Complications Following Surgical Intervention for Adult Lumbar Scoliosis

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Introduction

The surgical treatment of adult lumbar scoliosis is similar to any other surgery in that complications occur, and they can be challenging for both patient and surgeon. But what defines a complication? Is a dural tear that is primarily repaired and has no further consequence really a complication? Recent literature on this topic has divided surgical complications into categories and further subdivided these into major and minor complications. This chapter continues this organizational scheme and discusses both the types of complications and their potential impact.

Defining Complications

Rampersaud and colleagues [26] defined a complication as "a state, directly or indirectly resulting from a surgical operation that altered the anticipated recovery of the patient." Categorizing and grading complications is common in databases and outcome studies; however, standardized reporting has not been established. In the table below, complications are categorized and graded into major and minor derived from a consensus agreement of study group adult deformity surgeons (Table 19.1) [10, 40]. The grading reflects a combination of the impact on duration of stay and recovery, amount of additional treatment required, and whether there is prolonged or permanent morbidity. Any complications requiring reoperation were classified as major. Regardless of the category or grading, each complication may affect outcome measures in unique ways.

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Incidence of Complications

Understanding the incidence of the various complications allows providers to make informed treatment decisions and provide appropriate counseling to patients. Numerous studies have reported the incidence of complications, but most are limited by retrospective data collection, limited cohorts, and limited focus on complications. Several groups have provided comprehensive meta-analyses to simplify the challenge of navigating the wide spectrum of data. However, retrospective studies have inherent bias.

The Scoliosis Research Society (SRS) has one of the largest databases of adult scoliosis patients. Importantly, the SRS database is a voluntary self-reporting database of complications by member surgeons and likely represents a lower-end estimate of the rates for most reported complications. In a review of 4,980 cases of surgically treated adult scoliosis submitted from 2004 to 2007, Sansur et al. found 10.5 % (521 of 4980) of adult patients undergoing scoliosis correction

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Table 19.1 Complications checklist for patients undergoing ASD surgery [10, 40]

Complications	Major	Minor
Infection	Deep	Superficial
	Pneumonia	Urinary tract infection
	Sepsis	*Clostridium difficile*
Implant	Hook dislodgement	Cross-link dislodgement
	Interbody fracture	Interbody subsidence
	Interbody migration	Painful implants
	Rod fracture	Prominence
	Rod dislodgement	Screw malposition
	Screw fracture	Screw-bone interface loosening
		Set screw dislodgement
Neurological	Bowel/bladder deficit	Delirium
	Brachial plexus injury	Neuropathy or sensory deficit
	Cerebrovascular accident/stroke	Pain (radiculopathy)
	Nerve root injury with weakness	Peripheral nerve palsy
	Retrograde ejaculation	
	Spinal cord injury with complete deficit	
	Spinal cord injury with incomplete deficit	
	Visual deficit/blindness	
Cardiopulmonary	Acute respiratory distress syndrome	Arrhythmia
	Cardiac arrest	Coagulopathy
	Congestive heart failure	Pleural effusion
	Deep vein thrombosis (DVT)	Pneumothorax
	Myocardial infarction	
	Pulmonary embolism	
	Reintubation	
	Respiratory arrest	
Gastrointestinal	Bleed requiring surgery	Bleed not requiring surgery
	Cholecystitis requiring surgery	Cholecystitis not requiring surgery
	Liver failure	Ileus
	Obstruction	Pancreatitis not requiring surgery
	Pancreatitis requiring surgery	
	Perforation	
	Superior mesenteric artery syndrome	
Radiographic	Distal/proximal junctional kyphosis requiring surgery	Distal/proximal junctional kyphosis not requiring surgery
	Pseudarthrosis	Sagittal imbalance
		Coronal imbalance
		Adjacent segment degeneration
		Curve decompensation
		Heterotopic ossification
		Adjacent segment degeneration
Renal	Acute renal failure requiring dialysis	Acute renal failure requiring medical intervention
Wound problems	Dehiscence requiring surgery	Hematoma/seroma not requiring surgery
	Hematoma/seroma with neurological deficit	Hemia
	Hematoma/seroma, no neurological deficit requiring surgery	Dehiscence not requiring surgery
	Incisional hernia	

Table 19.1 (continued)

Complications	Major	Minor
Operative	EBL>4 L	Dural tear
	Retained sponge/instrument	Fixation failure (hook/screw)
	Unintended extension of fusion	Implant failure
	Vascular injury	Pedicle fracture
	Visceral injury	Posterior element fracture
	Wrong surgical level	Vertebral body fracture
Vascular	Vascular injury	Coagulopathy
		Thrombophlebitis

surgery experienced at least one major perioperative complication and reported an overall mortality rate of 0.3 % [27]. The most common complications reported were durotomy (2.9 %), superficial or deep wound infection (2.4 %), implant complication (1.6 %), acute or delayed neurological deficits (1.5 %), epidural or wound hematoma (0.6 %), and deep vein thrombosis/pulmonary embolism (0.4 %) [27].

