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Morbidity and mortality associated with spinal surgery in children: a review of the Scoliosis Research Society morbidity and mortality database

Clinical article

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Object. Currently, few studies regarding morbidity and mortality associated with operative treatment of spinal disorders in children are available to guide the surgeon. This study provides more detailed morbidity and mortality data with an analysis of 23,918 pediatric cases reported in the multicenter, multisurgeon Scoliosis Research Society morbidity and mortality database.

Methods. The Scoliosis Research Society morbidity and mortality database was queried for the years from 2004 to 2007. The inclusion criterion was age 18 years or younger. Cases were categorized by operation type and diagnosis. Details on the surgical approach, use of neurophysiological monitoring, and type of instrumentation were recorded. Major perioperative complications and deaths were evaluated. Statistical analysis was performed with chi-square testing, with a p value < 0.05 considered significant.

Results. A total of 23,918 patients were included. The mean age was 13 ± 3.6 years (± SD). Spinal pathology included the following: scoliosis (in 19,642 patients), kyphosis (in 1455), spondylolisthesis (in 748), trauma (in 478), and other (in 1595 patients). The overall complication rate was 8.5%. Major complications included wound infections (2.7%), new neurological deficits (1.4%), implant-related complications (1.6%), and hematomas (0.4%). The most common medical complications were respiratory related (0.9%). Morbidity rates differed based on pathology, with patients undergoing treatment for kyphosis and spondylolisthesis having higher overall rates of morbidity (14.7% and 9.6%, respectively). Patients undergoing revision procedures (2034) or corrective osteotomies (2787) were more likely to suffer a complication or new neurological deficit. The majority of these deficits improved at least partially. Thirty-one deaths were reported for an overall rate of 1.3 per 1000. Respiratory complications were the most common cause of mortality (13 cases). Twenty-six of the deaths occurred in children undergoing scoliosis correction.

Conclusions. Spinal surgery in children is associated with a range of complications depending on the type of operation. Mortality rates for all indications and operations were low. Patients undergoing more aggressive corrective procedures for deformity are more likely to suffer complications and new neurological deficits.
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Key Words • **pediatric neurosurgery** • **morbidity** • **mortality** • **spinal surgery**

The operative management of spinal pathology in the pediatric population is distinctly different from that in adults. For example, children are less likely to suffer from degenerative diseases and are more likely to present with congenital or acquired deformity. The modern surgical management of these patients can positively influence quality of life and future development.[10]

When a surgeon is planning surgical intervention, an understanding of the potential morbidity involved is essential in counseling the patient and family. For preoperative counseling of risks for morbidity and mortality, many surgeons turn to the literature. However, regarding spinal procedures performed in children, few studies have

Abbreviations used in this paper: IRB = institutional review board; SRS = Scoliosis Research Society.

reported specifically on the perioperative morbidity and mortality, and the studies that are available suffer from multiple limitations, including small numbers of patients, focus on a single procedure or complication, outdated surgical techniques, and confinement to single-surgeon or single-institution experiences. To date, there has been no specific analysis of complications associated with spinal surgery in children in total based on a large multicenter series.[1–4,6,7,13,14,17]

In this manuscript, we present data from the SRS morbidity and mortality database relating to surgery in the pediatric population. The utilization of this database provides a multicenter and multisurgeon analysis of a large sample of children who have undergone spine surgery. This database provides information on perioperative complications associated with the treatment of scoliosis, kyphosis, spondylolisthesis, and trauma. Recent years were analyzed to assess complication rates that reflect modern techniques, such as segmental pedicle screw fixation, osteotomies, and reduction techniques. The morbidity and mortality data in this study suggest that spinal surgery in children is associated with a range of complications depending on type of operation, but it has an overall low mortality rate. This information may prove useful in counseling patients on the potential risks of operative management, and it may help further ongoing efforts to improve the safety of patient care.

