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Complication Rates of Three Common Spine Procedures and Rates of Thromboembolism Following Spine Surgery Based on 108,419 Procedures

A Report From the Scoliosis Research Society Morbidity and Mortality Committee

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Study Design. Retrospective review of a prospectively collected database.

Objective. The Scoliosis Research Society (SRS) collects morbidity and mortality (M and M) data from its members. Our objectives were to assess complication rates for 3 common spine procedures, compare these results with prior literature as a means of validating the database, and to assess rates of pulmonary embolism (PE) and deep venous thrombosis (DVT) in all cases reported to the SRS over 4 years.

Summary of Background Data. Few modern series document complication rates of spinal surgery as routinely practiced across academic and community settings. Those available are typically based on relatively low numbers of procedures or confined to single-surgeon experiences.

Methods. The SRS M and M database was queried for lumbar microdiscectomy (LD), anterior cervical discectomy and fusion (ACDF), and lumbar stenosis decompression (LSD) cases from 2004 to 2007. Revisions were excluded. The database was also queried for occurrence of clinically evident PE and DVT in all cases from 2004 to 2007.

Results. A total of 9692 LDs, 6735 ACDFs, and 10,329 LSDs were identified, with overall complication rates of 3.6%, 2.4%, and 7.0%, respectively. These rates are comparable to previously published smaller series. For assessment of PE and DVT, 108,419 cases were identified and rates were calculated per 1000 cases based on diagnosis, age group, and implant use. Overall rates of PE, death due to PE, and DVT were 1.38, 0.34, and 1.18, respectively. Among 82,082 adults, the rate of PE ranged from 0.47 for LD to 12.4 for metastatic tumor. Similar variations were noted for DVT and deaths due to PE.

Conclusion. Overall major complication rates for LD, ACDF, and LSD based on the SRS M and M database are comparable to those in previously reported smaller series, supporting the validity of this database for study of other less common spinal disorders. In addition, our data provide general benchmarks of clinically evident PE and DVT rates as a basis for ongoing efforts to improve care.

Key words: spine surgery, complications, lumbar discectomy, lumbar stenosis, cervical fusion, pulmonary embolism, thromboembolism. **Spine 2010;35:2140–2149**

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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 de-identified data (IRB number 29045).

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All surgical procedures have inherent risks of complications. One of the most effective mechanisms by which the safety of patient care is improved is through assessing these complications. The Scoliosis Research Society (SRS) is a group of predominantly fellowship-trained spine surgeons dedicated to the study of spinal deformity. As part of its mission, the SRS collects surgical case data from its members, including morbidity and mortality (M and M). Three reports have documented complications associated with spine procedures based on the SRS M and M database.[1–3]

Lumbar microdiscectomy (LD), anterior cervical discectomy and fusion (ACDF), and lumbar stenosis decompression (LSD) are among the most common spine surgical procedures performed.[4] Several reports have documented the rates of complications associated with LD,[4–17] ACDF,[18–32] and LSD.[12,33–39] Advances in techniques have substantially decreased the rates of compli-

cations associated with these procedures.[5] However, there are few modern series that document complication rates of spinal surgery as routinely practiced across academic and community settings, and those that are available are typically based on relatively low numbers of procedures or confined to single-surgeon experiences.

Deep venous thrombosis (DVT) and pulmonary embolism (PE) are significant potential complications of spinal surgery. A limited number of reports have documented rates of these events in relatively small populations of patients.[40–54] A majority of these prior reports have focused on high-risk populations, including patients with trauma[44] or patients undergoing major reconstructive spinal surgery.[41,45–47,49,51,53]

Our objectives in the present study were 3-fold. First, we sought to assess the rates of complications associated with the surgical treatment of 3 common spine procedures in a large population of patients. Our second objective was to compare these rates with prior reports as a means of validating the SRS M and M database for the study of less common spine procedures and complications. Our third objective was to use all cases reported to the database over 4 consecutive years to assess rates of clinically evident PE and DVT following spinal surgery.

■ Materials and Methods

Patient Population

Before application for active membership in the SRS, surgeons must complete 5 years of candidate membership. International membership status is also available for surgeons outside of the United States. Candidate members are required to collect and submit data on all spine cases performed, including all associated M and M. Active members are also encouraged to submit their cases. Deidentified data are collected using a secure internet-based data entry form. The SRS has invested substantial resources in this database and emphasizes to its membership the importance of accurate and consistent reporting. In addition, data submission includes a process in which members formally attest that submitted data are true and complete.