Sciubba et al. [30] conducted a comprehensive review of adult spinal deformity literature published since 2000 and extracted 11,692 patients from 93 publications (81 retrospective, 12 prospective). Not all patients in these studies were diagnosed with scoliosis as the deformities included adult degenerative, idiopathic, neuromuscular, congenital, traumatic, and infection-related (e.g., tuberculosis), ankylosing spondylitis, osteoporotic, and iatrogenic. The patient population averaged 53.3 years old with 2.1 L blood loss. Follow-up ranged from as low as 6 weeks with an average of 3.5 years. On average, 34.2 % of patients experienced a perioperative complication (18.5 % major and 15.7 % minor). Long-term complications occurred in 20.5 % of patients [30]. The overall complication rate depended on the type of osteotomy with the highest rate in three-column osteotomy (66 %), followed by "non-three-column osteotomy" (45 %), and with the highest subtype of three-column osteotomy being vertebral column resection (35 %). The most common perioperative complications included any infection (3.2 %), neurological deficit (3.1 %), need for further surgery (3.0 %), any respiratory complication (2.1 %), instrumentation/graft failure (1.3 %), and excessive bleeding (1.2 %). Dural tears occurred in 3 % of cases and transient neurological deficits in 1.5 % (Table 19.2). The most common long-term complications included pseudarthrosis (7.6 %), instrumentation/graft failure (3.3 %), proximal junction kyphosis (PJK) (2.9 %), adjacent segment degeneration (2.7 %), and symptomatic instrumentation (2.0 %) (Table 19.2). The aggregate instrumentation related and radiographic defined failure was 20.5% [30].

These rates of complications are likely underestimated due to the study variations, inconsistent length of follow-up, and not including complications from any subsequent reoperation. Smith and colleagues reported substantially higher complication rates as the result of a rigorous prospective study of 291 adult spinal deformity patients from 11 centers with a minimum of 2-year follow-up using standardized data collection with on-site coordinators [34]. Inclusion criteria included a minimum degree of deformity, and ultimately the group averaged 11.1 surgical levels, 7.1 h operative time, and 1.9 L of blood loss, and 64 % received an osteotomy. 82 (28.2 %) patients required one or more reoperations. 69.8 % of patients experienced at least one complication. 52.2 % of patients experienced at least one perioperative complication (125 major and 145 minor, mean 0.93 complications per patient). 42.6 % of patients experienced at least one complication after 6 weeks post-op (137 major, 62 minor, mean 0.68 complications per patient). 82 (28.2 %) patients required one or more reoperations, and resulting complications from that revision surgery were also included in the data [34].

Table 19.2 The incidence of major perioperative complications, minor perioperative complications and long-term complications following adult spinal deformity surgery

Major perioperative complication	*n* (%)
All major complications	1,379 (18.5)
Neurological deficit (not transient, not full recovery, resolved with reoperation, or classified as "major")	322 (3.1)
Unspecified requiring surgery	148 (3.0)
Wound infection requiring debridement and/or reoperation (especially deep)	232 (2.4)
Instrumentation/graft failure requiring revision (breakage, dislodgement, or resulting in inadequate correction)	62 (1.3)
Excessive bleeding	122 (1.2)
Unspecified pulmonary	43 (0.9)
Pulmonary embolism or thrombosis of major vessel	71 (0.7)
Respiratory distress syndrome/respiratory failure	28 (0.6)
Pneumonia/lung infection	27 (0.6)
Vascular injury (intraoperative)	22 (0.5)
Death	44 (0.4)
Epidural hematoma	39 (0.4)
Wound hematoma or seroma	38 (0.4)
Pleural effusion or pneumothorax (requiring intervention)	15 (0.3)
Reintubation	15 (0.3)
Stroke	15 (0.3)
Vertebral compression fracture	12 (0.2)
Sepsis	23 (0.2)
Myocardial infarction/cardiac arrest	22 (0.2)
Misplaced screw possibly causing nerve-related pain (requiring reoperation)	10 (0.2)
Congestive heart failure or unspecified cardiac	9 (0.2)
Compartment syndrome ± shock (abdominal or extremity)	7 (0.1)
Cardiorespiratory (non-pleural effusion)/systemic	6 (0.1)
Visual acuity change	12 (0.1)
Pedicle or laminar fracture (intraoperative)	4 (0.1)
Wound dehiscence requiring surgery	4 (0.1)
Fistula	3 (0.1)
Gastrointestinal complication (bleeding, ischemia, or other)	3 (0.1)
Line-related infection	3 (0.1)
Post-thoracotomy syndrome or other pain-related issues	3 (0.1)
Breakdown of L5–S1 disc (perioperative not long term)	2 (0.0)
Cerebral edema	2 (0.0)
Incision abdominal hernia (reoperation)	2 (0.0)
Painful rib remnant requiring excision	2 (0.0)
Renal failure	2 (0.0)
Ischemia in extremities	1 (0.0)
Massive fluid overload	1 (0.0)
Multiple-organ failure	1 (0.0)
Pancreatitis	1 (0.0)
Retroperitoneal hematoma	1 (0.0)

