

Complications in Operative Scheuermann Kyphosis

Do the Pitfalls Differ From Operative Adolescent Idiopathic Scoliosis?

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Study Design. A prospective multicenter database of operative patients with Scheuermann kyphosis (SK) with minimum 1-year follow-up was studied for major complications compared with contemporaneous operative patients with adolescent idiopathic scoliosis (AIS) from the database.

Objective. To evaluate complications associated with current surgical techniques in SK and AIS.

Summary of Background Data. There is a paucity of literature regarding complications associated with SK surgical treatment, but prior data suggest an elevated neurological risk.

Methods. Complication rates were compared using analysis of variance and Fisher exact test analyses. Major complications were those that were life-threatening, caused spinal cord, nerve root, or ocular injury or required reoperation including surgical site infections. A binary logistic regression determined the likelihood of complications based on diagnosis, levels fused, blood loss, operative time, and length of stay.

Results. Ninety-seven patients with SK (57 males; mean age, 16.5 yr; 75.3° mean kyphosis) and 800 patients with AIS (622 females; mean age, 14.9 yr; 55.6° mean curvature) met inclusion criteria. Patients with SK had significantly more major complications than those with AIS (16.3% vs. 2.3%; $P < 0.001$). The SK group had more

infections (10.3% vs. 0.75%) and reoperations (14.4% vs. 1.4%) ($P < 0.001$). Operative time was longer and more levels were fused in the SK group ($P < 0.001$). Surgical site infection was the most common complication. There were no significant differences in length of stay or blood loss. Patients with SK were 3.9× more likely to have a major complication than those with AIS (odds ratio: 0.26, $P = 0.003$). The number of levels fused was an independent predictor of major complications: each additional level fused increased the odds of a complication by 36% in both groups (odds ratio: 1.36, $P = 0.034$).

Conclusion. Major complications are 3.9× more likely to occur in operative SK than in AIS. The number of levels fused is an independent risk factor for major complications. Patients with SK are at higher risk for infections and reoperation than those with AIS.

Key words: Scheuermann kyphosis, complications, adolescent idiopathic scoliosis, scoliosis.

Level of Evidence: 2

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Scheuermann kyphosis (SK) is characterized by vertebral endplate irregularities, Schmorl nodes, and wedging of the apical vertebrae, which can involve the thoracic or thoracolumbar spine.¹ Scheuermann disease has an estimated incidence of 0.4% to 10% and prevalence of 2.8%, affecting predominantly the adolescent population.²⁻⁴ The Scoliosis Research Society Morbidity and Mortality (2009) data reported a 14% complication rate in operative SK including 1.9% neurological and 0.6% mortality data.⁵

Prior studies on operative SK are generally retrospective and use relatively small cohorts.⁵⁻⁸ Adolescent idiopathic scoliosis (AIS) affects 0.5% to 3% of the adolescent population, a parallel population to that of SK; however, operative complication rates have historically been lower than that for SK.^{5,9-12} Male patients are more likely to require surgery in the population with SK, whereas females are more likely to require it in the population with AIS.^{5,6,9,13,14} Surgery is the treatment of choice for severe, progressive deformities in both entities; and for unacceptable disfigurement and pain especially in SK.^{6,15,16}

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Although the complications associated with AIS have been well documented, a paucity of prospective data for surgically treated, adolescent SK using contemporary operative techniques exists. Therefore, the purpose of this study was to assess early major complications associated with operative SK compared with operative AIS, including comparing reoperation and infection rates and determining factors predictive of complications in both groups.

MATERIALS AND METHODS

A prospective multicenter study of the surgical management of SK involving 10 institutions was conducted alongside a prospective multicenter study for surgically treated patients with AIS. Required inclusion criteria for the database were a minimum of 6 weeks of follow-up. Patients with SK, aged 10 to 24 years who underwent surgical correction between the years 2006 and 2010, were evaluated. Contemporaneous patients with AIS, aged 10 to 21 years, were included with surgical dates from 2006 to 2010.

For this study, 1-year follow-up was required in patients with SK. Patients with AIS required only 6 weeks of follow-up. However, the majority of the cohort had 1 to 2-year follow-up. Demographic data, including age and sex, and radiographical data were collected for all patients. No patients were excluded on the basis of any demographic parameter, including surgical approach.

