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Non-Neurologic Complications Following Surgery for Adolescent Idiopathic Scoliosis

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Background: The reported prevalence of non-neurologic complications following corrective surgery for adolescent idiopathic scoliosis ranges from 0% to 10%. However, most studies were retrospective evaluations of treatment techniques and did not focus solely on complications. The purpose of this study was to determine the prevalence of non-neurologic complications following surgery for adolescent idiopathic scoliosis and to identify preoperative and operative factors that can increase this risk.

Methods: The demographic data, medical and surgical histories, and prevalence of non-neurologic complications were reviewed in a prospective cohort of 702 patients who had undergone corrective surgery for adolescent idiopathic scoliosis and were consecutively enrolled in a multicenter database.

Results: There were 556 female and 146 male patients. The mean age at the time of surgery was 14.25 years (range, eight to eighteen years). Five hundred and twenty-three patients had only posterior spinal surgery, 105 had only anterior spinal surgery, and seventy-four had a combined anterior and posterior procedure. There was a total of 108 complications in eighty-one patients, for an overall prevalence of 15.4%. There were ten respiratory complications (1.42%), six cases of excessive bleeding (0.85%), five wound infections (0.71%), and five cases of wound hematoma, seroma, or dehiscence (0.71%). Five patients, two with an early infection and three with late failure of the implant, required a reoperation.

Factors that did not correlate with an increased prevalence of complications were age, body mass index, presence of cardiac or respiratory disease, previous surgery, pulmonary function, surgical approach, number of levels fused, graft material, use of a diaphragmatic incision, Lenke curve type, or region of the major curve. Although the number of patients with renal disease was small, these patients were 7.90 times more likely to have a non-neurologic complication. Increased blood loss as well as prolonged operative and anesthesia times were associated with a higher prevalence of non-neurologic complications.

Conclusions: The prevalence of non-neurologic postoperative complications following surgery for correction of adolescent idiopathic scoliosis in this study was 15.4%. The few factors noted to significantly increase the rate of complications include a history of renal disease, increased operative blood loss, prolonged posterior surgery time, and prolonged anesthesia time.

Level of Evidence: Prognostic Level I. See Instructions to Authors for a complete description of levels of evidence.

The reported prevalence of non-neurologic complications in children and adolescents treated with corrective spinal surgery for adolescent idiopathic scoliosis ranges from 0% to 10%¹⁻⁵, although most reports have been based on retrospective reviews^{3,6-10}. The objective of this study was to determine the prevalence of non-neurologic complications following surgery for adolescent idiopathic scoliosis

and to identify preoperative and operative factors that affect that prevalence.

Materials and Methods

We analyzed prospectively collected data on consecutive patients who underwent surgical correction of adolescent idiopathic scoliosis between December 2002 and Decem-

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ber 2004 and were included in a multicenter database. Of the patients who met eligibility criteria, 11.6% were not enrolled because of language constraints, because they refused to participate, or because follow-up data were not available. The patients were treated at fifteen sites, and twenty-seven surgeons participated. The institutional review board at each site provided approval before enrollment of any patient. The inclusion criteria were (1) a diagnosis of thoracic, thoracolumbar, and/or lumbar adolescent idiopathic scoliosis; (2) a patient age between eight years and zero months and seventeen years and eleven months at the time of diagnosis; and (3) surgery performed before the age of twenty-one years. All patients had a history, findings on physical examination, and a radiographic appearance consistent with the diagnosis of idiopathic scoliosis. Patients with congenital, neuromuscular, juvenile, or infantile scoliosis were excluded. All curve patterns were included and were classified with use of the system of Lenke et al.¹¹.