The SRS M and M database was queried for all reported LD, ACDF, and LSD cases from 2004 to 2007. Revision cases were excluded. LD cases including fusion and ACDF cases including corpectomy or posterior fusion were excluded. Only adult patients (≥21-years old) were included for the assessment of LSD. For neurologic complications, degree of recovery (complete, partial, or none) was recorded. New acute neurologic deficits were defined as those that developed intraoperatively or within 24 hours of surgery. Delayed new neurologic deficits were defined as those that developed after 24 hours following surgery.

The SRS M and M database was also queried for reports of DVT and PE in all cases from 2004 to 2007, including both primary and revision cases. Rates of DVT and PE, as well as deaths due to PE, were calculated per 1000 cases.

Rates of complications derived from the present study were compared with previously published reports. These reports were identified through a structured literature review. The English literature available through PubMed was searched using the terms "spine surgery" and "complications." The 12 reports from no earlier than 1970 that included at least 100 cases of LD, ACDF, and/or LSD and had specific documentation of complication rates were selected for comparison with the corresponding cases in the present series. Additional search strategies included "pulmonary embolism" and "spine surgery," as well as "deep venous thrombosis" and "spine surgery." The 15 reports from no earlier than 1990 that included specific documentation of DVT and/or PE rates associated with spinal surgery were selected for comparison with the present series.

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 use of deidentified data (IRB 29045).

Statistical Analyses

Frequency distributions and summary statistics were calculated for all clinical and demographic data. For categorical variables, cross-tabulations were generated and Fisher exact tests were used to compare distributions. All statistical analyses were 2-sided. $P < 0.05$ was considered significant.

■ Results

Patient Population

A total of 108,419 surgical cases were reported to the SRS M and M database from 2004 to 2007, including 9692 LD, 6735 ACDF, and 10,329 LSD procedures that met inclusion criteria. Patient age, whether a minimal access approach was used, and membership status of the submitting surgeon are summarized in Table 1.

Rates of Complications

Lumbar Discectomy. Among 9692 cases of LD, there were 346 complications reported, resulting in an overall complication rate of 3.6% (Table 2). There was a nonsignificant trend toward increased complications in patients >50 years old compared with patients ≤50 years old ($P = 0.06$). The rate of dural tear was significantly higher among patients >50-years old (2.1%), *versus* those ≤50-years old (1.4%) ($P = 0.02$).

New neurologic deficits were reported in 28 patients. One was related to spinal cord injury, and this patient had partial recovery. One case of *cauda equina* syndrome was reported, and this patient also had partial recovery. The remaining 26 were nerve root injuries, with 5 (19%) having complete, 19 (73%) having partial, and 2 (8%) having no recovery. Five delayed new neurologic deficits were reported. All of these occurred at the level of the nerve root, and 2 (40%) had complete and 3 (60%) had partial recovery.

Neuromonitoring was used for 895 (9%) of the LD procedures, including EMG monitoring in 577 (6%), SSEP monitoring in 765 (8%), and MEP monitoring in 83 (<1%). Of the 28 cases complicated by a new neurologic deficit, none used neuromonitoring.

The overall rates of complications among candidate, active, and international members were 4.1%, 3.4%, and 3.7%, respectively. Although the overall rate of complications was greater among candidate members compared with active members, this difference did not

Table 1. Summary Characteristics of 108,419 Cases of Spinal Surgery Submitted to the Scoliosis Research Society Morbidity and Mortality Database From 2004 Through 2007

	Total	Lumbar Micodiscectomy	ACDF	Lumbar Stenosis Decompression
No. cases (%)	108,419 (100)	9692 (8.9)	6735 (6.2)	10,329 (9.5)
Patient age				
Mean	47 yr	43 yr	49 yr	63 yr
Range	1 mo–97 yr	10–92 yr	15–89 yr	21–96 yr
Minimal access approach, n (%)				
Yes	14,301 (13)	3619 (37)	—	1260 (12)
No	94,115 (87)	6073 (63)	—	9069 (88)
Not recorded	3 (<1)	0	—	0
Membership status, n (%)				
Active	76,798 (71)	6956 (72)	5115 (76)	7755 (75)
Candidate	25,004 (23)	2042 (21)	1512 (22)	1777 (17)
International	6533 (6)	694 (7)	108 (2)	797 (8)
Not specified	143 (<0.1)	0	0	0

ACDF indicates anterior cervical discectomy and fusion.

reach statistical significance ($P = 0.07$). Candidate and active members did not significantly differ with regard to rates of dural tear (1.8% and 1.5%, respectively, $P = 0.2$), wound infection (0.8% for each group, $P = 0.6$), or new neurologic deficit (0.4% and 0.3%, respectively, $P = 0.2$).