Minor perioperative complications [30]	*n* (%)
Minor complications	1,215 (15.7)
Unspecified or other	302 (3.1)
Dural tear	292 (3.0)
Ileus/gastrointestinal complication	101 (2.1)
Transient neurological deficit (foot drop, brachial plexopathy, peroneal nerve palsy, radiculopathy, cauda equina, partial spinal cord injury, etc.)	148 (1.5)
Wound infection (medical/interventional treatment) or superficial	99 (1.0)
Deep vein thrombosis	66 (0.7)
Urinary tract infection	32 (0.7)
Delirium	28 (0.6)
Cerebrospinal fluid leak	20 (0.4)
Arrhythmia or tachycardia	15 (0.3)
Unspecified or miscellaneous infection (e.g., yeast)	15 (0.3)
Pleural effusion	12 (0.3)
Pneumothorax	11 (0.2)
Pulmonary congestion	10 (0.2)
Hemothorax	7 (0.2)
Hypotension	7 (0.2)
Other intraoperations	7 (0.2)
Instrumentation failure (managed conservatively)	6 (0.1)
Unspecified pulmonary (resolved via simple measures)	6 (0.1)
Wound healing complications (nonsurgical)	6 (0.1)

Table 19.2 (continued)

Minor perioperative complications [30]	*n* (%)
Other iatrogenic damages	4 (0.1)
Pedicle infraction (intra)	4 (0.1)
Subluxation or translation at surgical site (intraoperative)	3 (0.1)
Fever of unknown origin	2 (0.0)
Hematoma, seroma, or bursa (no surgery)	2 (0.0)
Miscellaneous cutaneous complications	2 (0.0)
Retained drain	2 (0.0)
Reversible coagulopathy	2 (0.0)
Exacerbation of carpal tunnel requiring release	1 (0.0)
Revision (intraoperative)	1 (0.0)
Symptomatic gallstones	1 (0.0)
Thrombophlebitis	1 (0.0)

Long-term complications	*n* (%)
All long-term complications	1,021 (20.5)
Pseudarthrosis	337 (7.6)
Instrumentation/graft failure (breakage, dislodgement, screw loosening, or resulting in sagittal/coronal decompensation)	295 (3.3)
Proximal junctional kyphosis, especially requiring extension	119 (2.9)
Adjacent segment degeneration	105 (2.7)
Symptomatic screws/skin impingement/prominent hardware/painful graft possibly requiring removal	80 (2.0)
Vertebral compression fracture	33 (0.8)
Late deep infection	18 (0.5)
Neurological deficit	8 (0.2)
Superficial wound infection or other wounds	7 (0.2)
Other fractures (e.g., sacral, pelvic)	5 (0.1)
Iliac stress fracture or sacroiliac joint degeneration	3 (0.1)
Unspecified revision	3 (0.1)
Disc herniation	3 (0.1)
Deep vein thrombosis	2 (0.1)
Death	1 (0.0)
Hearing loss	1 (0.0)
Pneumonia	1 (0.0)

Adapted from Sciubba et al. [30]

Analyzing Complications

Multiple methods of assessment for spine surgery complications result in highly inconsistent incidence data [9]. With the rapid development of outcome assessment standards in the management of spinal deformity, understanding the impact surgical complications have on outcomes will help to isolate risk factors and aid in risk management decisions. Reliable and consistent reporting of relevant complications is needed to maximize the knowledge ascertained from assessment standards [22]. Complications need to be assessed from both the patient's and the surgeon's perspective since even commonly reported complications can have little correlation with certain patient-reported outcomes [11]. Even patients who experience major perioperative complications still tend to have significant improvements in early clinical outcome measures, but when followed for 3–5 years, the complications correlated with significant impacts in ODI and SRS scores [36]. Multidimensional and longitudinal assessment methods are needed to understand how particular complications impact outcomes.

Surgical Complications

Early Complications

Neurological Injury

Spine surgery has the potential risk of neurological injury. Iatrogenic neurologic injury is among the most concerning complications of spine surgery. These injuries may lead to new radiculopathy, motor or sensory deficits, or paralysis and can occur intraoperatively or postoperatively. Mechanisms of injury include compression, traction, laceration, direct trauma, or vascular compromise.

In the ISSG multicenter prospective study [34], Smith and colleagues found 27.8 % of patients experienced a neurological complication, with 12.7 % of patients experiencing a major complication. 7.2 % of all patients underwent a reoperation that was at least partially related to a neurological deficit. The most common were radiculopathy (8.9 %), motor deficit (4.8 %), sensory deficit (3.8 %), and nerve root deficit (2.7 %) [34].

In a retrospective review of 5,801 cases of surgically treated scoliosis from the SRS, 107 (1.84 %) developed new neurological deficits: 88 (1.52 %) nerve root deficits, 15 (0.26 %) spinal cord deficits, and 4 (0.07 %) cauda equina syndromes [12]. Complete recovery occurred in the majority of patients (data included pediatric scoliosis). 52.9 % of nerve root deficits recovered completely, with only 1.7 % without deficit recovery. 37.5 % of patients who developed cauda equina syndrome recovered completely, and 25 % showed no improvement. 57.3 % of patients with new spinal cord deficit had completely recovery, and 6.1 % failed to improve. Of the subgroups in this analysis, degenerative scoliosis was associated with the highest rate of new neurologic deficit (2.49 %), followed by idiopathic scoliosis (1.45 %) and neuromuscular scoliosis (1.03 %) [12]. Of all SRS cases reviewed, variables associated with increased frequency of new neurologic deficit included revision procedures, fusions, and use of implants.

