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Surgical Complications of Spinal Deformity Surgery

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The purpose of this article is to review the major complications associated with spinal deformity. Important complications observed in spinal deformity surgery include pseudarthrosis, proximal junctional kyphosis (PJK), sagittal decompensation, deep wound infection, and neurovascular injury. The literature pertaining to the incidence and risk factors associated with each complication is discussed. Complications are an important and significant factor in deformity surgery and need to be considered by physicians and patients in making choices regarding operative and nonoperative care. Surgeon knowledge and awareness of these complications and risks can lead to improved management of complications and a better understanding of expectations and informed decision making for patients.

Adult spinal deformity: definition and overview

"Adult spinal deformity" encompasses abnormal alignment of the spine involving coronal, sagittal, or biplane deformity (eg, scoliosis, kyphosis, flatback syndrome) that involves several spinal segments [1]. Although there are many studies looking at complications in the spinal deformity literature, this broad definition underscores the difficulty of comparing complication rates from different studies. Adult deformity studies vary by the type of deformity (coronal, sagittal, or biplanar), the number of levels fused, fusion sites (lumbosacral junction versus thoracolumbar junction), a broad age range (18–85 years), patient comorbidities, the number of prior surgeries, and the patient's bone quality. There are multiple etiologies of spinal deformity, and complication rates vary significantly depending on the underlying cause of deformity. Degenerative scoliosis, defined as a coronal deformity of greater than 10°, is a common cause of lumbar deformity in the adult patient. Prospective series describing the incidence of degenerative scoliosis in the adult population have shown that this deformity can be identified in 33% to 68% of the adult population older than 50 years of age [2,3]. Other causes of spinal deformity include failed primary operations for idiopathic adolescent scoliosis or for degenerative conditions that lead to spinal deformity from adjacent segment disease, sagittal plane decompensation, or pseudarthrosis. After an extensive review of more than 3000 patients with spinal deformity, Guigui and Blamoutier [4] concluded that "the heterogeneous nature of the population and the methodology used to identify these factors only allowed detection of trends." Although the analysis of outcomes and complications in this heterogeneous patient population is limited, trends in complications can be identified, alerting the surgeon to potential pitfalls and lending insight into management of patients with spinal deformity.

With an aging population, surgical intervention for spinal deformity is increasing, and the complications associated with operative and nonoperative care of patients with spinal deformity are significant and important. Complications can be described as major or minor. Major complications include problems that lead to a revision surgery, such as pseudarthrosis, loss of sagittal or coronal balance, PJK, deep wound infections, or complications leading to permanent sequelae (eg, neurologic or vascular injury). Minor complications include problems that lead to a prolonged hospital stay, such as a urinary tract infection (UTI), deep vein thrombosis (DVT), superficial wound infections; minor respiratory problems, and minor operations (eg, removal of prominent

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hardware) [1,5]. Medical complications of spinal deformity surgery have been reported, and an excellent review by Baron and Albert [6] has been published recently. This review focuses on major complications associated with spinal deformity.

Overall complication rates for spinal deformity surgery have been reported in a few large series. Rates of reported complications have been extremely high, ranging from 81% historically to 21% more recently [4,7–11]. The most common major complications reported by most studies include pseudarthrosis, deep wound infection, PJK, and loss of sagittal balance. In 1981, Swank and colleagues [12] described complications in 222 patients after surgery for adult scoliosis. Complications developed in 53% of patients, with the overall mortality rate being 1.4%. Common complications included pseudarthrosis, loss of lumbar lordosis, and infection. In 1982, Floman and colleagues [10] reported on a series of 73 patients who underwent combined anterior and posterior procedures for correction of spinal deformity. The overall complication rate was 44%. In 1983, Kostuik and Hall [11] described an overall complication rate of 78% for adult patients with deformity being fused to the sacrum. Balderston and colleagues [7] reported on outcomes after fusion to the sacrum. In this series, only 28% of patients achieved a good result, with pseudarthrosis and loss of sagittal balance being the most common complications. In 1991, Boachie-Adjei and Bradford [13] reported an 81% complication rate in adults undergoing combined anterior and posterior surgery for spinal deformity. The retrospective series by Spivak and colleagues [14] of 93 patients with combined one- or two-stage anterior-posterior surgeries for adult scoliosis described an overall complication rate of 53%. Although the complication rate for spinal deformity surgery in early reports was high, a more recent prospective series of 3311 patients followed for more than 1 year described an overall complication rate of 21% [4].