The rate of complications for procedures performed using an open approach was modestly higher than for procedures performed using a minimal access approach (3.9% *vs.* 3.1%, $P = 0.05$). Further assessment demonstrated no significant differences in the rates of dural tear or new neurologic deficit between open and minimal access cases ($P = 0.3$ and $P = 0.2$, respectively). Procedures performed through a minimal access approach had a significantly lower rate of wound infection compared with procedures performed through a traditional open approach (0.4% *vs.* 1.1%, $P < 0.001$) (Figure 1). This difference was most pronounced for deep wound infections, for which the rate was 0.5% for open approaches and 0.08% for minimal access approaches ($P < 0.001$).

Table 2. Complications in Cases of First-Time Lumbar Microdiscectomy, Anterior Cervical Discectomy and Fusion, and Lumbar Stenosis Decompression Procedures From the Year 2004 to 2007

	Procedure		
Complication, Number (%)	Lumbar Micodiscectomy (n = 9692)	ACDF (n = 6735)	Lumbar Stenosis Decompression (n = 10,329)
Dural tear	156 (1.6)	11 (0.2)	321 (3.1)
Wound infection			
Superficial	45 (0.5)	13 (0.2)	93 (1.0)
Deep	34 (0.4)	9 (0.1)	111 (1.1)
Other	57 (0.6)	24 (0.4)	9 (0.01)
Acute neurologic	28 (0.3)	19 (0.3)	62 (0.6)
Wound hematoma	11 (0.1)	19 (0.3)	51 (0.5)
Delayed neurologic	5 (0.05)	3 (0.04)	0
Cardiorespiratory	3 (0.03)	3 (0.04)	7 (0.01)
Pulmonary (not PE)	2 (0.02)	6 (0.09)	13 (0.01)
Pulmonary embolus	2 (0.02)	3 (0.04)	9 (0.01)
Nonfatal hematologic	2 (0.02)	2 (0.03)	0
DVT	1 (0.01)	1 (0.01)	8 (0.01)
Death	0	4 (0.06)	13 (0.01)
Brachial plexus injury	0	2 (0.03)	0
Sepsis	0	1 (0.01)	1 (0.001)
Visual acuity change	0	0	0
Implant related	NA	17 (0.3)	21 (0.2)
Dysphagia	NA	14 (0.2)	NA
Recurrent laryngeal nerve injury	NA	8 (0.1)	NA
Total complications	346	159	719
Percent complications*	3.6%	2.4%	7.0%

*Percent complications = 100 × (total no. complications)/(no. patients).
ACDF indicates anterior cervical discectomy and fusion; PE, pulmonary embolism; DVT, deep venous thrombosis.

Anterior Cervical Discectomy and Fusion. Among 6735 cases of ACDF, there were 159 complications reported, resulting in an overall complication rate of 2.4% (Table 2). There were 4 deaths (approximately 1:1500), 3 due to PE and 1 due to "cardiopulmonary collapse." The overall complication rate was significantly higher for patients >50-years old (3.1%) compared with patients ≥50-years old (1.9%, $P = 0.03$).

The overall rates of complications among candidate, active, and international members were 2.5%, 2.3%, and 3.7%, respectively. The overall rate of complications

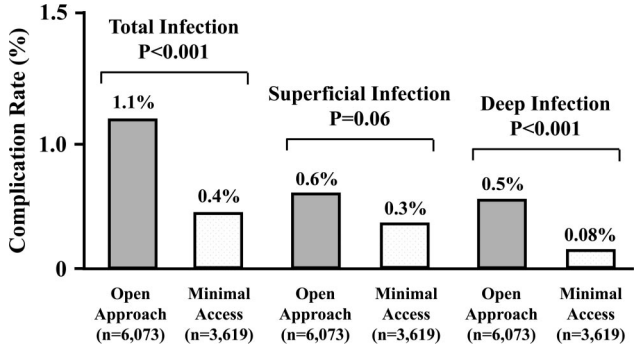

Figure 1. Rates of wound infection associated with primary lumbar discectomy, comparison of open approach with a minimal access approach.

