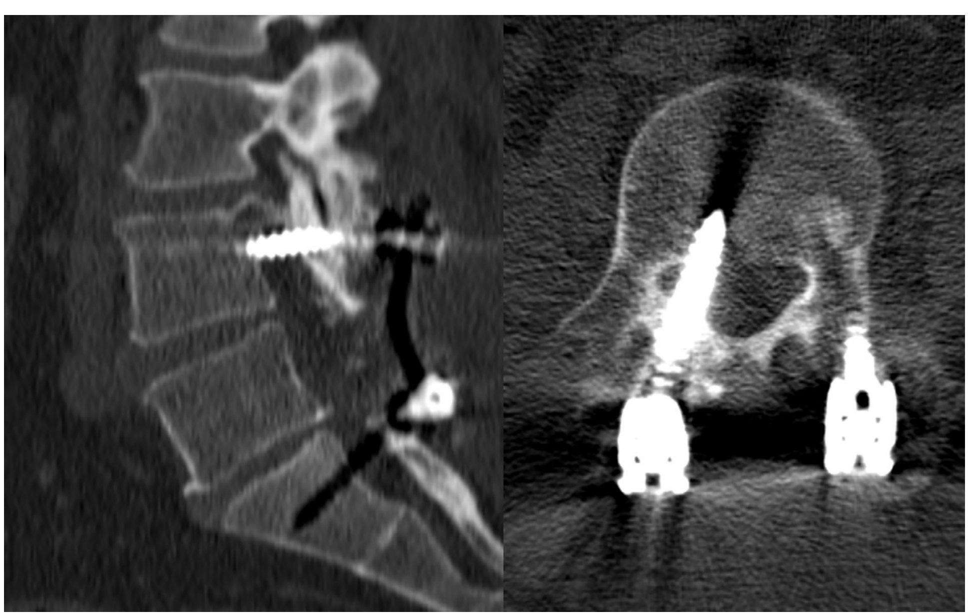

Fig. 1 – Malpositioned screw causing radiculopathy. Patient had worsening right L4 radiculopathy following an L4-S1 fusion with no pain-free interval. CT scan was obtained and showed malpositioned right L4 pedicle screw through the lateral aspect of the central canal.

pseudarthrosis) predicts that revision surgery will more likely provide benefit to the patient. A static pseudarthrosis, whereby a CT does not show solid bridging bone, yet the hardware is well engaged and no movement exists likely has scar tissue preventing movement and is less likely to benefit from revision surgery. Computed tomography (CT) is considered the gold standard for assessing fusion status and can more clearly demonstrate a bony nonunion.[37] Assessment of the neural elements may be indicated if there is concern for compressive pathology. Magnetic resonance imaging (MRI) with and without gadolinium enhancement is the most sensitive test in this setting given its ability to distinguish new pathology from prior epidural scar.[38] Furthermore, MRI with and without contrast is considered the most useful study in the evaluation for possible postoperative spinal infection. Other diagnostic modalities including electromyograms (EMGs) and nerve conduction velocity (NCV) studies may be useful to evaluate for extraspinal neural compression and exclude other etiologies such as peripheral neuropathy. While selective nerve root or facet injections can be both therapeutic as well as diagnostic, there is concern that patients who have undergone prior surgery may have soft tissue fibrosis and septations that can limit the effectiveness of such treatments.[39]