Surgery for spinal deformity often includes revision surgery to address the spinal deformity. A comparison of the complication rates for revision surgery versus primary surgery for spinal deformity suggests that the rates are comparable. In 1979, Cummine and colleagues [9] reported on a series of 59 adult patients who underwent revision for spinal deformity. The complication rate was reported to be high at 71%, with the most common complications being pseudarthrosis, infection, and loss of lumbar lordosis. The mortality rate was 3.4%, similar to those of earlier studies. In 1997, Farcy and Schwab [15] reported on 48 patients who underwent correction for flatback and kyphotic deformity. Their overall complication rate was 25%, with a pseudarthrosis rate of 10%. Pateder and colleagues [16] looked at 132 patients undergoing revision surgery for failed deformity surgery. The average number of operations was 3.7 in their population. Their overall complication rate was 33%; however, the pseudarthrosis rate was 10%. The wound complication rate was 7%, and the incidence of neurologic complications was 6%. Lapp and colleagues [1] reported a pseudarthrosis rate of 22% in their primary group compared with 4% in their revision group. Sagittal plane decompensation was comparable between the two groups. Infection rates in the revision setting have not been shown to be higher in revision cases than in the primary cases according to Fang and colleagues [17].

Specific complications

Pseudarthrosis

Pseudarthrosis is perhaps the single most common major complication reported in the spinal deformity literature, and this complication has been associated with lower functional outcomes [1,16,18–25]. Pseudarthrosis is most commonly identified at the lumbosacral junction or at the thoracolumbar junction, both of which are transitional areas [16]. Risk factors include patient age older than 55 years, thoracolumbar kyphosis greater than 20°, and fusions longer than 12 segments [16,19]. Spinal fixation has a clear impact on the complication of pseudarthrosis. The types of instrumentation and technology to instrument the spine are changing over time, and a comparison between pseudarthrosis rates in earlier studies with those of more current studies suggests a decrease in the incidence of the problem. In 1983, Kostuik and Hall [11] reported a pseudarthrosis rate of 22% (10 of 45 patients) for skeletally mature patients with scoliosis after attempted L5-S1 fusions. Lonstein and colleagues [26] reported on the use of pedicle screws in 222 procedures. A pseudarthrosis rate was found in 46 patients (20.7%). Several studies have indicated that the use of Luque-Galveston fixation at the L5-S1 junction is not ideal. In 1991, Boachie-Adjei and colleagues [8] demonstrated a pseudarthrosis rate of 41% using circumferential fusion with

Luque-Galveston rods. Emami and colleagues [27] also described high pseudarthrosis rates at the L5-S1 junction (despite circumferential fusion) in their groups with Luque-Galveston (36%) pelvic fixation and bilateral iliac screws (14%) in contrast to an 8.5% rate in their group with bicortical sacral screws.