Table 3. Thromboembolic Complications Reported for 108,419 Spine Procedures From the Year 2004 to 2007*

	n	PE Rate (per 1000 Cases)	PE Deaths (per 1000 Cases)	DVT Rate (per 1000 Cases)
Adult (≥21 yr old)				
Degenerative disease	47,389	0.89	0.19	0.80
Cervical	11,763	0.68	0.34	0.34
Thoracic	552	3.62	1.81	5.43
Lumbar	34,731	0.92	0.12	0.89
Lumbar discectomy	12,694	0.47	0.08	0.39
Lumbar stenosis	12,270	1.30	0.24	0.90
Fracture	6025	2.82	1.66	1.83
Kyphosis	2012	7.46	1.49	5.96
Spondylolisthesis	10,529	1.52	0.19	1.52
Scoliosis	5801	4.31	0.86	4.31
Other	10,326	2.32	0.58	1.55
Metastatic tumor	726	12.4	4.13	8.26
Total adult cases	82,082	1.69	0.43	1.44
Pediatric (<21 yr old)				
Degenerative disease	20	0.00	0.00	0.00
Fracture	623	1.61	0.00	1.61
Kyphosis	1555	0.64	0.64	2.57
Spondylolisthesis	827	1.21	0.00	2.42
Scoliosis	20,424	0.39	0.05	0.15
Other	1983	0.00	0.00	0.00
Total pediatric cases	25,432	0.43	0.08	0.39
Implants				
Yes	74,114	1.75	0.42	1.59
No	34,305	0.58	0.17	0.29
Primary *vs.* revision				
Adult primary	67,967	1.69	0.41	1.22
Adult revision	14,114	1.91	0.50	2.48
Pediatric primary	23,116	0.48	0.09	0.39
Pediatric revision	2316	0.00	0.00	0.43
All cases	108,419	1.38	0.34	1.18

*Patient age and/or diagnostic category not available for 905 cases.

between candidate and active members did not differ significantly ($P = 0.6$).

A total of 22 new neurologic deficits were reported, including 19 acute and 3 delayed. Acute injuries included 13 nerve root injuries, 3 incomplete spinal cord injuries, 1 Horner's syndrome, and 1 cerebellar stroke. Of the nerve root injuries, 4 had partial and 9 had complete recovery. All 3 of the incomplete spinal cord injuries had complete recovery. The median nerve injury was reported to have partial recovery. The outcomes of the cerebellar stroke and the Horner syndrome were not reported. The 3 delayed neurologic injuries included 2 nerve root injuries, 1 with partial and 1 with complete recovery, and an incomplete spinal cord injury that had partial recovery.

Neuromonitoring was used for 3110 (46%) of the ACDF procedures, including EMG monitoring in 1856 (28%), SSEP monitoring in 2606 (39%), and MEP monitoring in 956 (14%). Of the 4 cases complicated by spinal cord injury, only one used neuromonitoring (SSEP monitoring) and no intraoperative abnormalities were reported based on this monitoring. Of the 15 cases complicated by nerve root injuries, neuromonitoring was used for 6 cases, including combined EMG, SSEP, and MEP monitoring in 4 cases, combined EMG and SSEP monitoring in 1 case, and unspecified neuromonitoring methods in 1 case. No intraoperative abnormalities were reported based on these monitoring methods in cases complicated by nerve root injuries.

Lumbar Stenosis Decompression. Among 10,329 cases of LSD, there were 719 complications reported, resulting in an overall complication rate of 7.0% (Table 2). Further analyses of the complications associated with this series of LSD have been reported previously.[55]

Thromboembolic Events. Of the total 108,419 cases reported from 2004 to 2007, rates of PE, death due to PE, and DVT were 1.38, 0.34, and 1.18 per 1000 cases, respectively (Table 3). Among the 82,082 adult patients, the rate of PE varied based on diagnosis, ranging from 0.47 per 1000 cases for LD to 12.4 per 1000 cases for metastatic tumor. Similar variations were noted for the rate of deaths due to PE and the rate of DVT (Table 3). Among pediatric patients, the rates of thromboembolic events were substantially less than for adults (Table 3).

The rates of PE and DVT were significantly greater for cases that included implants (1.75 and 1.59 per 1000 cases, respectively), compared with cases not including implants (0.58 and 0.29 per 1000 cases, respectively; $P < 0.001$ for each comparison) (Table 3). There was a trend toward a higher rate of death due to PE in cases including