Methods

Prior to application for active membership in the SRS, surgeons must complete a 5-year period of candidate membership. Candidate members are required to collect and submit data on all spine cases treated, including all associated morbidity and mortality. Active and international members are also encouraged to submit their cases.[2,5,15,16] The SRS membership includes a wide range of surgeons from private practice and academic institutions. The majority of SRS members are in nonacademic practices. Throughout the data acquisition period, more than 50% of SRS members contributed to the SRS morbidity and mortality database. This shows that there is a wide representation of surgeons and practices in the database.

Data were gathered using a questionnaire developed by the SRS Morbidity and Mortality Committee in the early 1990s, which was updated to a secure internet-based data entry form in 2001. The SRS has invested substantial resources in this database and emphasizes to its membership the importance of accurate and consistent reporting. All data are de-identified upon entry into the database, and the patient, surgeon, and institution cannot be determined. Reported complications do not influence whether a candidate is offered membership, given that the SRS Membership Committee is provided only with an indication of whether each candidate member has completed the required case submission process, and not the number or types of complications for each candidate. This project was submitted to the Hospital for Special Surgery IRB and was determined to be exempt from IRB approval based on the use of de-identified data (IRB No. 29045).

To assess the incidence of morbidity and mortality associated with spinal surgery in children, all reported surgical cases reported from 2004 through 2007 were extracted from the SRS database. Inclusion criteria for this study included a patient age 18 years or younger. All diagnoses of spinal surgery in children were included (trauma, scoliosis, kyphosis, spondylolisthesis, and other conditions [for example, tumor or infection]).

For each case included in the present study, age, procedure type, and the presence or absence of complications, including death, were extracted from the database. In cases in which a complication occurred, the complications were classified into categories (for example, pulmonary embolus, deep venous thrombosis, and wound infection). Information regarding the occurrence of, extent of (spinal cord, cauda equina, or nerve root), and recovery from (complete, partial, or none) new neurological deficits was also available and extracted. Information on comorbidities, long-term follow-up, and objective outcome measures was not consistently included in the database; therefore, analyses related to these parameters were not performed in the present study.

Statistical comparisons between subgroups were performed using the Fisher exact or Pearson chi-square tests. A p value < 0.05 was considered statistically significant. All statistical analyses were 2-sided. Comparisons were made between patients who underwent revision versus those who underwent first-time surgery. As a measure of complexity, comparisons were also made between groups that included instrumentation versus those that did not, and between cases that included a corrective osteotomy or reduction versus those that did not.

Results

Of the 108,419 cases reported to the SRS morbidity and mortality database during the assessed time interval, 23,918 patients (22%) were 18 years of age or younger and were included in the present study. The mean age for included patients was 13 ± 3.6 years (± SD). While a majority of patients were treated for a diagnosis of spinal deformity, a wide variety of cases were represented in this sample. A total of 19,642 patients were treated for scoliosis, while 1455 and 748 were treated for kyphosis and spondylolisthesis, respectively; 478 patients were treated for trauma, and 1595 patients were treated for other indications, which included diagnoses such as infection or tumor. Figure 1 illustrates the numbers of cases with each diagnosis and the percentage of procedures within each diagnosis that were revision procedures.

A total of 2040 complications were reported, for an overall complication rate of 8.5%. Table 1 presents the distribution of complications. Infection was the most common source of morbidity, with an overall rate of 2.7% (1% superficial and 1.7% deep wound infections). Implant-related complications were reported in 1.6% of patients. Respiratory complications were the most common source of medical morbidity (0.9%). Hematomas and durotomies were less common at 0.4% and 0.5%, respectively. Pulmonary embolus and deep venous thrombosis were reportedly relatively rare occurrences (0.03% each).