The rotational components and superimposed degenerative disease can make instrumentation placement challenging for even experienced surgeons. Pedicles on the concave side tend to have significantly smaller diameters, as much as 25 % smaller [20]. With more extreme deformities, malpositioned screws and pedicle breaches occur more frequently [49]. Applying compression to realign the spine without aggressive foraminal decompression can also result in foraminal stenosis and potentially new symptoms. Rapid or overaggressive correction of curves may produce increased tension on neural elements. Insufficient arterial perfusion pressures (MAP < 60) may increase the risk of ischemic injury of already compressed or stretched neural elements, with potentially devastating results [23]. Special attention to evoked potentials during deformity correction is critical to identify and prevent neurologic injury. Slow, controlled corrective maneuvers with sufficient perfusion pressures allow tissue accommodation and may help to decrease the risks of new neurological deficits.

Durotomy

Unintended durotomy occurs in 1–4 % of patients treated for scoliosis in most studies, with an incidence of 2.2 % of degenerative scoliosis patients in the SRS registry [43]. In the ISSG multicenter prospective study [34], Smith and colleagues reported dural tears in 10.7 % of patients (31/291). Persistent cerebrospinal fluid (CSF) leaks, pseudomeningoceles, meningitis, headache, and intracranial/intraspinal hemorrhage can result from dural tears. Small CSF leaks can often be managed with a primary suture repair. Dural substitutes, fascial grafts, and a wide spectrum of glues and allografts are available to aid in the repair of more extensive injuries. The use of drains with a durotomy is highly dependent up on the individual case and surgeon preference. While some studies see no significant difference in incidences of dural tear between primary and revision procedures [8], the majority of studies suggest a significantly greater risk with revisions.

Surgical Site Infections

Infection is one of the leading causes of morbidity for many surgical procedures. It is responsible for up to 46 % of readmissions following de novo adult deformity operations [28] and 14.5 % of revision deformity cases [48]. Surgical site infections lengthen hospital stay by an average of 9.7 days and increase admission costs by $20,842 [4, 7]. The reported incidence of surgical site infections in instrumented spine operations is usually around 2–4 % [1, 4, 7]. Deep infections are those below the fascia, and superficial infections are supra-fascial, including the skin and subcutaneous tissue. In a review of 5,801 adult scoliosis operations from the SRS database, 1.1 % of patients developed superficial infections and 2.5 % developed deep infections (Table 19.3) [37]. A review of 108,419 spinal operations in the SRS database showed an increased risk of infection associated with implant use (28 % greater, 2.3 % vs. 1.8 %), spinal fusion (33 % greater,

Table 19.3 Rate of infection among patients with a primary diagnosis of scoliosis, stratified based on patient age and subtype of scoliosis [37]

Type of scoliosis	No. of cases	Superficial infection (%)	Deep infection (%)	Total infection (%)
Adult (>21 years) scoliosis	5801	66 (1.1)	146 (2.5)	212 (3.7)
Neuromuscular	292	8 (2.7)	18 (6.2)	26 (8.9)
Posttraumatic	30	0 (0.0)	2 (6.7)	2 (6.7)
Degenerative	2533	31 (1.2)	73 (2.9)	104 (4.1)
Congenital	137	1 (0.7)	4 (2.9)	5 (3.6)
Idiopathic	2488	23 (0.9)	46 (1.8)	69 (2.8)
Other	139	3 (2.2)	2 (1.4)	5 (3.6)
Not recorded	182	0 (0.0)	1 (0.5)	1 (0.5)

2.4 % vs. 1.8 %), and revision surgery (65 % greater, 3.3 % vs. 2.0 %) [37]. The surgeon-reported SRS database had a significantly lower infection rate when compared to the chart-abstracted American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database (1.21 % compared to 2.05 % in ACS-NSQIP, $p < 0.001$), and this significance remained when looking specifically at adult idiopathic scoliosis [42].

Gram-positive organisms are slightly more common than gram-negative (*S. aureus* 27 %, methicillin-resistant *S. aureus* 17 %, *S. epidermidis* 31 %, gram-negative 30 % [1]), although nearly half of spinal surgery site infections are polymicrobial [1, 25]. Surgical variables associated with surgical site infections include inadequate antibiotic dosing, longer operative time/number of levels, pelvic fixation, and blood transfusions [1, 25, 32, 48]. Potentially modifiable risk factors associated with increased rates of surgical site infectious include obesity (BMI > 30–35), smoking, diabetes/serum glucose, and MRSA colonization (Table 19.4) [4].

Vancomycin powder has been reported to be protective against superficial, deep, and staph infections [3, 5] with only rare case reports of anaphylaxis and sterile seromas [21, 47]. While there is some uncertainty about its utility, topical vancomycin powder is currently used by many surgeons in an attempt to reduce infectious complications.