Current techniques that involve fusing across the lumbosacral junction using a combination of bicortical sacral screws, augmented with iliac bolts and an anterior lumbar interbody fusion (ALIF) at L4-5, L5-S1 has been shown to have excellent results [21,23]. Islam and colleagues [28] examined the fusion rate of patients whose fusions were extended to the sacrum using ALIF with sacral screws, iliac screws, or a combination of the two. The pseudarthrosis rate using sacral screws only was 53%, it was 42% with iliac screws alone, and it was 21% when both were used. Using current techniques, in 2001, Lapp and colleagues [1] reported an incidence of pseudarthrosis of 11% in primary deformity cases, although the levels of pseudarthrosis were not reported. It seems that pseudarthrosis at the L5-S1 level can be limited when strict adherence to circumferential fusion techniques is augmented with iliac fixation [18]. For example, Tsuchiya and colleagues [24] reported on 5-year results of 33 patients treated with bilateral iliac screws and bilateral sacral screw fixation. The study demonstrated a pseudarthrosis rate of 6% (2 of 33 patients). Of the 2 patients who developed pseudarthrosis, 1 did not have anterior support at L5-S1 and was a smoker. The other had unilateral iliac fixation.

The pseudarthrosis rate at L5-S1 in fusions extending across the L5-S1 junction is similar to the rate in patients fused short of the sacrum, although the rate of pseudarthrosis at other levels may be increased in fusions that cross the L5-S1 junction [19]. In 2001, Eck and colleagues [29] reported on pseudarthrosis rates in long constructs ending at L4, L5, or S1. No patients fused to L4 developed pseudarthrosis, whereas 3 (14%) of 21 patients fused to L5 and 2 (13%) of 15 patients fused to S1 developed pseudarthrosis. Rinella and colleagues [25] described a group of 56 patients fused with long constructs above the sacrum. The study had a follow-up of more than 5 years and noted a pseudarthrosis rate of 9%. Six of 56 patients had pseudarthroses in the thoracic region between T7 and T12. Kim and colleagues [18] have reported on pseudarthrosis rates in long constructs. The incidence in their series was 24% (34 patients) in a study population of 144 patients. Seventeen patients (11.8%) had pseudarthrosis between T10 and L2, and 15 (10.4%) had pseudarthrosis at L5-S1, with 24 patients being reported to have nonunion at more than one level. Edwards and colleagues [42], however, described a significant difference between fusions ending at L5 and those ending at S1. The group reported a pseudarthrosis rate of only 4% for fusions stopping at L5 compared with 43% (5 of 12 patients) for those ending at S1 despite using circumferential fusion at the L4-L5 and L5-S1 levels with augmentation by iliac screws. The location of the pseudarthrosis in the S1 group occurred above the L5-S1 junction in 4 of 5 patients, however, with only one of five pseudarthroses occurring at the L5-S1 junction. Protecting S1 screws with iliac fixation and anterior column support is an important technique for avoiding pseudarthrosis in long fusions to the sacrum. The development of recombinant proteins and osteobiologics for use in the spine is likely to contribute further to reducing the incidence of pseudarthrosis in spinal deformity surgery.