Morbidity and mortality by surgical indication are

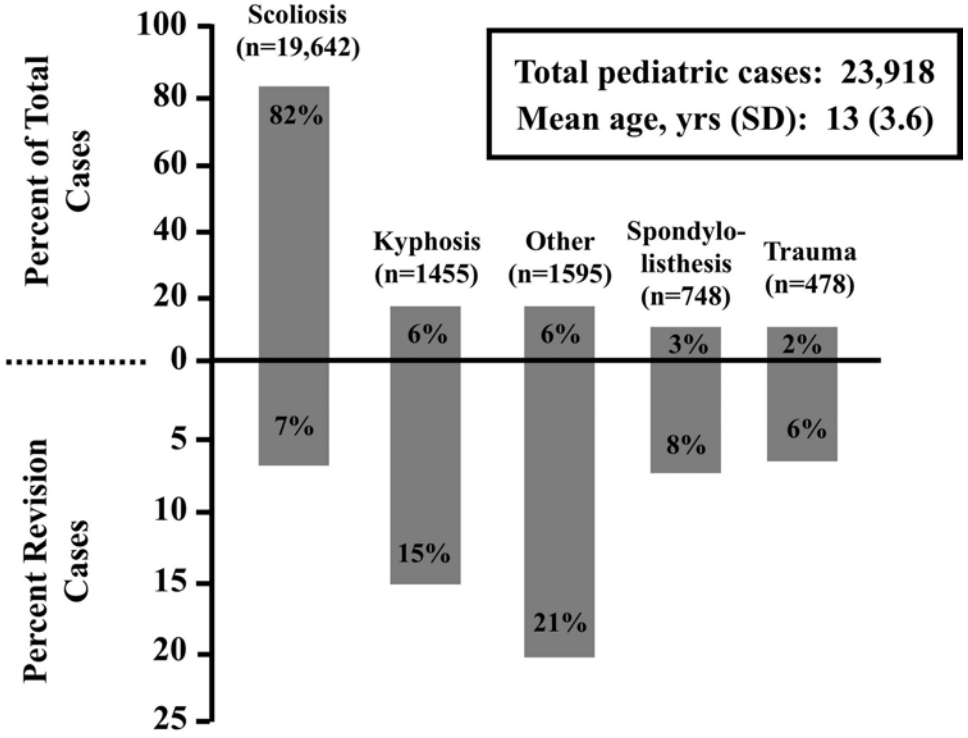

Fig. 1. Case distribution by diagnosis and revision status.

listed in Tables 2 and 3. The morbidity and mortality rates differed based on diagnosis. Patients treated for kyphosis or spondylolisthesis had the highest complication rates (15% and 10%, respectively), followed by patients treated for a diagnosis of scoliosis (8%). The overall mortality rate was 0.13% (1.3 per 1000 cases). Cases performed for a diagnosis of kyphosis or trauma had the highest mortality rates (0.21% each; Table 2). Death was caused primarily by respiratory (11 cases) and cardiac (9 cases) reasons. Sepsis, pulmonary embolism, and reactions to anesthesia were also cited.

New neurological deficits were reported in 324 patients, for an overall rate of 1.4%. Of these, 148 (0.6%) were nerve root deficits, 16 (0.1%) were cauda equina deficits, 124 (0.5%) were incomplete spinal cord deficits, 27 (0.1%) were complete spinal cord deficits, and 9 new deficits were not classified. Most patients suffering a new neurological deficit recovered to some extent; 185 (57% of affected patients) made a complete recovery and 117 (36% of affected patients) partially recovered from their deficits. Only 16 patients (5% of affected patients) were reported to have made no recovery. Of these 16 patients, 10 had complete spinal cord deficits, 3 were cauda equina deficits, 2 had nerve root deficits, and 1 had an incomplete spinal cord. For 6 patients, recovery data were not available. Different diagnoses had different rates ($p = 0.001$) of new neurological deficit with spondylolisthesis (5.9%) and kyphosis (3.7%) having higher rates than trauma (1.5%) and scoliosis (1%). Patients treated with implants had a higher rate of suffering a new neurological deficit (1.4% vs 0.9%, $p = 0.02$). Whether neuromonitoring was used did not appear to reduce the

TABLE 1: Complications of pediatric spinal surgery by category in 23,918 patients*

Complication	No. of Patients (%)
overall	2040 (8.5)
mortality	31 (0.13)
superficial wound infection	248 (1)
deep wound infection	413 (1.7)
pulmonary embolus	8 (0.03)
respiratory	224 (0.9)
hematoma	107 (0.4)
durotomy	115 (0.5)
implant related	371 (1.6)
DVT	9 (0.04)
new neuro deficit	324 (1.4)
other	190 (0.8)

* DVT = deep venous thrombosis; neuro = neurological.