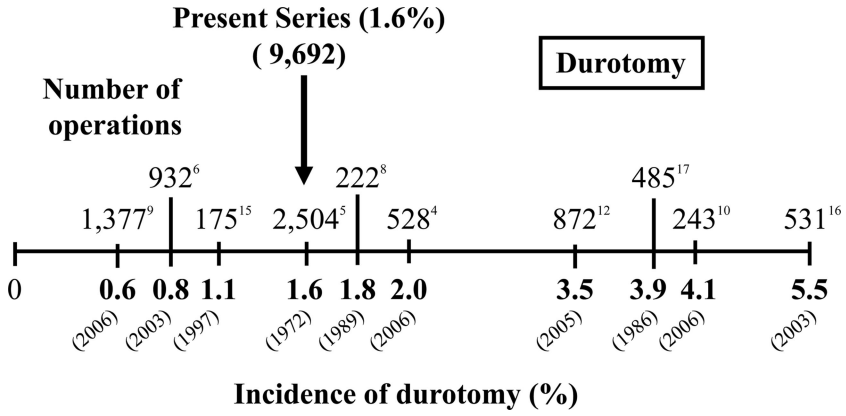

Figure 2. Comparison of the rates of dural tear associated with lumbar discectomy in the present series with rates from previously reported series. Numbers above the horizontal line indicate the number of procedures in each study, and numbers below the horizontal line indicate the percent of dural tears reported in each study.

implants (0.42 per 1000 cases) compared with cases not including implants (0.17 per 1000 cases; $P = 0.05$). Importantly, these data do not necessarily suggest a causation link between thromboembolic events and implants, but rather likely reflect a greater complexity and associated risk of cases that require implants.

Among adult cases, the rates of PE and death due to PE did not differ significantly between primary cases (1.69 and 0.41 per 1000 cases, respectively) compared with revision cases (1.91 and 0.50 per 1000 cases, respectively; $P = 0.6$ and $P = 0.7$, respectively) (Table 3). The rate of DVT for revision cases (2.48 per 1000 cases) was significantly greater than that of primary cases (1.22 per 1000 cases; $P = 0.001$). Among pediatric cases, the rates of PE, death due to PE, and DVT did not differ significantly between primary cases compared with revision cases (Table 3).

Comparison of Complication Rates With Prior Studies

Lumbar Discectomy. In an effort to assess the validity of the SRS M and M database as a resource to study less common spine procedures and complications, we compared the rates of the most common complications and the rate of mortality from the present series with those reported for similar series. For LD, the rate of dural tear ranged from 0.6% to 5.5% in previously reported series[4–6,8–10,12,15–17] (Figure 2). The majority of studies, especially those with greater numbers of patients, favored a rate of dural tear <2%. Each of these studies predominantly consisted of patients who underwent primary LD, except for the report by Best and Sasso,[9] in which 18% of the patients underwent LD for recurrent herniation. Despite the substantial inclusion of revision cases, the rate of durotomy was only 0.6%. The 1.6% rate of dural tear in the present series is consistent with these prior reports (Figure 2).

A majority of previous LD series report a rate of wound infection ≤1.6% (Figure 3).[5,6,9,10,13,15–17] Two series, published in 1986 and 1972,[5,17] report substantially higher infection rates (3.5% and 3.8%, respectively), however, these appear to be outliers relative to more recent studies. The report by Ramirez and Thisted[13] including 28,395 patients, was based on a national health care database and reports a rate of wound infection of 0.3%. The 0.8% rate of wound infection in the present series is comparable to recent reports (Figure 3).

New neurologic deficit is an uncommon event in LD, with recent series reporting rates of 0% to 0.6% (Figure 4).[5,6,8–10,13,15–17] The largest of these series,[13] reported a rate of 0.4%. Notably, the series of 1377 procedures from Best and Sasso, in which 18% of case were performed for recurrent herniation, reported a 0% rate of new neurologic deficit.[9] The 0.3% rate of new neurologic deficit in the present series is comparable to prior reports (Figure 4).

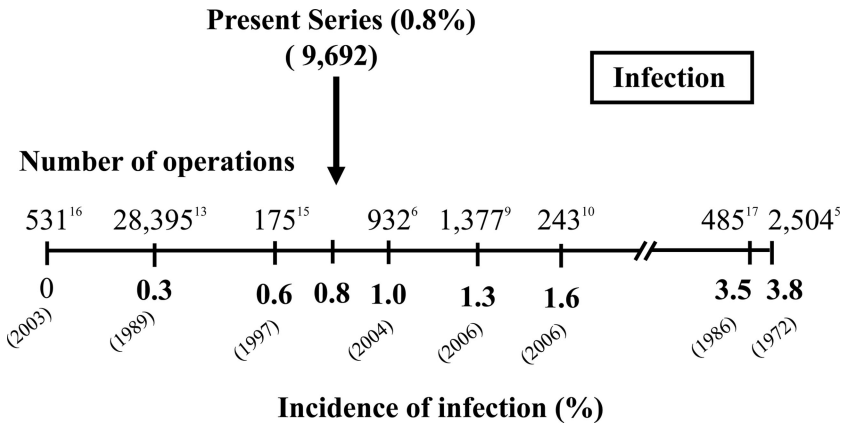

Figure 3. Comparison of the rate of wound infection associated with lumbar discectomy in the present series with rates from previously reported series. Numbers above the horizontal line indicate the number of procedures in each study, and numbers below the horizontal line indicate the percent of wound infections reported in each study.