Proximal junctional kyphosis/positive sagittal balance

PJK can occur at any level in the spine. It is most commonly seen at the thoracolumbar junction after long fusions to the distal lumbar spine. Rates for postoperative PJK in patients with spinal deformity range from 26% to 42% in the literature. The impact on function and health-related quality-of-life health outcomes seems to be variable [30–32]. Risk factors contributing to the likelihood of PJK are not well understood. Risk factors cited include greater than 5° to 10° of kyphosis at the adjacent level cephalad to the upper instrumented vertebra (UIV) and osteoporosis [30,32–34]. In a retrospective review by DeWald and Stanley [30] of 38 patients older than 65 years of age, 10 (26%) developed PJK. In 3 patients, compression fractures at one or two adjacent levels above the construct contributed to kyphosis, and augmentation of the most cephalad vertebrae did not always prevent PJK from occurring. Instrumentation type and upper instrumented level have also been associated with PJK [31]. Glattes and colleagues [31] described a 26% incidence of PJK in their population of 81 patients undergoing long fusions for spinal deformity. In the 51 patients instrumented to the upper thoracic spine, constructs stopped at T2 or T3 had a higher proportion of PJK than constructs stopped at T4. In all but nine constructs, hooks were used. Interestingly, in the 9 patients in whom pedicle screw constructs were used, 4 developed PJK, a disproportionately high rate, compared with the patients in whom constructs with only proximal hooks were used. Because of the reduced numbers in the study, no statistical significance was found. PJK was not associated with postoperative positive sagittal balance or adjacent level kyphosis. Nevertheless, Yang and Chen [32] identified adjacent level kyphosis as a risk factor, as did Lee and colleagues [34]. Kim and colleagues [33] reported on long-term follow-up of patients with adolescent idiopathic scoliosis after fusion with all hooks or hybrid constructs using distal pedicle screws and proximal hooks. Preoperative PJK occurred in 10% of patients with a preoperative sagittal Cobb angle (T5-T12) of less than 10°, in 28% of patients with a preoperative Cobb angle between 10° and 40°, and in 44% of patients with a preoperative Cobb angle greater than 40°, suggesting kyphosis as a contributing factor to PJK in this population. Furthermore, they noted that use of "hybrid" constructs was a risk factor compared with use of "all hook" constructs. The authors commented that the difference may be attributable to the difference in rigidity of the constructs, with the hybrid constructs being more rigid. The authors did not determine that the UIV or number of hooks used proximally was a risk factor.

Loss of sagittal balance

Loss of sagittal balance (sagittal decompensation) is also well described in the literature and is a major complication that may lead to revision surgery. In 1988, LaGrone and colleagues [35] reported on a cohort of 55 patients treated with distraction instrumentation with "flatback syndrome," 95% of whom could not stand erect. Although distraction instrumentation is not commonly used anymore, it underscores the importance of neutral sagittal balance and the need for recognition of lumbar lordosis in reconstruction of the spine. Sagittal decompensation is defined as having the C7 plumb line 5 cm or more anterior to the posterior aspect of the S1 superior end plate. The effect of proper sagittal balance is paramount, because its lack has been correlated to reduced outcome scores [36,37]. Causes of sagittal decompensation include osteoporotic compression fractures within or adjacent to a deformity construct, ankylosing spondylitis, post-traumatic kyphosis, distraction instrumentation, subjacent or adjacent segment disease, and poor correction based on the patient's preexisting global sagittal balance [38–41]. Risk factors include age older than 55 years, number of medical comorbidities, osteoporosis, and pre- and postoperative radiographic parameters, with a preoperative positive sagittal balance greater than 5 cm being cited as a significant risk factor for suboptimal postoperative sagittal balance [29,41–44]. In fusions short of the sacrum, subjacent level disc degeneration is common, although sagittal decompensation is not as frequent. Brown and colleagues [41] reported on 16 patients, with short-term follow-up of patients with scoliosis treated with long constructs stopping at L5. Six (38%) of 16 patients showed evidence of disc degeneration at the L5-S1 level, and 7 (44%) showed radiographic evidence of sagittal decompensation, although 3 (19%) required revision. The short-term follow-up suggests an underestimation of revision rates. Eck and colleagues [29] reported on 44 patients fused short of the sacrum and described 6 (16%) patients who went on to display subsequent degeneration below the fusion level. Although lordosis of the lumbar spine was increased along the construct, a loss of lordosis between the last instrumented vertebra and the sacrum occurred (6° in this group). Sagittal balance was more positive in four of six cases, with 4 patients becoming symptomatic. Likewise, Edwards and colleagues [42] showed that in 27 patients fused to L5, there was radiographic evidence of advanced L5-S1 disc degeneration associated with inferior sagittal balance. There was loss of 9° of lordosis across the L5-S1 level in the patients fused to L5, the overall sagittal balance was inferior in the L5 group, and the maintenance of sagittal balance was worse in the L5 group compared with the group fused to the sacrum. The revision rate for the L5 group at 2 years with subjacent disc degeneration was 22%. Kim and colleagues [45] matched a cohort of patients fused to L5 or S1 from the thoracolumbar spine and determined the differences between those with optimal sagittal balance (<3 cm) compared with those with suboptimal sagittal balance (>3 cm). The authors examined the combination of thoracic kyphosis, lumbar lordosis, and pelvic incidence as risk factors. The total angle (thoracic kyphosis + pelvic incidence − lumbar lordosis) was described, and the authors concluded that a combined angle less than 45° was the cutoff for good sagittal balance. Because the pelvic incidence remains fixed, surgical planning and intervention therefore include altering the lumbar lordosis and thoracic kyphosis as required.