Clinical data were recorded in real time from the initial hospitalization and subsequently at each follow-up visit. Any associated complication data or follow-up information on previous complications was recorded at every postoperative visit (3 mo, 6 mo, 1 yr, and 2 yr [when available]) using a predefined complications data collection form. Complications were divided into 7 categories: surgical site (infection) (SSI), instrumentation-related, neurological, pain, pulmonary, gastrointestinal, and other medical issues. Reoperations were also recorded within all categories.

Complications were then analyzed on the basis of only on defined major complications: those that were considered life-threatening, caused spinal cord or nerve root injury, or required reoperation. This included deep or superficial wound infections requiring operative treatment (irrigation and debridement in the operating room) and instrumentation problems requiring reoperation only. Excluded complications considered "minor" included instrumentation not requiring reoperation, SSI not requiring operative treatment, junctional kyphosis, blood loss more than 2500 mL, resolved postoperative numbness or pain, ileus, atelectasis, and pneumothorax not requiring chest tube intervention. These were excluded to avoid the possible disparities among sites in diligence of reporting minor problems such as postoperative incisional numbness/discomfort.

Various parameters were assessed to determine factors predictive of major complications.

Statistical Analysis

Groups were compared using analysis of variance analysis to determine statistically significant differences between

demographic, radiographical, and complications data. SK and AIS groups were compared on the basis of number of major complications and complication category, as well as reoperation rates and SSI rates. Complications are reported on the basis of the percentage of complications within the entire cohort and the specific percentage of each complication type within the complications group. Operative outcomes, including levels fused, estimated blood loss, operative time, and length of stay were compared with isolate differences between the groups. Levels fused and length of stay were analyzed using a nonparametric Mann-Whitney *U* test.

A binary logistic regression was performed to determine which variables were most predictive of major complications in each group. The variables entered into the equation included age, sex, levels fused, estimated blood loss, and operative time.

RESULTS

Demographic and Surgical Data

Ninety-seven patients in the SK arm (57 males; mean age, 16.5 yr) and 800 patients with AIS (622 females; mean age, 14.9 yr) fit the inclusion criteria. A total of 198 subjects had less than 1-year follow-up, 46 had only 1-year follow-up, and 653 subjects had 2-year follow-up. There were significantly more females in the AIS group than the SK group and the SK group was significantly older ($P < 0.001$). Radiographical data for the 2 groups are described in Table 1.

All patients in both groups had a posterior spinal fusion. This data point seemed to be an artifact of requiring a minimum of 1-year follow-up in all patients in the study cohort; those patients in the database who underwent an anterior or

TABLE 1. Demographic Data/Operative Data

	SK (n = 97)	AIS (n = 800)	<i>P</i> *
No./Sex (%)	39/F (40.2) 57/M (58.8)	622/F (77.8) 178/M (22.3)	<0.001
Surgical approach	PSF 97	PSF 800	
Age at surgery (yr) (mean ± SD)	16.5 ± 2.0	14.9 ± 2.1	<0.001
Levels fused (mean ± SD)	12.9 ± 0.9	10.8 ± 2.3	<0.001
Operative time (min) (mean ± SD)	316.5 ± 116.3	275.3 ± 121.1	0.002
Estimated blood loss (mL) (mean ± SD)	1196.4 ± 784.4	1045.7 ± 945.7	0.138
Length of stay (d) (mean ± SD)	6.0 ± 3.8	5.7 ± 1.3	0.851

*Bold values indicate statistical significance.

AIS indicates adolescent idiopathic scoliosis; SD, standard deviation; SK, Scheuermann kyphosis; PSF, posterior spinal fusion.

combined approach procedure did not routinely return for 1- to 2-year follow-up for no known reason. Patients with SK and AIS had similar estimated blood loss (1196.4 mL *vs.* 1045.7 mL, $P = 0.14$) and length of stay (6 d *vs.* 5.7 d, $P = 0.85$) (Table 1). Patients with SK had longer operative times (316.5 min *vs.* 275.3 min, $P = 0.002$) and more levels fused (12.9 *vs.* 10.8, $P < 0.001$).

Complications

There were 16 (16.3%) major complications in 97 patients with SK compared with 18 (2.3%) in 800 patients with AIS ($P < 0.001$) (Table 2). Patients with SK were significantly more likely to have SSI (10.3% *vs.* 0.75%, $P \leq 0.001$). Both groups sustained statistically similar rates of deep *versus* superficial infections (SK: 100%, AIS: 83.3%, $P = 0.375$).