The use of recombinant human bone morphogenetic protein-2 (rh-BMP2) has been associated with a higher rate of deep wound infections in combination with anterior/posterior thoracolumbar fusions (1.1 % vs. 0.2 %, $p < 0.001$); however, the same study showed no difference in the patients being treated for adult scoliosis (1.8 vs. 2.0 %, $p = 0.9$) [44]. The impact that rh-BMP2 has on infection is unclear.

Table 19.4 Modifiable risk factors associated with spinal SSI

Obesity BMI > 30	Smoking
Diabetes	Suboptimal antibiotic timing
Thoracolumbar surgical site	History of previous SSI
Greater operative blood loss	Razor shaving of hair
Longer surgical duration	Participation of >2 residents

Evidentiary table-modifiable risk factors [4]

Surgical site infections in scoliosis patients where stability is dependent upon instrumentation present unique challenges. If detected early and managed aggressively with debridement, infections can often be treated reliably (88.2–89.3 % [2, 33]) without the need for instrumentation removal.

Bleeding/Hematoma

In the ISSG multicenter prospective study [34], Smith and colleagues reported 8.9 % (26/29) of patients had an estimated blood loss of >4 L, which they defined as a major complication. The use of cell-saving devices and ensuring adequate preoperative blood availability help to minimize blood loss-related complications. Multiple groups have investigated the effects of perioperative aspirin on blood loss and associated complications. Most studies do find a significant but small increase in perioperative blood loss with aspirin, but outcomes do not seem to be affected. Park et al. demonstrated that perioperative blood loss among two-level posterior lumbar fusions was significantly greater in patients currently taking aspirin (1297 ml, $p = 0.033$) or holding aspirin for 7 days (1298 ml, $p = 0.034$) compared to no aspirin (960 ml) [24]. However, there was no difference when the groups were not controlled for any other NSAID usage [24]. Given the irreversible mechanisms of aspirin, some effects may remain even after a week. Kang et al. compared patients not taking aspirin to those who stopped aspirin 7 days prior to surgery in a retrospective case study of 38 patients undergoing posterior lumbar instrumentation and fusion [14]. While there were no differences in patient outcomes or intraoperative blood loss, those patients holding aspirin for 7 days had significantly higher wound drain outputs (864 ml vs. 458 ml, $p < 0.001$) and transfusion requirements postoperatively (2.4 units vs. 1.6 units, $p = 0.030$) [14]. Looking specifically at patients with cardiac stents, Cuellar et al. found that perioperative aspirin resulted in no significant increase on perioperative blood loss, bleeding-related complications, length of stay, or readmission rate [6].

Late Complications

Implant-Related and Radiographic-Identified Complications

Implant-related complications (IRC) and radiographic-identified complications (RIC) are usually the most common cause of reoperation. In the ISSG multicenter prospective study [34], Smith and colleagues reported 24 % (71/291) of patients required reoperation, primarily due to RIC and/or IRC. With ever-expanding surgical techniques and implant designs, understanding potential complications is essential for both patient selection and safety. Implant-related complications include breakage, malposition, migration/dislodgement, and pain/prominence. Radiographic-defined complications included PJK, distal junctional kyphosis, pseudarthrosis, adjacent segment degeneration, sagittal malalignment, curve decompensation, heterotopic ossification, and vertebral fracture [41].

Table 19.5 Radiographic and implant-related complications from 246 patients [41]

Complication	*N*	%
Implant related		
Rod breakage	16	47
Prominence	5	14.70
Painful implant	4	11.70
Screw breakage	3	8.80
Screw loosening	2	5.90
Screw malposition	2	5.90
Implant dislodgement	2	5.90
Total	34	13.82
Radiographic		
Proximal junctional kyphosis	24	54.50
Pseudarthrosis	5	11.40
Adjacent segment disease	5	11.40
Distal junctional kyphosis	5	11.40
Sagittal malalignment	3	6.80
Implant fracture	2	4.60
Flat back	1	2.30
Total	45	18.29
Total (radiographic + implant-related)	79	31.7

In a review of adult spinal deformity patients with more than 20 degrees of scoliosis from the ISSG, Soroceanu et al. [41] reported that 32 % (78 of 246) of patients developed an implant or radiographic-identified complication, of which 53 % required reoperation (Table 19.5). Rod breakage and PJK accounted for more than half of the complications (40/79). When compared to patients without radiographic or implant-related complications, these patients had greater BMI, had more comorbidities, and were more likely to have had previous operations. Patients with radiographic-identified complications tended to have greater preoperative pelvic tilt (PT), greater mismatch between pelvic incidence and lumbar lordosis (PI-LL), and greater sagittal malalignment [41].