3. Common diagnoses in revision spine surgery

3.1. *Inadequate decompression or recurrent disc herniation*

Recurrent leg pain requiring revision spine surgery is most commonly due to recurrent disc herniation or residual stenosis (inadequate decompression). The incidence rate for recurrent lumbar disc herniation has been estimated from 5% to 15%.[40] Rates of revision surgery for residual cervical stenosis have been reported to range from 6.6% to 9.2%[41,42]. Patients with recurrent disc herniations will likely report an initial improvement after their index surgery followed by recurrence of pain or new pain. In contrast, patients presenting with residual stenosis or inadequate decompression are unlikely to achieve any meaningful improvement in their symptoms after their index surgery. In either scenario, symptoms will likely be similar those that led to their initial surgery. MRI with and without gadolinium enhancement is the study of choice when evaluating for recurrent disc herniations or residual neural compression in the setting of previous spine surgery (Fig. 2).[43] Epidural scar will enhance with contrast, while recurrent disc herniations and hypertrophic ligamentum flavum are non-enhancing. CT myelogram can be obtained if the patient is unable to obtain an adequate MRI. Due to scar tissue and septations within the soft tissues after a spine surgery, diagnostic nerve root injections may be less reliable in the postoperative patient.

Treatment recommendations should be similar in the setting of primary pathology typically with a trial of nonsurgical therapy followed by surgical management if the patient's symptoms are refractory to non-operative modalities. In the setting of revision surgery where a repeat or more extensive decompression is needed, a fusion procedure may be considered if not already performed at the index procedure. Some studies have shown that performing spinal fusion at the time of first reoperation can improve patient outcomes.[44] However, other recent studies have shown repeat discectomy versus discectomy and fusion for the treatment of recurrent lumbar disc herniation has demonstrated similar short-term clinical outcomes with shorter operative times and length of stay and significantly lower hospital charges for the repeat discectomy group.[45]

3.2. *Adjacent-level degeneration & disease*

Adjacent-level degeneration refers to the radiographic changes while adjacent-level disease (ALD) refers to symptomatic changes to the adjacent level following spine surgery. Spine surgery results in anatomic, biomechanical, and physiologic changes to the operative site and adjacent segments and the influence a spine fusion procedure has on the normal age-related

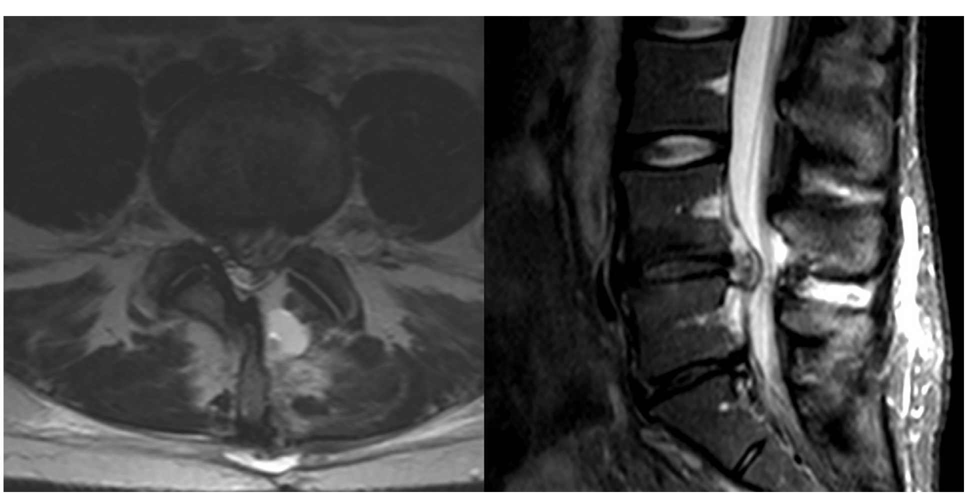

Fig. 2 – Recurrent disc herniation. Patient had undergone left L4 hemilaminectomy and microdiscectomy with some initial improvement in symptoms. However, the patient soon presented with recurrence of symptoms and MRI was obtained showing recurrent paracentral left L4-5 disc protrusion.