SSI (10.3%), instrumentation (3.1%), and neurological (2.1%) complications were the most common complications reported in the SK cohort (Table 3). Infections (0.75%) and instrumentation (0.63%) were the most common in the AIS cohort (Table 3). Neurological complications in the SK group were reported at a rate of 2.1% and at a rate of 0.13% in the AIS group (Table 3).

Of those patients with complications, 10 (62.5% of total complications) patients with SK had SSI compared with 6 (33.3% of total complications) with AIS (Table 3). All reported SSI in both groups were treated operatively. Three (18.7%) patients with SK experienced instrumentation complications compared with 5 (27.8%) with AIS (Table 3). All 3 patients with SK with instrumentation issues required reoperation for loss of fixation to bone, occurring at 1 day, 2 months, and 4 months postoperatively. Of the 5 patients with AIS with instrumentation problems, 4 underwent reoperation (2 for loss of fixation at 1 day and 2 months postoperatively, and 2 for misplaced screws noted at 6 and 9 mo postoperatively). The 1 case without a reoperation had a screw pullout that was recommended for reoperation but not treated at 2-year follow-up. Cases of instrumentation pullout were not due to pseudarthrosis. Figures 1(A–C) and 2(A–C) present 2 of the instrumentation complications.

Of those with complications, 2 patients with SK (12.5%) and 1 with AIS (5.6%) had neurological complications (Tables 3, 4). One of the patients with SK experienced radiculopathy and neck pain postoperatively due to C5–C6 disc protrusion

treated nonoperatively. The other SK neurological complication consisted of postoperative unilateral lower extremity weakness; immediate postoperative magnetic resonance imaging revealed a T10–T11 disc herniation with spinal cord compression that was not present preoperatively. All instrumentation was subsequently removed and decompressive discectomy was performed and implants replaced; leg strength subsequently improved to preoperative baseline. The AIS neurological complication required screw removal due to related radiculopathy. There were 4 pulmonary (2 pleural effusions requiring intubation, 1 respiratory failure, and 1 atelectasis

TABLE 3. Major Complications in SK and AIS by Type

Complications	Total Cohort Comparison	
	SK (n = 97 Total)	AIS (n = 800)
Surgical site infection	10.3% (10/97)	0.75% (6/800)
Instrumentation	3.09% (3/97)	0.63% (5/800)
Neurological	2.06% (2/97)	0.13% (1/800)
Pulmonary	0	0.5% (4/800)
Gastrointestinal	0	0.13% (1/800)
Medical	0	0.13% (1/800)
Pain	1.03% (1/97)	0
	Within Complication Group, Cohort Comparison	
Complications by type	SK (16 total)	AIS (18 total)
Surgical site infection	62.5% (10/16)	33.3% (6/18)
	10 cases of deep wound infection requiring I & D procedure	5 cases of deep wound infection requiring I & D procedure 1 case of superficial wound infection
Instrumentation	18.7% (3/16)	27.8% (5/18)
Loss of fixation	3	2
Misplaced screws	0	2
Loss of fixation (no reoperation)	0	1
Neurological	12.5% (2/16)	5.6% (1/18)
Pulmonary	0	22.2% (4/18)
Gastrointestinal	0	5.6% (1/18)
Medical	0	5.6% (1/18)
Pain	6.3% (1/16)	0

AIS indicates adolescent idiopathic scoliosis; I & D, irrigation and debridement; SK, Scheuermann kyphosis.

TABLE 2. Major Complications in SK and AIS

	SK (n = 97)	AIS (n = 800)	Significance
Complications	16 (16.5%)	18 (2.3%)	$P < 0.001$
Infections	10 (10.3%)	6 (0.75%)	$P < 0.001$
Deep infections/total infections	10/10	5/6	NS
Reoperations	14 (14.4%)	11 (1.4%)	$P < 0.001$

AIS indicates adolescent idiopathic scoliosis; SK, Scheuermann kyphosis; NS, not significant.



