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Morbidity and Mortality in the Surgical Treatment of Six Hundred Five Pediatric Patients With Isthmic or Dysplastic Spondylolisthesis

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Study Design. Retrospective analysis of prospectively collected database.

Objective. To analyze the rate of complications, including neurologic deficits, associated with operative treatment of pediatric isthmic and dysplastic spondylolisthesis.

Summary of Background Data. Pediatric isthmic and dysplastic spondylolisthesis are relatively uncommon disorders. Several prior studies have suggested a high rate of complication associated with operative intervention. However, most of these studies were performed with sufficiently small sample sizes such that the presence of one complication could significantly affect the overall rate. The Scoliosis Research Society (SRS) prospectively collects morbidity and mortality (M&M) data from its members. This multicentered, multisurgeon database permits analysis of the surgical treatment of this relatively rare condition on an aggregate scale and provides surgeons with useful information for preoperative counseling.

Methods. Patients who underwent surgical treatment for isthmic or dysplastic spondylolisthesis from 2004 to 2007 were identified from the SRS M&M database. Inclusion criteria for analysis included age ≤21 and a primary diagnosis of isthmic or dysplastic spondylolisthesis.

Results. Of 25,432 pediatric cases reported, there were a total of 605 (2.4%) cases of pediatric dysplastic (n = 62, 10%) and isthmic (n = 543, 90%) spondylolisthesis, with a mean age of 15 years (range, 4-21). Approximately 50% presented with neural element compression, and less than 1% of cases were revisions. Surgical procedures included fusions in 92%, osteotomies in 39%, and reductions in 38%. The overall complication rate was 10.4%. The most common complications included postoperative neurologic deficit (n = 31, 5%), dural tear (n = 8, 1.3%), and wound infection (n = 12, 2%). Perioperative deep venous thrombosis and pulmonary embolus were reported in 2 (0.3%) and 1 (0.2%) patients, respectively. There were no deaths in this series.

Conclusion. Pediatric isthmic and dysplastic spondylolisthesis are relatively uncommon disorders, representing only 2.4% of pediatric spine procedures in the present study. Even among experienced spine surgeons, surgical treatment of these spinal conditions is associated with a relatively high morbidity.

Key words: pediatric, isthmic, dysplastic, spondylolisthesis, reduction, morbidity. **Spine 2011;36:308–312**

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Isthmic and dysplastic spondylolisthesis are the result of pars defects and dysplastic facets, respectively. Pars abnormalities are present in a sizable proportion of the pediatric population, with reports suggesting that 4.4% of children at age 6 have either unilateral or bilateral pars defects.[1] The natural history of most low grade cases is benign, with long-term observation reporting little radiographic or symptomatic progression.[1,2] Given this natural history, operative intervention for this condition remains a small proportion of most spinal surgeons' practice. However, when such operations need to be performed, *i.e.*, for high grade symptomatic patients, they can result in significant morbidity. Complications

ranging from wound infections to neurologic deficits have been reported to occur frequently in both historic and modern series.[3–16] Reduction procedures appear to have a higher complication rate, with some reports indicating a higher incidence of neurologic complications with reduction in the pediatric population.[6,7,9,12,17] However, the case numbers reported in these series are small, usually less than 50, and most often only 10 to 15, likely due to the infrequency of surgical treatment of this condition. To obtain a larger population from which to ascertain benchmark complication rates, we queried the multisurgeon, multicenter Scoliosis Research Society (SRS) Morbidity and Mortality (M&M) database.

MATERIALS AND METHODS

Before application for active membership in the SRS, surgeons must complete a 5-year period of candidate membership. International membership status is also available for surgeons outside of the United States. Candidate members are required to prospectively collect and submit data on all spine cases performed, including all associated morbidity and mortality. Active and international members are also encouraged to submit their cases.[18] Data are gathered using a questionnaire that was developed by the SRS M&M Committee in the early 1990s and 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 deidentified on entry into the database. This project was submitted to the Hospital for Special Surgery (New York, NY) Institutional Review Board (IRB) and was determined to be exempt from IRB approval based on the use of deidentified data (IRB number 29045).