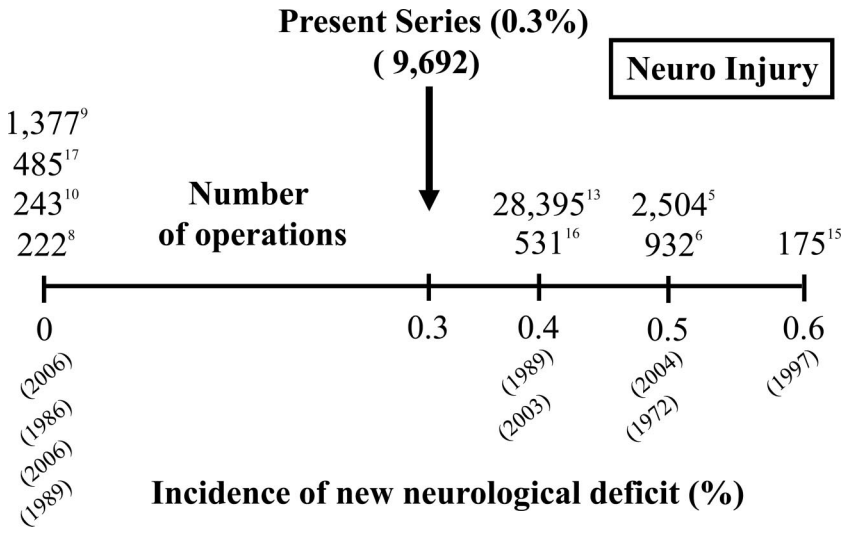

Figure 4. Comparison of the rate of new neurologic deficit associated with lumbar discectomy in the present series with rates from previously reported series. Numbers above the horizontal line indicate the number of procedures in each study, and numbers below the horizontal line indicate the percent of new neurologic deficits reported in each study.

Death associated with LD is a rare event in modern series, with reported rates ranging from 0% to 0.2% (Figure 5).[4–10,14–17] A substantial number of series lack any cases of mortality. The 0% rate of mortality in the present series is consistent with prior recent reports.

Anterior Cervical Discectomy and Fusion. Previous reports of overall complication rates for ACDF vary broadly: 0% (n = 42 and n = 251),[20,23] 1.8% (n = 109),[31] 10.8% (n = 56),[30] 11% (n = 90),[27] 11.7% (n = 103),[29] 14.2% (n = 450),[19] 19.3% (n = 1015),[26] 19.9% (n = 348),[21] 31.2%,[18] and 36.6% (n = 46).[28] Many factors may account for this wide variation, including how carefully one assesses for postoperative dysphagia and hoarseness, and the threshold at which one considers these to be complications. Dysphagia and hoarseness typically account for the majority,[18,26–28] or in some cases nearly all,[21,29,30] of the complications in the series with the greatest overall complication rates. In addition, earlier reports were typically performed on small populations of patients in which the complication rate can be significantly affected by a single incident. Furthermore, some series focus on more complex patient groups, for example, 3-level ACDFs,[28] which can substantially effect the complication rates. The overall rate of complications in the present series, 2.4%, is within the range of prior reports, but on the lesser end of this range, likely due to the considerably lower rates of dysphagia and hoarseness/recurrent laryngeal nerve palsy reported in the present series.

Dysphagia was reported in 0.2% of patients in the present series. Prior series have reported this rate to vary broadly: 0%,[23] 0.9%,[31] 5.4%,[30] 5.6%,[18] 5.8%,[29] 6.7%,[27] 9.5%,[26] 16.1%,[21] and 24%.[28] The reported rate of hoarseness/recurrent laryngeal nerve palsy also varies widely: 0%,[23,27,28] 0.9%,[31] 2.3%,[21] 3.1%,[26] 3.9%,[29] 5.4%,[30] and 7.9%.[18] Recurrent laryngeal nerve palsy was reported in 0.1% of cases in the present series.