Figure 1. A, Preoperative sagittal image. B, One-month postoperative sagittal image displaying complication. C, Nine-month postrevision surgery/10 months postindex surgery sagittal image. In this case, the distal portion of both rods dislodged from the caudal most screws shortly after surgery. Given the significant corrective forces applied and the significant tension on the distal construct the rods should have been longer. A revision consisted of cutting the rods proximal to the distal screws and extending the rod construct *via* rod-to-rod connectors and protecting the distal fixation with a single infralaminar hook.

requiring intubation) 1 gastrointestinal, and 1 medical complication in the AIS group and none in the SK group. The gastrointestinal complication was a superior mesenteric artery syndrome that required hospitalization and the medical complication consisted of extensive blood loss (3 units).

Patients with SK were overall more likely to require a second operative procedure as a result of a complication (14.4%

vs. 1.4%; $P < 0.001$) (Table 2). The most common indication for reoperation in patients with SK was wound infection (10 cases of deep infection) and then instrumentation (3 cases, Table 5). One neurological case in each group required reoperation: one for a new-onset thoracic disc herniation after corrective instrumentation and another for misplaced screw. Diagnosis was a significant independent predictor of

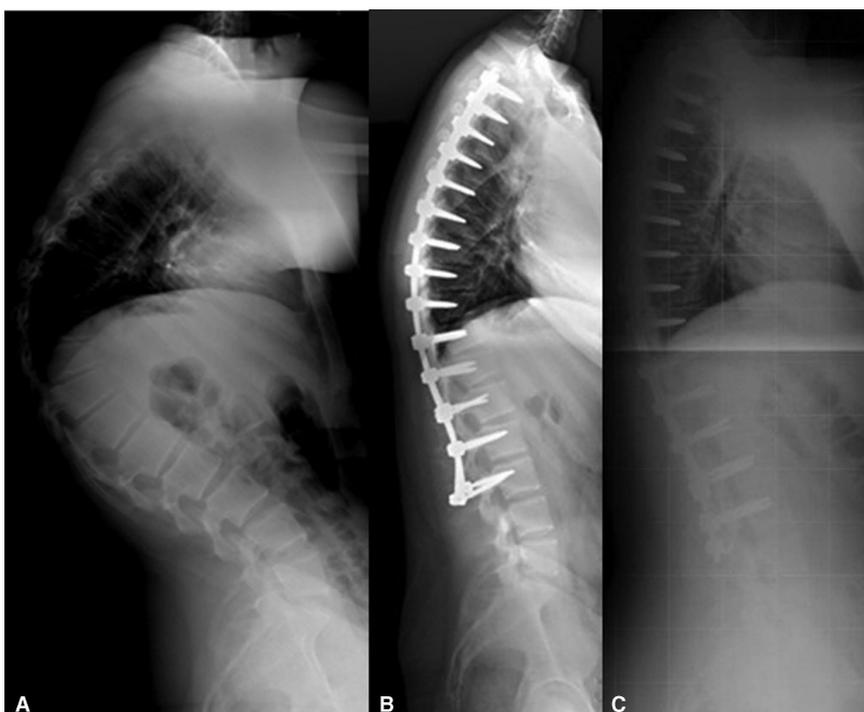


Figure 2. A, Preoperative sagittal image. B, One-year postoperative sagittal images displaying complication. C, 1-year postrevision surgery/2-year postindex surgery sagittal image. This patient developed distal screw pullout several months postoperatively that was revised by extending the instrumentation to L3. In retrospect, this complication might have been predicted by a lowest instrumented vertebrae that was cephalad to the sagittal stable vertebrae.

TABLE 4. Neurological Complications Type

	Nerve Root/ Radiculopathy	Spinal Cord
SK	1	1
AIS	1	0

AIS indicates adolescent idiopathic scoliosis.

complications in the study (odds ratio = 0.26, $P = 0.003$). The SK group was 3.85 times more likely to have a major complication than the AIS group. Number of levels fused was also a significant independent predictor of complications in both groups (odds ratio = 1.36, $P = 0.034$). For each additional level fused, the odds of a complication increased 36% in both groups.