Ideally, a greater lumbar lordosis angle should be created compared with the thoracic kyphosis. Although radiographic alignment is important, Lee and colleagues [43] described the phenomenon that despite adequate radiographic correction, 20% of their patients continued to walk with a stoop. They postulated that weak extensor muscles were the cause, which supports the notion that medical comorbidities play a role in the overall balance of the patient.

Treatment of sagittal decompensation usually requires revision surgery that involves using a Smith-Peterson osteotomy or pedicle subtraction osteotomy (PSO). Farcy and Schwab [15] found that the success rate in patients with flatback syndrome or sagittal decompensation was 27% without realignment surgery. The risks and outcomes of these procedures have been well described, but it is important to highlight the role and complications of the techniques [35,46–49]. In the series of LaGrone and colleagues [35], 60% of patients had one or more complications and 47% continued to lean forward. Bridwell and colleagues [50] looked at 33 consecutive patients using PSO in the lumbar spine. Despite overall improvement in the Oswestry Index scores, there were seven pseudarthroses identified, with 1 being at the site of the PSO. There were five transient neurologic deficits identified, which resolved after central canal enlargement, and two cases of PJK [48]. Berven and colleagues [51] described one case of PJK and four cases of transient paresis in their study of PSOs in 13 patients with fixed sagittal balance. The authors also reported a high patient satisfaction rate after surgery.

Deep wound infection

Deep wound infection is another major complication reported in the literature common to deformity surgery. Acute or late infections require operative management, although protocols for managing acute and late infections vary depending on the severity of the infection, involvement of the surrounding bone, and requirements of the implants. For example, in an acute infection, it is unreasonable to remove the implants in an unstable spine even though it may optimize management of the infection. Late infection has also been associated with pseudarthrosis [52,53]. Infection rates differ between adolescent and adult deformity, indicating that host-related factors play a role. Lonstein and colleagues [53] reported that the incidence of infection in 80 patients older than 20 years of age after Harrington instrumentation for scoliosis was 20% compared with adolescent patients, with an incidence of 7.5%. Other studies report infection rates for adolescent deformity surgery between 1.76% and 4.7% [54–56]. In a review of 3230 cases, Kuo and colleagues [56] reported an overall incidence of infection in instrumented spine cases of 2.2%. Forty-three percent of infections were identified within 2 weeks, 40% between 2 and 4 weeks, and 16% after 4 weeks. Several other series report late infections, although the incidence of late infection of the spine is lower [57]. *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Propionibacter* sp, and *Enterococcus* sp are the most common cultured bacteria [55,58,59]. In comparison to infection rates in adolescent deformity surgery, Weinstein and colleagues [57] reported on 2394 adult spine cases over a 9-year period and identified 46 (2%) patients with deep wound infection, whereas Fang and colleagues [17] reported on a series of 1629 procedures in 1095 patients and found that postoperative infection developed in 48 patients (4.4%).

At the author's institution, most acute posterior spinal wound infections are treated by aggressive irrigation and debridement, with retention of implants, primary closure, and intravenous antibiotics given for 6 weeks. Late or chronic infections are usually treated with aggressive debridement and removal of implants if the spine appears to be well fused. Ideally, if pseudarthrosis is identified and the spine is stable, the patient is staged with removal of instrumentation and debridement and is refused with instrumentation once the infection is cleared. One-stage revisions have been completed with success, however, especially in the unstable spine.