degenerative process is unclear.[46] Adjacent-level degeneration covers many changes including adjacent disc degeneration or herniation, stenosis, listhesis, scoliosis and kyphosis, proximal junctional failure (PJK), sagittal imbalance, instability, facet degeneration, and spondylolysis. Incidence rates of ALD depend on the surgical site, approach, number of levels, and procedure performed. For example, the annual incidence of adjacent-level disease after a lumbar fusion has been reported at 1.7% for single-level fusion, 3.6% after a 2-level fusion, and 5% after 3- or 4-level fusions.[47] A review of non-fusion patients at 10-year follow-up found a reoperation rate of 11% of patients who had initially undergone laminectomy. Adding a fusion to laminectomy for the treatment of spinal stenosis appears to increase the 10-year reoperation rate.[48] ALD after ACDF ranges from 0.8% to 2.9%.[49,50] Patients with ALD will typically report short-term positive outcomes, with progressively worsening symptoms over a year after surgery. Many risk factors have been reported including length and type of fusion, ending the fusion at L5, excessive distraction after posterior lumbar interbody fusion, laminectomy adjacent to a fusion, pelvic incidence/lumbar lordosis mismatch, sagittal alignment, and iatrogenic muscle damage to name a few. Rates of ALD and difficulty in treating ALD have prompted new techniques such as total-disc replacement (TDR) and minimally invasive surgery (MIS) in attempts to preserve biomechanics and physiology. However, while radiographic adjacent level degeneration appears to be lessened, reoperation rates between fusion and TDR and between open versus MIS appear similar.[51,52]

Initial workup should include dynamic flexion-extension x-rays and standing full length spine x-rays to assess sagittal balance. As mentioned previously, MRI with and without gadolinium is the study of choice for evaluating adjacent neurologic compression and CT scan will best identify adjacent facet arthropathy, spondylolysis and pedicle stress fractures. Nonoperative management can be attempted but often revision and extension of the fusion is necessary. To minimize future recurrent ALD, revision surgeries for ALD should be performed by surgeons who are experts in revision techniques.

3.3. *Complications of prior surgery*

3.3.1. *Pseudarthrosis*

Pseudarthrosis remains one of the most common complications of fusion spine surgery, and one of the most common indications for revision spine surgery.[53–55] Given that fusion surgeries have been on the rise over the last several decades, pseudarthrosis should always considered when evaluating a patient with new or ongoing symptoms and a history of prior fusion surgery. Patients presenting with pseudarthrosis can have a variable clinical presentation with recurrent or persistent neck, back, arm or leg pain. A thorough history may reveal patient or surgical risk factors for pseudarthrosis. A detailed understanding of the index procedure including graft selection is important in understanding the patient's risk of pseudarthrosis. A systematic review of the literature concluded that iliac crest autograft appears to be the gold standard for fusion, while an interbody cage is the gold standard when strictly evaluating complication rates.[56] Other patient and surgical risk factors for pseudarthrosis include smoking, increasing body mass index, increasing ODI/NDI scores, younger age, vitamin D deficiency, history of non-instrumented fusion, non-circumferential thoracolumbar fusion and long segment fusion in spinal deformity.[1,57–62] While the gold standard for diagnosing pseudarthrosis remains surgical exploration, noninvasive methods can help assess the fusion status. Evaluation begins with dynamic x-rays of the affected area and basic laboratory work-up. Infection and adjacent segment disease should always be ruled out. For diagnosing anterior cervical pseudarthrosis, the method reported by *Riew et al.*, has demonstrated a sensitivity and specificity similar to CT scan. By their method, flexion and extension radiographs are magnified to 150% and interspinous motion is measured, with a cutoff of ≥1mm for interspinous motion indicative of a pseudarthrosis, with at least ≥4mm of superjacent interspinous motion to constitute adequate dynamic motion (Fig. 3).[63] When evaluating the lumbar spine or cervical spine without adequate dynamic x-rays, CT remains the preferred method.[36] However, these two modalities should be