In order to assess the incidence of complications associated with the surgical treatment of pediatric isthmic and dysplastic spondylolisthesis, all reported surgical cases with these diagnoses from 2004 through 2007 were extracted from the SRS database. Inclusion criteria for this study were age $\leq$21 and a primary diagnosis of isthmic or dysplastic spondylolisthesis. Excluded were patients who received operations for other indications, such as concomitant burst fracture.

For each case included in the present study, the following data were extracted: patient age, diagnosis, presence of preoperative neural compression, procedure type (reduction, osteotomy, instrumentation), electrophysiological monitoring parameters, and presence or absence of complications and/or mortality. Complications were additionally subclassified (*e.g.,* pulmonary embolus, deep venous thrombosis, *etc.*). Occurrence of, extent of (spinal cord, *cauda equina,* or nerve root), and recovery from (none, partial, or complete) new neurologic deficits were also available and extracted. Not consistently included in the database were information on spondylolisthesis grade, ASA grade, success of reduction, long-term follow-up, and objective outcome measures. Therefore, with the exception of Meyerding Grade for patients from 2007, analyses related to these parameters were not performed in the present study. Although presence of preoperative neural element compression was not specifically collected as part of the SRS M&M database reporting process, surgeons did report whether a direct decompression of the neural elements was performed as part of the surgical procedure. In the present study, the reported performance of a direct decompression was used as a surrogate for the presence of preoperative neural element compression.

Statistical analysis was performed using SPSS software (SPSS Inc., Chicago, IL). Statistical comparisons between subgroups were performed using Fisher exact test. A $P < 0.05$ was considered statistically significant. Comparisons of complication occurrence, neurologic deficit occurrence, preoperative neurologic element compression, and specific complications were made between those who underwent reduction procedures *versus* those who underwent *in situ* fusion procedures. Comparison of the presence of preoperative neurologic element compression with the occurrence of new neurologic deficits was also performed. In addition, comparisons of age and electrophysiological monitoring status with complications or new neurologic deficits were also performed.

RESULTS

Of the 25,432 pediatric spine cases reported during the 4 years from 2004 to 2007, 605 cases of isthmic or dysplastic spondylolisthesis were identified, representing 2.4% of the total. Of the 605 cases reported in the database, 63 were reported to have complications, resulting in a 10.4% overall complication rate. No deaths were reported. The most common complications are listed in Table 1 in both the aggregate and by the presence or absence of a reduction procedure. By far, the most common complication was a new postoperative neurologic deficit, occurring in 31 cases and accounting for approximately 50% of the complications. Of the 31 new neurologic deficits, 30 were nerve root injuries, and 1 was a *cauda equina* syndrome. Four (13%) were reported to have occurred intraoperatively, presumably determined from electromonitoring. Nineteen (61%) occurred acutely within 24 hours of surgery, and 8 (26%) were reported to have occurred in a delayed fashion of greater than 24 hours after surgery. Of the 31 patients with new neurologic deficit, 29 (94%) had recovery from these deficits, with 15 making complete and 14 making partial recoveries. One patient had no recovery, and 1 patient's recovery was not specified. Two revisions were performed to remove implants after deficits occurred, and both of these patients were reported to have made complete recoveries.

The majority of patients undergoing fusion procedures were instrumented (n = 518). There was no statistically significant difference in terms of complication rate (11% *vs.* 7.5%, $P = 0.3$) or rate of new neurologic deficit (5.8% *vs.* 1.2%, $P = 0.1$) between those instrumented and those not instrumented. In addition, there were no differences between the complication (10.6% *vs.* 9.1%, $P = 0.7$) and new neurologic deficit (5.3% *vs.* 4%, $P = 0.8$) rates in those patients over age 12 (n = 506) *versus* those under age 12 (n = 99).