DISCUSSION

There are little data in the literature regarding complications associated with operative SK. To our knowledge this is the largest prospective study analyzing complication rates in the adolescent population with SK after surgery using contemporary surgical technique. AIS is a far more common entity than SK and has been studied extensively, commensurate with its higher operative incidence. Recent data from the Scoliosis Research Society (SRS) Morbidity and Mortality Committee revealed a 5.7% complication rate for AIS, with an overall rate of neurological deficit in the range from 0.26% to 1.75% depending upon surgical approach. Previous studies have reported the potential complications associated with SK and AIS operative management: including pulmonary embolus, superficial and deep wound infection, vascular lesions, pseudarthrosis, loss of correction, hemothorax, pneumothorax, persistent pain, instrumentation failure (intraoperative and postoperative), neurological compromise, and death.^{5,7,9}

In this study, the overall complication rate was significantly greater for patients with SK than for patients with AIS. This difference is consistent with data reported by Coe *et al*^{5,9} and in 2 studies using the SRS Morbidity and Mortality data. A complication rate of 5.7% was reported for a cohort of 6334 patients with AIS, whereas a complication rate of 14% in 683 patients of all ages with SK undergoing various procedures was found.^{5,9} For those patients with SK younger than 19 years (the most similar group in that study to this cohort), the

total complication rate was 11.8%, including 3.8% for SSI and 2.2% implant-related complications.

We reported higher overall complication rates in the SK group (16.3%) and lower rates in the AIS group (2.3%) than other published reports. This difference could also be attributed to reporting bias due to the retrospective nature of the prior studies compared with our prospectively collected data. Other reports of surgical complications in operative SK have been incomplete, inconsistently reported as a footnote in a larger clinical article, and with very few series assessing contemporary surgical technique.^{1-8,11,13,17-25}

SSI, instrumentation, and neurological complications occurred with greater frequency in the SK patient cohort. The most common complications in the SK cohort were SSI and instrumentation complications, consistent with the findings by Coe *et al*,^{5,9} whereas the AIS group experienced a more widely distributed range of complications. In patients with AIS, deep SSI and pulmonary complications were among the most common, consistent with previously reported data.¹⁶

In this study, the 2 groups displayed a relatively small rate of overall neurological complications compared with published data. Coe *et al*⁹ reported an acute neurological complication rate of 1.6% (8/499) in the less than 19-year cohort, including 2 spinal cord injury cases, whereas this study only included 1 intraoperative spinal cord injury and 1 neurological complication not related to the SK surgery (neurological complication rate of 2.06%). Our series, however, was much smaller than the retrospective, self-reported data for the SRS study. The rate of neurological complications in our posterior-only AIS group was 0.13% and was lower than reported neurological complication rates for anterior, posterior, and combined procedures in AIS: 0.26%, 0.32%, and 1.75%, respectively. A significant difference in neurological complications between the 2 groups could not be elucidated as the number of patients with this complication was small and the cohort is likely underpowered to show a significant difference.

Historically, there is an increased rate of neurological complications in SK surgery in comparison with that for AIS. Extradural spinal cysts, compression of the spinal cord at the apex of the kyphosis, and disc herniation at the apex of the kyphosis have all been suggested as risk factors for increased neurological risk.¹⁷ In 1975, MacEwan *et al*¹⁸ reported on 7885 patients with scoliosis treated surgically for the SRS Morbidity and Mortality report. Neurological complications occurred in 0.72%. Thirty percent of patients with a major neurological complication had an associated severe kyphosis. The authors concluded that kyphosis “increased the risk of neurological complications markedly.”¹⁸ Sucato¹⁹ associated significant neurological risk with kyphosis secondary to the spinal cord being “draped over the apex of the deformity” as well as a disturbance of the anterior vertebral artery and spinal cord perfusion. Qiu *et al*¹⁰ analyzed the data of 756 patients with AIS treated with surgical correction. Of these, 96 patients had hyperkyphosis (>40°). They found the hyperkyphosis group to have significantly more neurological complications (4.17% vs. 0.61%). Coe *et al*^{5,9} also found a higher

TABLE 5. Reasons for Reoperation in SK and AIS Groups

	Deep Infection	Neurological/ Spinal Cord	Loss of Fixation/ Instrumentation
SK (total n = 14)	10 (71.4%)	1 (7.1%)	3 (21.4%)
AIS (total n = 11)	6 (54.5%)	1 (9.1%)	4 (36.4%)

AIS indicates adolescent idiopathic scoliosis; SK, Scheuermann kyphosis.

rate of neurological complications in patients with SK (1.9%) than in patients with AIS (0.49%) in a more recent SRS Morbidity and Mortality report.