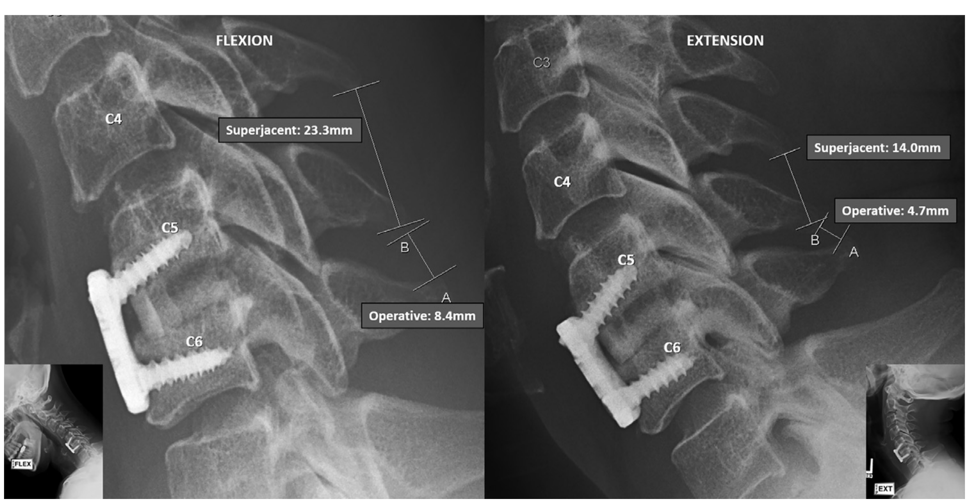

Fig. 3 – Cervical pseudarthrosis on dynamic x-rays as described by *Riew et al.* Flexion and extension cervical radiographs are magnified to 150% on the same monitor, and the interspinous motion of the superjacent level (C4-5) was measured and found to be 9.3 mm (23.3 mm − 14 mm), indicating adequate dynamic x-rays had been obtained (i.e. >4 mm of motion). The interspinous motion at the operative level (C5-6) was found to be greater than the 1 mm cutoff at 3.7 mm (8.4 mm − 4.7 mm), indicating excessive motion at the fusion site, consistent with a pseudarthrosis.

used in conjunction to differentiate a dynamic from a static pseudarthrosis.

Once a diagnosis of pseudarthrosis is suspected, a careful investigation into the patient's risk factors for pseudarthrosis should be performed and optimized prior to revision surgery. Vitamin D insufficiency (<30 ng/mL) and deficiency (<20 ng/mL) rates in all elective spine patients has been reported up to 57% and 30%, respectively.[58,64] Additionally, Vitamin D deficiency has been identified as an independent predictor of pseudarthrosis.[57] Patients should be evaluated for osteoporosis, as recent studies have shown teriparatide to promote bone formation in osteoporotic spine fusion and osteoporotic fracture patients.[65–67] Management of comorbidities such as diabetes mellitus, obesity, and tobacco use should be optimized. For these reasons, a bone metabolic evaluation by a specialist should be considered in patients preparing for revision surgery for pseudarthrosis.

3.3.2. *Instrumentation & surgical construct failure*

Instrumentation or construct failure covers a wide range of complications including screw bending, breakage, loosening, or contributing to a new neurologic complication. Rate of instrumentation or surgical construct failure have been reported from 0.5% up to 20% depending on the technique, location in spine, surgical approach, graft choice, length of construct and type of instrumentation.[68–71] Persistent leg or arm pain in the same dermatome as the surgical site may be due to a malpositioned screw causing nerve root irritation. New or persistent neck or back pain may be due to painful or broken instrumentation. Timing can be variable, as an analysis of instrumentation failure after adult spinal deformity surgery showed a peak at 12–24 months and again at ≥24 months.[72]

Patients with implant failure may be asymptomatic or present with severe pain and progressive neurological deficit, and with variable timing. Failed instrumentation is often detected on routine x-rays or for initial workup of symptoms. In symptomatic patients, other sources should be carefully investigated. Infection, pseudarthrosis, inadequate decompression, nerve root injury, physical deconditioning, incorrect diagnosis at the index operation, and adjacent segment disease should all be ruled out before attributing symptoms purely to implant failure. Reviewing the implants used in the index operation and understanding the biomechanics of the implant is important to understanding the reason for failure and for selecting appropriate revision implants. A mismatch in the modulus of elasticity between the cage and host bone will inevitably lead to sage subsidence.