A striking difference illustrated in Table 1 is the difference in complication rates between those patients undergoing a reduction procedure and those that did not. The overall complication rate is almost double in patients undergoing

TABLE 1. Complications in 605 Cases of Surgically Treated Pediatric Isthmic/Dysplastic Spondylolisthesis

Complication, No. (%)	All (n = 605)	Reduction (n = 229, 38%)	No Reduction (n = 376, 62%)	*P*
Wound infection				
Superficial	7 (1.2)	2 (0.9)	5 (1.3)	0.72
Deep	5 (0.8)	1 (0.4)	4 (1.1)	0.66
Neurological injury	31 (5.1)	23 (10.0)	8 (2.1)	0.001
Implant related	2 (0.3)	1 (0.4)	1 (0.3)	0.9
Dural tear	8 (1.3)	5 (2.2)	3 (0.8)	0.16
Death	0 (0)	0 (0)	0 (0)	NA
Pulmonary embolus	1 (0.2)	0 (0)	1 (0.3)	1
DVT	2 (0.3)	0 (0)	2 (0.5)	0.53
Other	7 (1.2)	1 (0.4)	6 (1.6)	0.07
Visual acuity change	0 (0)	0 (0)	0 (0)	NA
Total complications (%)	63 (10.4)	33 (14.4)	30 (7.9)	0.01

reduction ($P = 0.01$). Most of this difference can be attributed to the difference in the rate of new neurologic deficits. Neurologic deficits developed in 10% (23/229) of reduced patients *versus* only 2% (8/376) of patients without reduction ($P = 0.001$). Electrophysiological monitoring did not necessarily mitigate the rate of new neurologic deficits, as significantly more patients who had electromonitoring (29/422 or 6.9%) developed deficits than those who were not monitored (2/183 or 1%) ($P = 0.02$), although this is likely related to the use of such monitoring with more complex cases. In patients undergoing reduction, there was no significant difference in the development of neurologic deficit between those who were monitored (22/189) and those who were not (1/40) ($P = 0.09$).

Specific electromonitoring methods were recorded in the database. Most procedures that were monitored employed multiple methods. Of those patients monitored with EMG, 73% were also monitored with SSEP and 50% were also monitored with MEP. Of those who had SSEP monitoring, 63% also underwent MEP monitoring. Determining the neurologic deficit rate for a specific modality is therefore not readily possible from the database. In 8 of the monitored cases, abnormalities were detected, of which 7 employed EMG. Of these 8 cases, 5 resulted in new neurologic deficit, whereas the remaining 3 did not have a new deficit. Whether or not the lack of deficits in these 3 cases was due to a change in the procedure secondary to monitoring findings can not be ascertained from the information in the database.

Presence of preoperative neurologic element compression that warranted direct decompression was present in 49% (296) of the patients. Patients undergoing reduction procedures were significantly more likely to have had compression compared with those undergoing *in situ* fusion procedures (75% *vs.* 33%; $P = 0.001$). Also, of note, patients with preoperative compression were more likely to develop new neurologic deficits (9.5% *vs.* 1%; $P = 0.001$). Beginning in 2007 Meyerding grades were recorded and an analysis could be performed based on grade for 127 of the patients. Patients with high grade spondylolisthesis (Grades 3–5) were more likely than patients with low grade spondylolisthesis (grades 1–2) to require decompression (66% *vs.* 40%, $P = 0.004$), undergo reduction (76% *vs.* 32%, $P = 0.001$), and suffer new postoperative neurologic deficit (11.3% *vs.* 1.4%, $P = 0.021$). Few of the patients were treated with minimally invasive procedures (43/605). While none of these patients were reported to have developed new neurologic deficits, the difference did not reach statistical significance ($P = 0.16$).

DISCUSSION

The surgical treatment of pediatric isthmic and dysplastic spondylolisthesis has been associated with a high rate of surgical complications (Table 2) .[4,7,9,10,17,19] This study, which reports the data from the SRS M&M database, provides morbidity data on 605 pediatric isthmic/dysplastic spondylolisthesis cases. The overall rate of major complications of 10.4% is comparable to previous studies. These prior studies report variable rates ranging from 5% to 40%.[3,4,7–10,12,14–16,19,20] However, most of these studies are sufficiently small that the presence of a single complication can greatly affect the overall complication rate. The SRS M&M database provides for a larger population as it is a multicenter and multisurgeon self reported prospective database. A recent report has supported its utility for conditions such as adolescent idiopathic scoliosis.[18]

Another variable found in most of the previous studies was the reporting of pseudarthrosis as a complication. These rates ranged from 0% to 19%.[2,3,7,8,10,19] The SRS M&M database does not specifically report pseudarthrosis as a complication as it is not designed for reporting long-term outcomes. Therefore this report does not provide data on this complication,