The rate of wound infection in the present series, 0.3%, is comparable to prior series, in which it ranges from 0%[23,27,29–31] to 1.6%.[19] The rate of new neurologic deficit in the present series, 0.3%, is also compara-

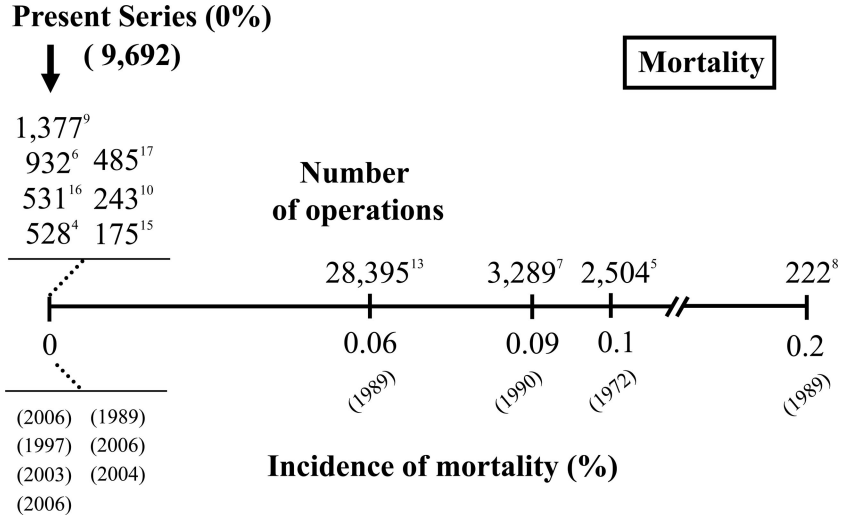

Figure 5. Comparison of the rate of mortality associated with lumbar discectomy in the present series with rates from previously reported series. Numbers above the horizontal line indicate the number of procedures in each study, and numbers below the horizontal line indicate the percent of deaths reported in each study.

ble to previous reports, in which it ranges from 0%[21,23,27,29–31] to 0.9%.[18] Wound hematoma was reported in 0.3% of cases in the present series and has been previously reported in 0%[20,23,27,29–31] to 5.6%[26] of cases. Death occurred in 0.06% (approximately 1 per 1500 cases) in the present series and has been previously reported to occur in 0%[18–21,23,27–31] to 0.1%[26] of cases.

Lumbar Stenosis Decompression. Few prior reports detail the M and M encountered with LSD.[33,35–37,39] The overall complication rate in the present series, 7.0%, is comparable to those of prior reports: 6% (n = 50),[39] 9.8% (n = 133),[35] 14.2% (n = 127),[36] 22% (n = 124),[37] and 12.2% (n = 471,215).[33] Durotomy was reported in 3.1% of the cases in the present series, which is comparable to prior reports: 2%,[34,39] 2.4%,[37] 2.6%,[12] 3.1%,[38] 6.8%,[35] and 11.8%.[36] The occurrence of wound infection in the present series, 2.1%, was also within the range of prior reports: 0%,[39] 0.3%,[33] 0.8%,[36,37] and 2.3%.[35] Three prior reports lacked any cases complicated by new neurologic deficit,[35,37,39] and 2 reports included neurologic complications with rates 0.7%[33] and 1.6%.[36] The neurologic complication rate in the present series, 0.6%, is comparable to these prior reports. Wound hematoma complicated 0.5% of the cases in the present series, which is comparable to the rates previously reported: 0%,[35,37] 2%,[39] 3.1%,[36] and 5.2%.[33] Most prior series lack any cases complicated by death.[35–37,39] The series from Li *et al*[33] reported a rate of death of 0.17% (approximately 2.5:1500), which is comparable to the present series (approximately 1:1500).

Thromboembolic Events. The reported rates of PE with spinal surgery range from 0% to 7.6%, and the reported rates of DVT range from 0.27% to 31% (Table 4). A majority of prior reports have focused on major spinal procedures[41,45–51,53] or specific high-risk patients.[42,44] In general, the reported rates of thromboembolic events are higher in studies that included routine screening methods (Table 4). For example, Piasecki *et al* reported 66 patients who underwent major spinal reconstructive surgery for adult deformity and identified DVTs in 9.1% and PEs in 7.6% of patients based on routine use of screening methods for both DVT and PE.[47] In contrast, Platzer *et al* reported 978 trauma patients who underwent spinal surgery and identified, in this high-risk population, symptomatic DVTs in 1.7% and PEs in 0.9% without routine use of screening methods.[44] It is unlikely, although there is no way of knowing for certain, that routine screening methods were used for the majority of cases in the present series, resulting in rates of DVT and PE that reflect clinically symptomatic events. In addition, in the present series, utilization of prophylaxis likely varied, not only among the surgeons who contributed cases but also based on patient age, diagnosis, and complexity of procedure.