An ISSG prospective series of surgically treated deformity patients reported a 9.0 % (18/200) overall rate of rod fracture, with mean occurrence at 14.7 months postoperatively [38]. In the ISSG multicenter prospective study [34], Smith and colleagues reported 13.7 % (40/291)

Table 19.6 Rates of implant and radiographic complications in 291 adults surgically treated for spinal deformity with minimum 2-year follow-up [34]

Complication	Minor	Major	Required re-op
All implants n (%)	14 (4.8)	67 (23)	32 (11)
Rod breakage	0	40 (13.7)	15 (5.2)
Implant prominence	6 (2.1)	5 (1.7)	4 (1.4)
Painful implant	2 (0.7)	5 (1.7)	5 (1.7)
Screw breakage		6 (2.1)	1 (0.3)
Screw loosening	4 (1.4)	2 (0.7)	1 (0.3)
Interbody spacer dislodgement		3 (1)	1 (0.3)
Screw medial breach	1 (0.3)	1 (0.3)	1 (0.3)
Implant failure		1 (0.3)	1 (0.3)
Rod dislodgment		1 (0.3)	1 (0.3)
Screw dislodgement		1 (0.3)	1 (0.3)
Cross-link dislodgement	1 (0.3)		
Fixation failure		1 (0.3)	1 (0.3)
Hook dislodgement		1 (0.3)	
All radiographic n (%)	29 (10)	52 (17.9)	39 (13.4)
Proximal junctional kyphosis	18 (6.2)	21 (7.2)	18 (6.2)
Pseudarthrosis		15 (5.2)	10 (3.4)
Adjacent segment disease	6 (2.1)	4 (1.4)	2 (0.7)
Coronal imbalance	4 (1.4)	4 (1.4)	4 (1.4)
Sagittal imbalance	1 (0.3)	4 (1.4)	3 (1)
Distal junctional kyphosis		4 (1.4)	2 (0.7)

of patients developed a rod fracture by 2 years postoperative (Table 19.6). The highest rate of rod fracture was seen in patients undergoing pedicle subtraction osteotomy (PSO), with 22 % of patients exhibiting rod fracture versus 4.7 % in those without PSO (Fig. 19.1) [38]. Only 66 % (12 of 18) of the patients with rod fractures were symptomatic with new onset pain [38]. Significant risk factors included older age, greater BMI, history of previous spine surgery, PSO, greater baseline sagittal spinopelvic malalignment (SVA, PT, and PI-LL mismatch), and greater magnitude of sagittal spinopelvic malalignment correction with surgery (SVA and PI-LL mismatch) [38].

Increasing literature regarding implant-related complications and the desire to provide greater sagittal plan correction have led to renewed interest in methods of avoidance. The use of multiple-rod constructs across three-column osteotomy sites has been demonstrated to significantly reduce rates of implant failure and pseudoarthrosis [13]. Optimal deformity correction with advanced lumbosacral fixation and restoration of global sagittal alignment have been reported to significantly decrease revision rates and improve clinical outcomes [16]. The high incidence of reoperations for correction of radiographic and implant-related complications has led to the development of optimal radiographic alignment parameters and to aid with patient selection and counseling [15–18, 29, 39]. Numerous studies have reviewed risk factors associated with the development of PJK and pseudarthrosis. These risk factors include type of osteotomy, greater number of levels fused, fusion to the sacrum, thoracoplasty procedure, disruption of supporting ligaments, older age, higher BMI, and lower bone density. A comprehensive discussion of these topics can be found in Chaps. 3, 5, 9, 16, 17, 18, 19, and 22.

Medical Complications

Death

While rates of mortality are low, patient safety demands a careful understanding of factors associated with mortality. In the ISSG multicenter prospective study [34], Smith and colleagues reported two mortalities of 339 patients (5.9 per 1000) within 6 weeks of surgery. Mortality within 6 weeks of surgery occurred in 20 of 5801 adult scoliosis cases in the 2004–2007 SRS database,