The database included 734 patients at the time of data extraction for the present study. Of these patients, 702 had complete data and they make up the cohort in this study. Patient demographics, the medical history, surgical data, and the prevalence of non-neurologic complications were reviewed. A complication was defined as any unanticipated event requiring active medical or surgical intervention. Non-neurologic complications were classified as perioperative (intraoperative and those occurring in the first seven days after the opera-

tion), early postoperative (those occurring between eight and thirty days after the operation), and late postoperative (those occurring after thirty days). All complications reported by the participating spine surgeons were included. These complications were not classified as major or minor.

Data were analyzed with use of the chi-square test for dichotomous variables, and independent t tests were used to determine any association between preoperative factors (such as age, body mass index, pulmonary function test results, medical comorbidities, Lenke curve type, curve magnitude, and region of the major curve) or surgical factors (such as operative time, anesthesia time, blood loss, surgical approach, number of levels fused, type of graft material, and use of a diaphragmatic incision) and the prevalence of a non-neurologic complication. Odds ratios for dichotomous variables were also calculated. Receiver operating characteristic curve analysis was done on variables that appeared to be predictive of the prevalence of non-neurologic complications. Receiver operating characteristic analysis is used to evaluate the predictive value of a given measurement by selecting all possible cut-points for the measurement and then calculating the sensitivity and specificity of each cut-point. A receiver operating characteristic curve is then drawn, plotting the sensitivity versus 1 minus specificity for each of the cut-points. The area under the receiver operating characteristic curve is a measure of the diagnostic power of a given measurement. High (near 1.0) and low (near 0.0) values indicate a strong diagnostic tool, and values near 0.5 indicate that the measurement is no more predictive than random chance.

Results

There were 556 female patients and 146 male patients, and the mean duration of follow-up (and standard deviation) was 12.42 ± 2.0 months. The mean age at the time of surgery was 14.25 ± 2.12 years (range, eight to eighteen years). Five hundred and twenty-three patients had only posterior spinal surgery, 105 had only anterior spinal surgery, and seventy-four had a combined anterior and posterior procedure. There were 108 complications in eighty-one patients, for an overall prevalence of 15.4%. There were forty-three perioperative complications in forty-one patients, forty-four early complications in twenty-three patients, and twenty-one late complications in seventeen patients (Table I). Five patients required a reoperation; two because of early infection and three because of late failure of the implant. The majority of the complications were singular events and are noted under "Other" in Table I; they included chylothorax, superficial venous thrombosis, transverse process failure, laminar fracture, urethral trauma due to catheterization, ileus, lateral femoral cutaneous nerve dysesthesia, intercostal nerve dysesthesia, diarrhea, and allergic reactions to medication.

Preoperative factors that did not correlate with an increased prevalence of complications were age ($p = 0.478$), body mass index ($p = 0.668$), presence of cardiac disease ($p = 0.999$, odds ratio = 1.15), presence of respiratory disease ($p = 0.639$, odds ratio = 1.24), and previous surgery ($p = 0.823$, odds ratio = 1.23). Pulmonary function tests were performed

TABLE I Summary of Non-Neurologic Complications

Complication	No.	Rate (%)	Total for Period
Perioperative			43
Visceral injury	2	0.28	
Excessive bleeding	6	0.85	
Incidental durotomy	2	0.28	
Technical	4	0.57	
Respiratory	10	1.42	
Urinary	3	0.43	
Superior mesenteric artery syndrome	2	0.28	
Other	14	1.99	
Early postoperative			44
Wound infection	5	0.71	
Respiratory	3	0.43	
Superior mesenteric artery syndrome	1	0.14	
Urinary	1	0.14	
Wound hematoma, seroma, or dehiscence	5	0.71	
Ileus	3	0.43	
Other	26	3.70	
Late postoperative			21
Implant failure	3	0.43	
Other	18	2.56	

TABLE II Mean Pulmonary Function Test Results According to Whether the Patient Had No or at Least One Complication

Test*	No Complications	At Least One Complication	P Value
FEV1			
L	2.5	2.4	0.732
% predicted	77.7	81.3	0.371
FVC			
L	2.8	2.8	0.889
% predicted	81.5	84.3	0.500
TLC			
L	4.2	4.2	0.963
% predicted	87.5	90.7	0.661