TABLE 2: Spinal surgery morbidity and mortality rates in children categorized by diagnosis

Disease Process	No. of Patients	No. of Complications (%)	No. of Deaths (%)
scoliosis	19,642	1619 (8.2)	26 (0.13)
kyphosis	1,455	214 (14.7)	3 (0.21)
spondylolisthesis	748	72 (9.6)	0 (0)
trauma	478	36 (7.5)	1 (0.21)
other*	1595	99 (6.2)	1 (0.06)

* Includes pathologies such as infection and tumor.

overall new neurological deficit rate, as monitored patients had a higher rate of new deficits (1.5% vs 0.8%, p = 0.001), perhaps reflecting a disproportionate use of monitoring in higher risk cases.

To determine if the morbidity rate was affected by the complexity of the operation, we examined rates based on operative techniques/types. Specifically, we examined whether patients who underwent revision, fusion, reduction, or osteotomy were more likely to have had a complication than those who did not undergo these procedures. Complications by operation type are listed in Table 3. A total of 2034 patients were reported to have undergone revision surgery. These patients were significantly more likely than first-time patients to have had a complication (12% vs 8%, respectively; p = 0.001). Patients undergoing revisions, in comparison with first-time patients, were more likely (p < 0.05) to have had a deep wound infection (4% vs 1.5%, respectively), durotomy (0.9% vs 0.4%, respectively), implant-related complication (3% vs 1.4%, respectively), and new neurological deficit (1.9% vs 1.3%, respectively). Patients undergoing fusions (19,936) did not have a higher overall complication rate than those who did not undergo fusion (3982 [Table 3]). However, fusions were associated with a higher rate of new neurological deficits (1.5% vs 0.7%, p = 0.001).

A reduction was performed in 533 patients. These were predominantly patients with spondylolisthesis, and these patients did not have a significantly different rate of overall complications than those treated without reduction. In terms of the occurrence of new neurological deficits, patients treated with reduction had a more than 5-fold higher rate of new neurological deficits (7.3% vs 1.2%, p = 0.001). Patients treated with osteotomies (for example, Smith-Petersen osteotomies, pedicle subtraction osteotomies, and vertebral column resections) were 50% more likely to suffer a complication, compared with those whose procedure did not include an osteotomy (21,131 patients, 12% vs 8%; p = 0.001). Patients who underwent an osteotomy were more likely to have had a deep wound infection (2.2% vs 1.6%, p = 0.034) and implant-related complications (1.9% vs 1.5%, p = 0.001). They were also more than twice as likely to suffer a new neurological deficit (2.8% vs 1.2%, p = 0.001). Collectively, these findings suggest that revision procedures and procedures requiring reduction or an osteotomy are associated with higher rates of new neurological deficits.

TABLE 3: Complications and new neurological deficits by operation classifier

	Rate (%)			
Op Type	Complication	p Value	New Neurological Deficit	p Value
revision vs 1st op	12 vs 8	0.001	1.9 vs 1.3	0.02
fusion vs no fusion	9 vs 8	0.75	1.5 vs 0.7	0.001
reduction vs no reduction	10 vs 8	0.13	7.3 vs 1.2	0.001
osteotomy vs no osteotomy	12 vs 8	0.001	2.8 vs 1.2	0.001