TABLE 2. Summary of Prior Reports on the Incidence of Complications With Surgical Treatment of Pediatric Isthmic and Dysplastic Spondylolisthesis

Study	No. Patients	Age Group	Procedure	Comp Rate Excluding Pseudoarthrosis	Neuro Deficit Rate
Boxall *et al*[9]	39	Children and adolescents	Reduction or in situ fusion	10%	5.1%
Stanton *et al*[21]	20	Children and adolescents	*In situ* fusion	5%	5%
Dick and Schnebel[10]	15	Adolescents and young adults	Reduction	40%	27%
Lindholm *et al*[3]	57	Children and adolescents	Reduction	7%	1.7%
Schoenecker *et al*[15]	189	Children and adolescents	*In situ* fusion	NA	6.3%
Poussa *et al*[4]	22	Adolescents	Reduction or *in situ* fusion	18%	4.5%
Hu *et al*[19]	16	Adolescents and young adults	Reduction	25%	25%
Muschik *et al*[12]	59	Children and adolescents	Reduction and *in situ* fusion	12%	3.4%
Molinari *et al*[7]	32	Children and adolescents	Reduction or *in situ* fusion	22%	11%
Roca *et al*[20]	14	Adolescents and young adults	*In situ* fusion	14%	14%
Shufflebarger *et al*[16]	18	Adolescents	Reduction	27%	0%
Ruf *et al*[14]	27	Adolescents and young adults	Reduction	26%	22%
Helenius *et al*[8]	70	Children and adolescents	*In situ* fusion	10%	5.7%

and the overall complication rate should be viewed accordingly. Specifically, as previous studies suggest a lower pseudarthrosis rate for reduction procedures,[6] the overall difference in complications between *in situ* fusion and reduction may decrease if pseudarthrosis could be included.

Past studies have suggested that pediatric patients undergoing reduction are more likely to suffer neurologic deficits.[4,7] The data from the SRS M&M database supports this, as patients undergoing reduction had a 5 times higher rate of developing new neurologic deficits. However, it should be noted that patients undergoing reduction were more likely to have had preoperative neurologic compression. One of the shortcomings of this database is its lack of data on specific preoperative parameters, including degree of slip. If one takes the reporting of preoperative neurologic element compression as a proxy for increased degree of spondylolisthesis, then it suggests that those patients undergoing reduction were more likely to have a higher grade of spondylolisthesis. It should also be noted that patients with preoperative neurologic element compression were more likely to develop new neurologic deficits after surgery. This begs the question of whether or not patients undergoing reduction were more prone to deficit due to the nature of their deformities and not necessarily because of the procedure performed. Recent studies with advanced reduction techniques have suggested that reduction can be performed safely with no or only minor transient neurologic deficits.[14,16] However, our analysis of complication rates based on the subset in 2007 in which Meyerding grades were reported suggests that many patients with high grade slips, underwent reduction, and suffered a significant rate of new neurologic deficit after surgery.

The present study has several strengths. This is the largest study to date to evaluate the incidences of complications in the surgical treatment of isthmic/dysplastic pediatric spondylolisthesis by a large group of spinal deformity surgeons. Furthermore, since all of these cases were submitted during a recent 4-year period, they likely reflect a relatively current standard of care.

There are several limitations of this study. The SRS database relies on the accurate submission of data by members. Thus, it is possible that not all complications have been thoroughly documented, which could result in underestimation of complication rates. No method currently exists to evaluate the completeness and accuracy of the data, instead relying on good faith of those surgeons reporting. It is likely that major complications and neurologic complications are more accurately reported, however, this cannot be verified.[18] In addition, although data are reported prospectively, this is a retrospective study and as such is subject to the weaknesses inherent to such investigations including confounding variables and reporting bias.

➢ Key Points

- ❑ The surgical treatment of pediatric isthmic and dysplastic spondylolisthesis is associated with a relatively high rate of morbidity.
- ❑ Patients undergoing reduction were more likely to suffer a new neurologic deficit, although most were transient.
- ❑ Patients with higher grades of spondylolisthesis were more likely to suffer a new neurologic deficit with surgical treatment.

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