*FEV1 = forced expiratory volume in one second, FVC = forced expiratory vital capacity, and TLC = total lung capacity.

for 398 (56.7%) of the patients, and they showed no difference in the percent predicted FEV1 (forced expiratory volume in one second) ($p = 0.371$), FVC (forced expiratory vital capacity) ($p = 0.500$), or TLC (total lung capacity) ($p = 0.661$) between patients who had at least one complication and those who did not (Table II).

Four patients had a history of renal disease (polycystic kidney, single kidney, ureteropelvic junction obstruction, and a previous renal transplant). Two of these four patients had a complication after surgery: one had excessive blood loss, and the other had a pleural effusion. Analysis with these small numbers showed patients with a history of renal disease to be 7.90 (95% confidence interval, 1.10 to 56.86) times more likely than other patients to have a non-neurologic complication.

The Lenke curve type ($p = 0.483$), Lenke lumbar modifier ($p = 0.106$), Lenke sagittal thoracic modifier ($p = 0.549$), and region of the major curve ($p = 0.175$) were not found to correlate with the risk of non-neurologic complications. To determine the effect of curve magnitude on the prevalence of complications, the absolute values of all of the curves were added together to obtain a single value. There was no significant difference ($p = 0.355$) in the total absolute curve magnitude between the patients with ($117.0^\circ \pm 34.1^\circ$) and those without ($120.5^\circ \pm 26.0^\circ$) a complication.

The prevalence of perioperative and overall non-neurologic complications in the patients who had had combined anterior and posterior spinal surgery was higher than that in the patients who had had only anterior or only posterior surgery,

although the difference was not significant (Table III). There was no significant difference in the prevalence of non-neurologic complications in the early or late postoperative period among the patients who had anterior surgery only, those who had posterior surgery only, and those who had combined anterior and posterior surgery. There was also no association between the number of levels fused ($p = 0.566$), the type of bone graft used ($p = 0.778$), or diaphragm detachment during an anterior approach ($p = 0.689$) and the prevalence of non-neurologic complications.

The overall prevalence of non-neurologic complications appears to be associated with the time of posterior spinal surgery, total anesthesia time, and blood loss during posterior spinal surgery (Table IV). A trend was also noted in the relationship between blood loss during anterior spinal surgery and the overall rate of non-neurologic complications. The prevalence of non-neurologic complications in the perioperative period was associated with the same three surgical factors. Specifically, the prevalence of respiratory complications (pleural effusion and respiratory distress) was associated with a prolonged posterior spinal surgery time and a prolonged total anesthesia time ($p = 0.001$). No factors were found to correlate with any complication in the early postoperative period. Total anesthesia time was associated with the prevalence of late postoperative non-neurologic complications.

Since blood loss with posterior spinal surgery and total anesthesia time were associated with an increased prevalence of non-neurologic complications, receiver operating characteristic analysis was performed to determine how well these

TABLE III Prevalence of Non-Neurologic Complications According to Surgical Approach

	Posterior Only (%)	Anterior Only (%)	Anterior and Posterior (%)	P Value
Perioperative	5.4	6.7	11.4	0.334
Early postoperative	6.9	5.7	8.6	0.799
Late postoperative	2.5	1.9	2.9	0.909
Overall	11.5	12.4	17.1	0.607