Patients with SK (16.3%) were significantly more likely to undergo reoperation than their AIS (2.3%) counterparts. SK reoperation rates have been reported to be between 0% and 27%.^{6,8,20–25} SSI was the most common cause of reoperation, followed by loss of fixation in both SK and AIS. This is consistent with previously reported data.²⁶ We think that the difference between groups is likely attributed to the higher rate of SSI in patients with SK as well as the cantilever forces required to correct significant kyphosis and a tendency for failure of the bone screw interface due to persistent pullout forces at the proximal and distal ends of a kyphosis construct. Proper rod contouring and adequate terminal fixation and appropriate end-instrumented vertebrae selection are important to minimize these complications. Figures 1 and 2 discuss 2 of the instrumentation complications found in the SK cohort.

Although there were no patients who needed a second operation due to development of symptomatic junctional kyphosis, this cause of reoperation has been reported previously in the literature. Further follow-up will be required to determine the rate of junctional kyphosis and the associated need for reoperation. Lonner *et al*⁶ reported that of 78 patients with SK, 3 required operative revision due to junctional kyphosis. Similarly, Lee *et al*²⁴ reported 3 cases of junctional kyphosis requiring reoperation in 39 patients with SK. The surgeon must be aware of this complication and monitor patients accordingly.

The SK group in this study was 3.85 times more likely to have a major complication than the AIS group. It is clear that patients with SK undergoing surgical treatment are at higher risk of complications than their AIS counterparts, and preoperatively must be counseled accordingly when addressing expectations and outcomes. The predictive factors behind the rate of complications in both groups included number of levels fused, which raised the odds of a complication occurring by 36% in both groups, however, age, sex, and operative time were not predictive factors. These results contradict data linking increased operative time to increased incidence of complications; Carreon *et al*¹⁶ reported an increased prevalence of non-neurological complications associated with the duration of posterior spinal surgery and total anesthesia time in surgery for AIS.^{5,9}

Other explanations for the difference in complication rates include less surgeon experience with SK operative correction as well as greater fusion length in comparison with AIS.^{5,9,16} Furthermore, the increased rate of SSI may be a result of the proximal extent of dissection at the base of the neck commonly required in SK, which has the potential for contamination due to the difficulty of sealing the proximal surgical draping intraoperatively.

This study has several strengths. First, it prospectively and reliably recorded the overall and specific incidences of complications in adolescent patients with SK and patients with AIS treated at the same institutions and by the same group

of surgeons. Second, the data are systematically collected from multiple institutions throughout the country, increasing its broad applicability. Finally, all of the operations occurred during or after 2006, reflecting a relatively homogenous, routine, and relevant standard of care.

This study has some potential limitations. Although the data were collected prospectively, despite the quality assurance processes that are in place, variations in how and when complications are reported may exist between the sites. However, the study group itself has a robust quality-assurance review process that helps preserve the veracity and completeness of the data, along with site-specific study coordinators. The length of follow-up is relatively short and some of the complications, particularly revision operations for junctional kyphosis and pseudarthrosis may occur at a time point beyond the follow-up of this study. In addition, the authors recognize the large difference in cohort size between the SK and AIS groups; ideally, the groups would be equally sized to minimize potential variability. Because of the lower incidence of operative SK cases, equally sized comparison groups between these diagnoses is not feasible. Despite these limitations, this analysis provides surgeons with valuable surgical complication information because it is one of the largest prospective studies of SK operative management reported in the literature.

CONCLUSION

Patients with SK were significantly more likely to experience complications, develop an SSI, and undergo a second operation than patients with AIS in this study. We found no significant difference for neurological complications between the 2 groups despite historical reports to the contrary; however, a larger cohort of patients in the SK group is required to accurately support that statement. The prolonged operative time, anatomic variation, and surgical volume compared with AIS likely makes the incidence of major complications in the operative management of patients with SK a more frequent occurrence than in patients with AIS. Improved understanding of the nature of the complications in these patient cohorts may inform strategies for reducing complications. Future prospective studies, with larger cohorts, need to be performed to determine the reasons for the differences in complication rates. It is clear from this study that surgeons must pay special attention to patients with SK when counseling them regarding surgical complications.

➤ Key Points

- ❑ Patients with SK are at higher risk (3.9× more) for major complications than patients with AIS.
- ❑ Patients with SK were significantly more likely to undergo reoperation and experience infectious complications than patients with AIS.
- ❑ Levels fused is an independent risk factor for major complications in both groups.

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