A review of patients treated with anterior cervical locking plate found an implant-related complication rate of 10.7%. Complications included oblique plating, screw malposition into or excessively close to the disc space, screw or plate loosening or breaking, esophageal perforations and overly long plates causing adjacent level degeneration and ultimately revision surgery.[73] All of these complications are prone to pseudarthrosis. While rare, esophageal perforation is a well-known complication of anterior cervical plating and potentially fatal. If the anterior cervical plate or screws become dislodged, loosened, or symptomatic (e.g. dysphagia), the implants should be promptly removed.[69]

3.3.3. *Infection*

Post-operative spine infections most commonly present with increased pain after a pain-free interval following their index operation, and usually within 1 year. Estimates on the incidence of late post-operative spine infections, those presenting after 12 months, are generally less than 1–2%.[74–76] Reports of infection after anterior cervical surgery are especially low (0%–0.39%), and thus any postoperative anterior cervical spine patient presenting with new pain, fevers, wound drainage, or dysphagia with elevated inflammatory markers should have an esophageal perforation ruled out by barium esophagogram.[77] Risk factors for postoperative spine infection include patient risk factors (diabetes mellitus, smoking, malnutrition, obesity, older age, immunomodulators used in systemic arthritis's, chronic steroid exposure), and surgical risk factors (fusion surgery, posterior procedures, longer surgical time and higher blood loss).[74] The most common causative organism of postoperative spinal infection is *Staphylococcus aureaus*.[76] Physical exam can be normal but peri-incisional erythema, tenderness, induration or drainage all certainly suggest infection. Diagnostic workup includes laboratory and imaging. C-reactive protein is the post sensitive indicator of postoperative spine infection, whereas white blood cell count is typically unreliable.[34] Plain x-rays may show signs of disc space narrowing in setting of discitis or instrumentation loosening, but advanced imaging with MRI with gadolinium contrast is the most useful modality when evaluating for infection. Findings on MRI suggestive of infection include rim enhancing fluid collections, epidural collections, bony destruction, and progressive marrow signal changes. Still, the gold standard for diagnosing surgical infection is tissue culture. A CT-guided biopsy can be considered before proceeding with revision surgery. F-fluoro-d-deoxyglucose positron emission tomography (PET) scans have shown to be a useful adjunct in postoperative infections when MRI is not an option, however other nuclear medicine studies have been less helpful.[78]

When considering a revision surgery, the presentation and diagnostic workup in patients with latent infection such as from *P. acnes* may be consistent with the diagnosis of pseudarthrosis or construct failure. A 10-year review of infections after instrumented fusion surgery found 17% of CRP values, 45% of ESR, and 95% of WBC values to be normal, and found *P. acnes* to be the causative organism in just over half of all cases.[79] Thus, it is always important to consider latent infection and if intraoperative cultures are obtained, they should be incubated for a minimum 13 days.[80]

4. Conclusions

Outcomes following revision spine surgery are less favorable than primary surgery. Careful patient selection and accurate diagnosis for primary surgery is the best method for preventing revision surgery. When patients with a prior spine surgery present with new or recurrent symptoms, it is helpful to develop a differential based on their symptom response following their index surgery. Patients who achieved no relief after their index surgery likely had an unindicated surgery (including incorrect preoperative diagnosis), technically flawed procedure, or were a poor surgical candidate. Reasons for recurrent symptoms after initial relief include recurrent disc herniation, pseudarthrosis, surgical construct or implant failure, postoperative infection, and adjacent level disease. A strategic evaluation to establish a diagnosis consistent with the patient's history, symptoms, laboratory and imaging findings, along with careful consideration of patient factors, is critical to avoid a repeat failed spine surgery.

5. Disclosures

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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