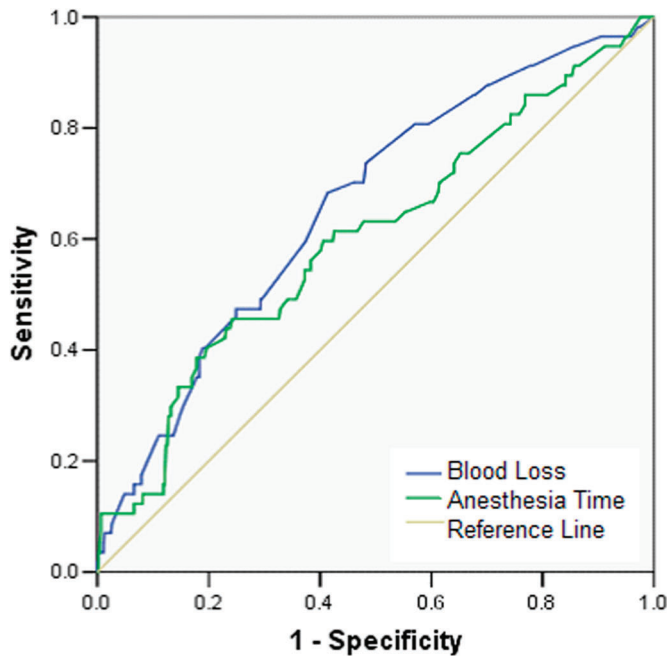


Fig. 1
Receiver operating characteristic plot for blood loss with posterior surgery and total anesthesia time. The area under the receiver operating characteristic curve is equal to 0.660 for posterior blood loss ($p < 0.0001$) and 0.603 for total anesthesia time ($p = 0.011$).

two factors discriminated between patients with a non-neurologic complication and those without such a complication. Figure 1 shows a receiver operating characteristic plot for blood loss with posterior spinal surgery and for total anesthesia time, with sensitivity on the y-axis versus 1 minus specificity on the x-axis. Each point on the jagged lines represents a cut-point for blood loss or total anesthesia time at which the sensitivity and specificity for predicting the presence of a perioperative complication was evaluated. A cut-point of 775 mL of blood loss with posterior surgery and 368 minutes of total anesthesia time produced the best discrimination between patients with and without a complication ($p = 0.011$).

The estimate of the area under the receiver operating characteristic curve, which is a measure of the diagnostic

power of a given measurement, is 0.660 for blood loss during posterior spinal surgery and 0.603 for total anesthesia time. As these values are near 0.50, these parameters are not especially useful as predictors of non-neurologic complications after surgical treatment of adolescent idiopathic scoliosis.

Discussion

Previous reports on the prevalence of complications following surgical correction of adolescent idiopathic scoliosis have been based on retrospective case series^{1,3,5} or have been case reports¹²⁻¹⁴. In the most recent study, performed by the Scoliosis Research Society (SRS) using data in their Morbidity and Mortality Database collected over a three-year period, the prevalence of complications was 5.7% in a cohort 6334 patients². The prevalence of complications following combined anterior and posterior spinal surgery (10.2%) was twice that following anterior surgery alone (5.2%) or posterior surgery alone (5.1%). No analyses to determine correlations between preoperative or operative factors and the prevalence of complications were performed.

We believe that our study is the first in which the prevalence of non-neurologic complications after surgery for adolescent idiopathic scoliosis was identified with use of prospectively collected data from institutions with experienced spine surgeons to determine preoperative and operative factors that increase the prevalence of these complications. The overall prevalence of non-neurologic complications was 15.4%, with the majority occurring in the perioperative (6.13%) and early postoperative (6.27%) periods.

Despite the fact that the most common perioperative complication was respiratory in nature, there was no difference in the pulmonary function test results between the patients who had a complication and those who did not. This finding is in contrast to those in previously published studies showing that patients with preexisting respiratory disease^{15,16} or compromised pulmonary function¹⁷ are at an increased risk for the development of postoperative complications. However, those studies included patients who had congenital and neuromuscular scoliosis, in whom lung development during early childhood may have been compromised. Such patients were excluded from the present cohort. Curve magnitude was also not significantly different between the patients who had a com-

TABLE IV Surgical Parameters According to Whether the Patient Had No or at Least One Complication