Discussion

In this study, we report on the morbidity and mortality of one of the largest samples of spinal surgery performed in children. As this is a multicenter, multisurgeon database, we are able to report morbidity profiles on less common procedures and provide a perspective on the safety of spinal surgery performed in children in the aggregate. While previous reports have addressed specific operations or complication in small series of children, none has reported comprehensive morbidity and mortality data on spinal surgery in children using modern techniques.[1,4,7–9,12,13]

In the present series, few patients suffered from more common "adult" complications, such as deep venous thrombosis or pulmonary embolus. The most common medical complications were respiratory related. Durotomy was relatively uncommon when compared with adults.[5] Mortality rates were low across different diagnoses and operation types. Of concern were rates of infection and new neurological deficits that ranged from 1% to 4% depending on disease process or operation type. These results suggest that the 2 most common major complications may be infection and development of a new neurological deficit. Patients undergoing revision are especially at risk. However, all patients who may require an osteotomy or reduction should be made aware of the increased risk of a new neurological deficit.

Several previous reports have addressed the issue of infection related to instrumented spinal fusion in children. This study's finding of an overall rate of 2.7% is comparable with prior reports or rates, ranging from 3.4% to 4.4%.[9,12] These prior studies were single center and analyzed populations of fewer than 500 patients. This multicenter study confirms a significant risk of infection in these cases and argues against infection being considered a "never" event.[11]

Previous reports of new neurological deficits in pediatric populations have reported lower rates than those reported here. A study on the safety of pedicle screws in children for treating a variety of pathologies reported a neurological complication rate of 0.8% in 229 patients.[1] A rate of neurological deficit of 0.69% was reported for 1301 consecutive adolescent patients with idiopathic scoliosis.[4] The rate in our study most likely is higher because of the inclusion of a higher number of patients undergoing reduction and osteotomy procedures.

There are several limitations of this study. The SRS database relies on the accurate submission of data by its members. Collection and maintenance of these data are solely supported by the SRS, and no external funding source exists to facilitate formal auditing of the data. It is likely that major complications, such as infections, new neurological deficits, and deaths are more accurately reported; however, this cannot be verified.[2] As a means of validating the SRS morbidity and mortality database for the assessment of perioperative complications, a recent report documented complication rates of 3 common spine procedures in adults, based on the SRS morbidity

and mortality database, and the study demonstrated that these rates are comparable to those previously reported in the literature for these procedures.[15] Nevertheless, it remains possible that all complications were not thoroughly documented, which could result in the underestimation of complication rates.

Although the data are reported prospectively, this study is retrospective and as such is subject to the weaknesses inherent to such investigations, including confounding variables and reporting bias. In addition, since the SRS Morbidity and Mortality database is not designed to capture long-term outcomes, it is impossible to assess the potential clinical impact of complications. In addition, the database does not provide for analysis of pseudarthrosis and other late complications (for example, acquired deformity), which would be of concern to pediatric patients undergoing these procedures.

Conclusions

Varying rates of complications are reported for pediatric patients undergoing spinal surgery. Patients undergoing more complicated procedures, such as revision, reduction, or osteotomy procedures were more likely to have increased rates of newly acquired neurological deficits. Most of these deficits resolved either completely or partially. Patients requiring treatment for kyphotic deformities or spondylolisthesis were more likely to suffer morbidity. Overall mortality rates for the pediatric population treated with spinal surgery are low.

Disclosure

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Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: Perra. Analysis and interpretation of data: Fu. Drafting the article: Fu. Critically revising the article: all authors. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: Fu, Smith.