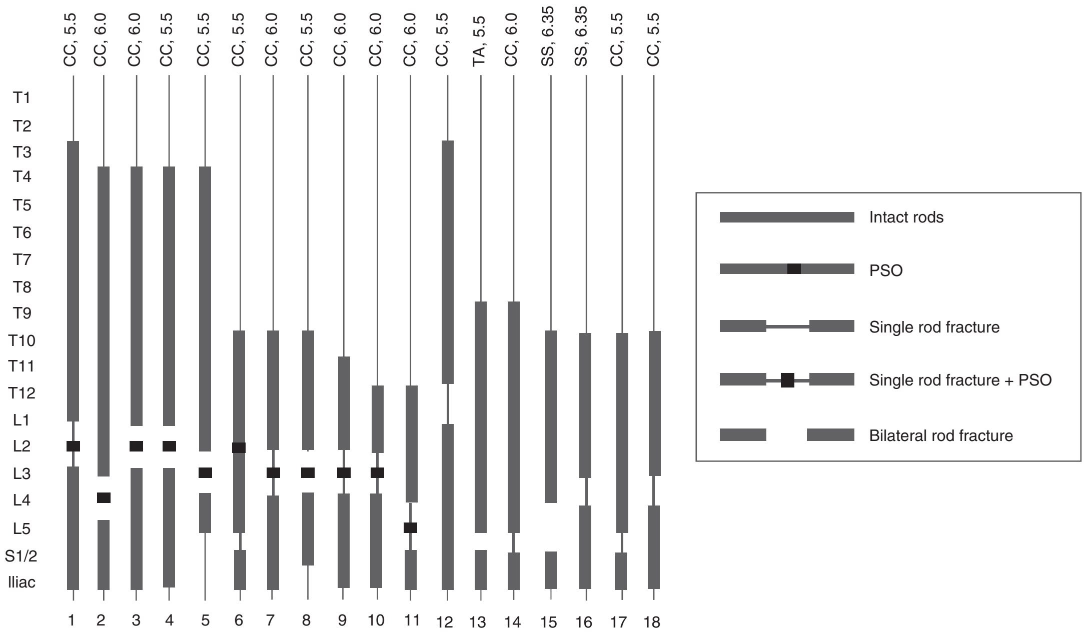

Fig. 19.1 Characteristics of instrumentation constructs developing rod fractures [38]

yielding an overall mortality rate of 3.5 per 1000 cases (2.0 per 1000 for all adult cases) (Table 19.7) [35]. Similar to rates in the data from 2009 to 2011, respiratory/pulmonary, cardiac, sepsis, stroke, and intraoperative blood loss represented the most common causes. Higher ASA scores and the use of implants or a fusion were also associated with higher mortality rates [31, 35].

Using the Nationwide Inpatient Sample (NIS) to review 11,982 adult scoliosis operations with greater than four levels fused, Worley et al. analyzed surgical factors and comorbidities associated with increased morbidity/mortality (Table 19.8) [46]. The overall mortality rate they reported was 28 per 1000 patients (0.28 %). A review of surgical factors found that revision status and greater number of levels fused were not associated with additional mortality risk, but age >65 had a significant increased risk (OR 3.49). Morbidity risk did increase in patients having greater than nine levels fused (OR 1.69) or revision surgery (OR 1.08) [46].

Cardiopulmonary

Cardiopulmonary complications are the source of the vast majority of mortalities related to adult scoliosis surgery. Cardiac complications are mainly due to myocardial infarction and heart failure. Appropriate preoperative assessment, identification of cardiac risk factors, and rapid identification and treatment of cardiac insults are essential. Myocardial infarction following noncardiac surgery is associated with a mortality rate as high as 70 % [45]. In a review by Sciubba et al. [30], 2.1 % of patients experienced a major pulmonary complication. Minimizing these risks begins at the first patient visit, working to control modifiable risk factors (smoking cessation, weight loss, rehabilitation programs, and appropriate pharmacologic and medical management). Continuing a low-dose perioperative aspirin may be warranted in some of these patients. A vigilant and experienced medical team will help to control these risks in the perioperative period.

GI

Ileus is not uncommon following surgery, but can become problematic when it lasts for an extended period. Standardized protocols will help minimize these complications and early mobilization is usually one of the most useful therapies.

Table 19.7 Reported causes of mortality stratified by primary diagnosis [31, 35]

Reported causes of mortality	SRS 2004–2007		SRS 2009–20,011	
	Scoliosis (26, 421)	All cases (107,996)	Scoliosis (50,553)	All cases (87,161)
Respiratory/pulmonary	18	83	24	48
Respiratory failure	6	23	6	13
PE		11	9	15
Presumed PE	2	9	3	8
Pneumonia	2	9	3	5
Aspiration	2	9	2	5
ARDS	2	3	1	2
Other/not specific	4	19		
Cardiac	8	41	19	32
Failure/not specific	4	8	9	12
Cardiac arrest	3	13	4	9
Myocardial infarction		16	6	11
Sepsis	7	35	7	12
Multisystem organ failure		3	4	9
Stroke	3	15	5	6
Blood loss	5	8	7	7
Other	4	6	5	13
Unknown	3	6	3	3
Total	48	197	74	130
Deaths per 1000 cases	1.82	1.82	1.46	1.5

Reported causes of mortality, stratified by primary diagnosis for cases collected on the basis of the new system (2009–2011) [31]

Table 19.8 Medical comorbidities as risk factors for mortality [46]

Comorbidity	Odds ratio	Lower – 95 % CI	Upper – 95 % CI	*p*-value
Liver disease	36.09	16.16	80.59	<0.0001
Pulmonary circulation disorders	8.94	4.43	18.03	<0.0001
Pathologic weight loss	7.28	4.36	12.14	<0.0001
CHF	5.67	3.3	9.73	<0.0001
Renal failure	5.51	2.57	11.82	<0.0001
Electrolyte imbalance	4.63	3.15	6.81	<0.0001
Coagulopathy	2.32	1.44	3.76	0.0006
Peripheral vascular disorders	1.76	0.68	4.53	0.24
Neurological disorders	1.24	0.63	2.46	0.539
Obesity	0.74	0.29	1.94	0.545
Chronic pulmonary disease	0.32	0.16	0.64	0.001
Diabetes, uncomplicated and complicated	0.25	0.09	0.67	0.006
Hypertension, uncomplicated and complicated	0.15	0.09	0.23	<0.0001
Anemia (deficiency)	0.11	0.04	0.28	<0.0001

Vascular

Deep vein thrombosis (DVT) and related pulmonary thromboembolism are unfortunately common and well-established risks of both morbidity and mortality. Low thresholds for assessing duplex ultrasounds can be beneficial as can standard preoperative screening in high-risk patients. The potential risks and benefits of perioperative TXA and amicar in relation to increased thromboembolism are discussed in Chap. 10.