Variable	No Complication	At Least One Complication	P Value
Mean surgical time (min)			
Posterior	277.97	316.06	0.029
Anterior	297.70	300.75	0.914
Total	457.35	459.67	0.980
Mean surgical blood loss (mL)			
Posterior	822.22	1114.90	0.012
Anterior	447.07	800.42	0.089
Mean total anesthesia time (min)	355.23	403.23	0.011

plication and those who did not. The group with a complication had an absolute mean curve magnitude of about 4° less than that in the group without complications. Recent technical advances resulting in improved anesthetic techniques, perioperative monitoring, and postoperative care may have contributed to the decreased prevalence of complications despite the presence of compromised lung function and large curves.

Excessive bleeding was the second most common complication in the perioperative period, but the prevalence was still low (0.85%). This low prevalence may have been due to the routine use of blood-sparing techniques during surgery and the lower risk of excessive blood loss in patients with adolescent idiopathic scoliosis in comparison with the risk in patients with neuromuscular disorders^{18,19}. The mean estimated blood loss in the six patients with excessive bleeding was 2337 mL.

The next most common complications were wound infections and wound-related complications such as wound hematoma, seroma, or dehiscence. The prevalence in this study was similar to that in previous reports²⁰, which is not surprising as these procedures involve extensive soft-tissue dissection. Most of the wound complications resolved with nonoperative treatment, with only two patients requiring subsequent open wound drainage.

The most significant preoperative factor associated with the development of non-neurologic complications was a history of renal disease. The question arises of whether, despite the absence of other symptoms indicative of a syndrome or a nonidiopathic cause of these curves, these curves were truly idiopathic. There is no consensus among surgeons on this issue. The increased prevalence of complications in this small cohort may be evidence that the curves in patients with renal disease were not idiopathic. Impaired renal function has been found in several studies to be a significant predictor of postoperative complications^{21,22}. The precise mechanisms through which underlying renal dysfunction increases surgical complications are yet to be elucidated. Possible causes may be decreased excretion of volume loads and impaired platelet function contributing to respiratory complications and bleeding. The two complications noted in the patients with renal problems (excessive bleeding and pleural effusion) are consistent with these pathophysiologic mechanisms.

Although the prevalence of non-neurologic complications was consistently higher, across all time points, in the patients who had undergone combined anterior and posterior spinal surgery, this increase was not significant. This finding is similar to the observation, in the most recent article from the SRS Morbidity and Mortality Committee², that patients who had undergone combined anterior and posterior spinal surgery had twice as many complications as patients who had had anterior or posterior surgery alone. Other authors have reported no major complications in their series of patients with

adolescent idiopathic scoliosis requiring combined anterior and posterior spinal surgery¹.

As was the case in previous reports, excessive bleeding was one of the major complications in the current study. The finding of a considerably larger amount of blood loss during posterior procedures than during anterior procedures is consistent with the findings of previous reports¹⁹ and was associated with the prevalence of non-neurologic complications. This association is to be expected as the loss of large volumes of blood has deleterious effects on the cardiovascular, metabolic, and hemostatic systems^{23,24}.

Prolonged anesthesia time is widely accepted as a risk factor for the development of surgical complications, with reported odds ratios ranging from 1.47 to 3.47²⁵. Although receiver operating characteristic curve analysis showed that 775 mL of blood loss during posterior spinal surgery and 368 minutes of total anesthesia time were the best predictors of non-neurologic complications, those values are not particularly useful as a predictive model since the area under the receiver operating characteristic curve was only 0.660 for posterior blood loss and 0.603 for total anesthesia time.

In this prospective study of patients with adolescent idiopathic scoliosis enrolled consecutively at several sites, the prevalence of non-neurologic postoperative complications following corrective surgery was 15.4%. The few factors noted to significantly increase the rate of complications include a history of renal disease, increased operative blood loss, prolonged posterior spinal surgery time, and total anesthesia time. ■

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