References

1. Brown CA, Lenke LG, Bridwell KH, Geideman WM, Hasan SA, Blanke K: Complications of pediatric thoracolumbar and lumbar pedicle screws. **Spine 23:**1566–1571, 1998
2. Coe JD, Arlet V, Donaldson W, Berven S, Hanson DS, Mudiyam R, et al: Complications in spinal fusion for adolescent idiopathic scoliosis in the new millennium. A report of the Scoliosis Research Society Morbidity and Mortality Committee. **Spine 31:**345–349, 2006
3. Coe JD, Smith JS, Berven S, Arlet V, Donaldson W, Hanson D, et al: Complications of spinal fusion for Scheuermann kyphosis: a report of the Scoliosis Research Society Morbidity and Mortality Committee. **Spine 35:**99–103, 2010
4. Diab M, Smith AR, Kuklo TR: Neural complications in the surgical treatment of adolescent idiopathic scoliosis. **Spine 32:**2759–2763, 2007
5. Fu KMG, Smith JS, Polly DW Jr, Perra JH, Sansur CA, Berven SH, et al: Morbidity and mortality in the surgical treatment of 10,329 adults with degenerative lumbar stenosis. Clinical article. **J Neurosurg Spine 12:**443–446, 2010
6. Hod-Feins R, Abu-Kishk I, Eshel G, Barr Y, Anekstein Y, Mirovsky Y: Risk factors affecting the immediate postoperative course in pediatric scoliosis surgery. **Spine 32:**2355–2360, 2007
7. Hod-Feins R, Anekstein Y, Mirovsky Y, Barr J, Abu-Kishk I, Lahat E, et al: Pediatric scoliosis surgery—the association between preoperative risk factors and postoperative complications with emphasis on cerebral palsy children. **Neuropediatrics 38:**239–243, 2007
8. Kamerlink JR, Errico T, Xavier S, Patel A, Patel A, Cohen A, et al: Major intraoperative neurologic monitoring deficits in consecutive pediatric and adult spinal deformity patients at one institution. **Spine 35:**240–245, 2010
9. Linam WM, Margolis PA, Staat MA, Britto MT, Hornung R, Cassedy A, et al: Risk factors associated with surgical site infection after pediatric posterior spinal fusion procedure. **Infect Control Hosp Epidemiol 30:**109–116, 2009
10. Marks M, Petcharaporn M, Betz RR, Clements D, Lenke L, Newton PO: Outcomes of surgical treatment in male versus female adolescent idiopathic scoliosis patients. **Spine 32:**544–549, 2007
11. Michaels RK, Makary MA, Dahab Y, Frassica FJ, Heitmiller E, Rowen LC, et al: Achieving the National Quality Forum's "Never Events": prevention of wrong site, wrong procedure, and wrong patient operations. **Ann Surg 245:**526–532, 2007
12. Milstone AM, Maragakis LL, Townsend T, Speck K, Sponseller P, Song X, et al: Timing of preoperative antibiotic prophylaxis: a modifiable risk factor for deep surgical site infections after pediatric spinal fusion. **Pediatr Infect Dis J 27:**704–708, 2008
13. Molinari RW, Bridwell KH, Lenke LG, Ungacta FF, Riew KD: Complications in the surgical treatment of pediatric high-grade, isthmic dysplastic spondylolisthesis. A comparison of three surgical approaches. **Spine 24:**1701–1711, 1999
14. Puisto V, Kääriäinen S, Impinen A, Parkkila T, Vartiainen E, Jalanko T, et al: Incidence of spinal and spinal cord injuries and their surgical treatment in children and adolescents: a population-based study. **Spine 35:**104–107, 2010
15. Smith JS, Fu KMG, Polly DW Jr, Sansur CA, Berven SH, Broadstone PA, et al: Complication rates of three common spine procedures and rates of thromboembolism following spine surgery based on 108,419 cases: a report from the Scoliosis Research Society Morbidity and Mortality Committee. **Spine 35:**2140–2149, 2010
16. Smith JS, Shaffrey CI, Sansur CA, Berven SH, Broadstone PA, Choma TJ, et al: Rates of infection following spine surgery based on 108,419 procedures: a report from the Scoliosis Research Society Morbidity and Mortality Committee. **Spine** [in press]
17. Transfeldt EE, Mehbod AA: Evidence-based medicine analysis of isthmic spondylolisthesis treatment including reduction versus fusion in situ for high-grade slips. **Spine 32 (19 Suppl):**S126–S129, 2007

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