Neurovascular injury

Neurologic injury is another important major complication associated with spinal deformity surgery. Paralysis from deformity surgery is often paramount in the mind of the patient and the surgeon. Paralysis has been associated with rapid correction, curve type, and neural compromise from vascular ischemia [60]. Swank and colleagues [12] reported on 222 adult patients with scoliosis treated with surgery. One patient developed paraplegia. Winter and colleagues [61] described 1197 consecutive cases from 1967 to 1991 with anterior approaches ranging from T1-L3. No paralyses were identified. They suggested that it is safe to ligate the segmental vessels provided that vessel ligation is unilateral, it is done on the convexity of the curve, it is done in the midportion of the vertebral body, and hypotensive anesthesia is avoided. Bridwell and colleagues [62], however, described neurologic deficits in a retrospective study of 1090 patients who underwent corrective spinal deformity surgery. Four major neurologic deficits were identified, most likely from a vascular causes. The patients in this series who developed the deficits all had harvesting of the unilateral convex segmental vessels but with intraoperative controlled hypotensive anesthesia. Interestingly somatosensory evoked potential (SSEP) monitoring did not pick up the deficit during surgery in 1 patient with vascular compromise. Monitoring is protective, however, because Meyer and colleagues [63] compared monitored with unmonitored patients and found a significant difference between the two groups. In those monitored, the incidence of a new neurologic deficit was 0.7% compared with 6.9% for those unmonitored, an almost 10-fold increase. In an evaluation of more than 3300 patients, Guigui and Blamoutier [4] reported a general incidence of neurologic complications of 1.8%, with increased risk being associated with the initial angle of deformation and double thoracic and lumbar curves. Hales and colleagues [64] reported on late neurologic complications after Harrington rod instrumentation to the L5 level. Late complications were caused by migration of the caudal hook into the canal, with occurrences developing as late as 32 months after surgery.

Neurologic compromise can occur after the use of pedicle screws. Irritation of nerve roots from pedicle screw placement ranges from 0.15% to 1% [26,65,66]. In the series by Lonstein and colleagues [26], three of nine patients with nerve root irritation had permanent neurologic weakness despite removal of the screws. Neural complications may be underreported in large series, because rates seem higher in prospective trials with close follow-up and many patients present with preoperative deficits that may not be recorded or recognized as changed. With the advent and use of better neuromonitoring and pedicle screw stimulation, the incidence is likely to decline.

Rajaraman and colleagues [67] noted that in their series of 60 patients, the anterior approach for ALIF at the lumbosacral junction was associated with sympathetic dysfunction in 10% of patients and sexual dysfunction occurred in 5%. Flynn and Price [68] reported an incidence of 0.42% in a survey of 20 surgeons contributing 4500 cases, however. Vascular compromise during ALIF varies between 1.4% and 20% [69], with the most common site being the L4-5 disc space. The most common vessel injured is the left common iliac vein, followed by the iliolumbar vein, although segmental vessels were more commonly injured in laparoscopic cases. Arterial injuries occur less frequently, with the left iliac artery being most commonly injured [69]. Although rare, these injuries are life threatening and require the assistance of well-qualified vascular surgeons.

Summary

Spinal column reconstruction for the management of spinal deformity is technically challenging and has been associated with high complication rates. Major complications include pseudarthrosis, PJK, sagittal decompensation, deep wound infection, and neurovascular injury. The technology and instrumentation used to treat spinal deformity continue to develop, and the complication rates seem to be decreasing. Although only trends can be identified because of the disparity between diagnoses, patient characteristics, levels, and the three-dimensional complexity of deformity problems, complications are to be expected when performing this surgery. Awareness of the occurrence of complications can lead to better information and guidance of the surgeon's expectations as well as the patient's.

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