Renal/Genitourinary

Urinary tract infections (UTIs) have been reported to be the most frequent postoperative medical complication of adult scoliosis surgery [27]. UTIs have potential to lead to bacteremia and sepsis. Early removal of Foley catheters can help to minimize the risk of developing UTIs, but must be carefully weighed against the benefits from accurate monitoring of urinary output to guide fluid replacement and mitigate hypovolemia and renal failure.

Acute renal failure can result from suboptimal management of prerenal failure secondary to hypoperfusion. Avoidance of perioperative administration of blood pressure medications which interfere with the renin-angiotensin pathway will significantly reduce these risks. Standardized nursing protocols to monitor urine output and watch for urinary retention are essential to minimize these complications.

Retrograde ejaculation can be found in up to 4 % of patients after spinal fusion and is mainly associated with anterior transperitoneal approaches to the lumbar spine, more so than with retroperitoneal approaches. Injury to the hypogastric plexus must be avoided during approaches to the lumbar spine. The plexus is located in front of the vessel bifurcation, close to the peritoneum. In transperitoneal approaches, the plexus is split directly under the peritoneum. Retroperitoneal approaches allow reflection of the peritoneum and therefore make injury less likely. The restrictive use of bipolar cauterization may also reduce this risk.

Impact of Complications

Correction of adult lumbar scoliosis and deformity utilizes a variety of complex and technically demanding procedures with high associated complication rates. With an aging population presenting with more challenging conditions, minimizing the complications is essential. Using the 2004–2007 Scoliosis Research Society database, Sansur et al. found only 10.5 % (521 of 4980) of adult patients undergoing scoliosis correction surgery experienced at least one complication [27]. However, complication rates as high as 95 % have been reported in patients over 70 years old [19]. Using the Adult Deformity Outcomes (ADO) multi-institutional database, Smith et al. demonstrated that despite a perioperative complication rate of 71 %, the elderly experienced a significantly greater benefit from spinal deformity surgery than the younger patients with only a 17 % perioperative complication rate (Figs. 19.2 and 19.3) [36].

Even patients who experience major perioperative complications still tend to have significant improvements in early clinical outcome measures.

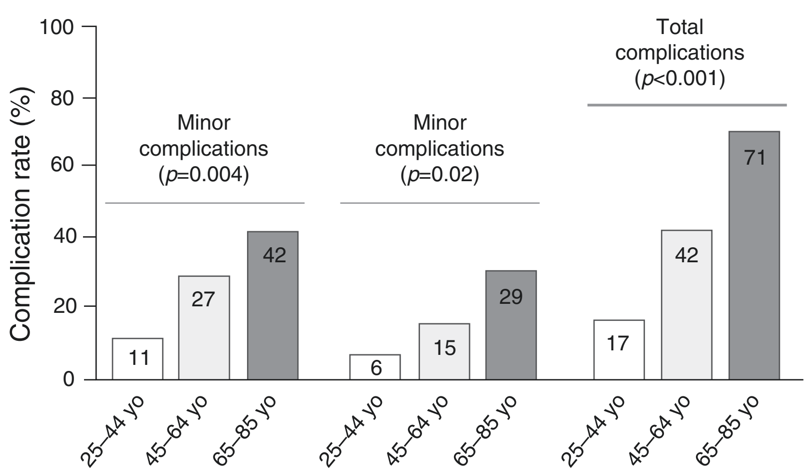

Fig. 19.2 Short-term complication rates with scoliosis undergoing surgery stratified by age from the Adult Deformity Outcomes (ADO) multi-institutional database [36]

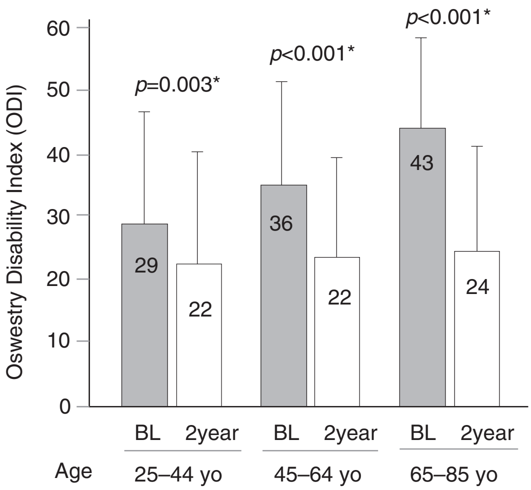

Fig. 19.3 "Relationship of patient age to improvement of disability in adults with scoliosis after surgical treatment. Bars indicate standard deviations. *p-values are from paired t-tests. [36]"

Conclusion

With the rapid development of outcome assessment standards in the management of spinal deformity, understanding the impact surgical complications have on outcomes will help to isolate risk factors and aid in risk management decisions. Multidimensional and longitudinal assessment methods should be used to understand the true significance of these complications on surgical outcomes.

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