■ Discussion

This study provides the rate of complications in the operative treatment of 3 common spine procedures based on a large number of cases performed predominantly by fellowship-trained spine surgeons. We have demonstrated that the rates of specific complications in the present series, especially major complications, are comparable to those in recent reports of smaller series. Collectively, these findings support the validity of the SRS M and M database as a resource to study other less common spinal disorders. Furthermore, we have used all of the cases submitted over a recent 4-year period to assess rates of PE, death due to PE, and DVT, and stratified these results based on diagnosis, patient age, whether implants were used, and whether the surgery was primary or revision.

The SRS M and M database is the compilation of submissions of SRS members around the world. The majority currently reside within North America. For the years that the data were collected and reviewed for this report, candidate members had a mandatory requirement to report their M and M. Active members were strongly encouraged to report their results. There is no currently existent method to determine the completeness of data submission, nor the accuracy of the reporting. It is dependent on the efforts of the participants. As such there are limitations to the data integrity, as there is with any large dataset.

It is the authors' opinion that major complications, such as new neurologic deficit, are probably most reliably reported within the database. These typically occur acutely and have the full attention of the treating surgeon. So, we suspect that recall bias in the reporting of major complications is limited but cannot prove or disprove this opinion. Importantly, the rates of DVT and PE reported herein likely reflect only those cases in which these events were symptomatically evident.

While it is possible that this dataset may have the bias of selective reporting, we believe that it does represent a cross section of practicing clinicians. Although there is the possibility that it may have the bias of reporting from younger surgeons in their candidate period and could represent somewhat of a worst case analysis, there are very senior surgeons reporting as well.

What is this database useful for? Rare conditions that have relatively uncommon events can only be examined in large datasets. While we wish we had a mechanism to achieve higher quality datasets, these have proven to be quite expensive ($13 Million NIH funding for the Spine Patient Outcomes Research Trial study, which enrolled perhaps 2000 patients with common conditions).[4,10] It would also be preferable to have outcomes data, but this carries additional expense and response burden. So, the question becomes what incremental value is gained from the incremental investment. No funding agency has paid for the SRS M and M dataset to date. It has been a goodwill volitional contribution from the members of

Table 4. Summary of Prior Reports of the Rates of Pulmonary Embolism (PE) and Deep Venous Thrombosis (DVT) in Spinal Surgery*

Author	Patient Population	No. Cases	Rates of PE/DVT	Prophylaxis	Comments
West and Anderson[50]	Major adult spinal surgery	41	DVT 14% PE 0%	Compression stockings	All patients screened with LE Doppler
Ferree[52]	Lumbar laminectomy/ laminotomy	60	DVT 5% PE 0%	Compression stockings	All patients screened with LE Doppler
Smith, *et al*[51]	Major reconstructive spinal surgery	317	DVT 0.6% PE 0.3% PE death 0.3%	Compression stockings and pneumatic compression	Prospective; 126 of the patients screened with LE Doppler
Rokito *et al*[41]	Major reconstructive spinal surgery	329	DVT 0.3% PE 0%	Compression stockings alone, with pneumatic compression, or with warfarin	Prospective; 110 of the patients screened with LE Doppler
Wood *et al*[49]	Major spinal surgery	136	DVT 0.7% PE 0.7% PE death 0%	Randomized to pneumatic thigh-high or foot wraps	Prospective, randomized; all patients screened with LE Doppler
Dearborn *et al*[53]	Major thoracolumbar spinal surgery	116	DVT 0.9% PE 2.6% PE death 0%	Compression stockings and pneumatic compression	Prospective; all patients screened with LE Doppler and 73 screened for PE with lung perfusion scan
Oda *et al*[40]	Posterior spinal surgery	110	DVT 15.5% PE 0%	None	All patients screened with LE Doppler
Epstein[43]	Anterior cervical spinal surgery with or without posterior cervical fusion	200	DVT 4% PE 1.5% PE death 0%	Compression stockings and pneumatic compression	Prospective; all patients screened with LE Doppler
Leon *et al*[42]	High-risk spinal surgery patients	74	DVT 31% PE 1.4% PE death 0%	Preoperative IVC filters placed in all patients	Prospective; all patients screened with LE Doppler and one-third underwent chest/pelvis CT
Platzer *et al*[44]	Trauma patients undergoing spinal surgery	978	DVT 1.7% PE 0.9% PE death 0.6%	792 LMWH; 153 compression stockings; 21 pneumatic compression; 12 no prophylaxis	No routine LE Doppler or CT imaging; rates reflect clinically symptomatic events
Cho *et al*[45]	Posterior fusion and instrumentation for degenerative scoliosis	47	DVT 0% PE 2.1% PE death 2.1%	Not specified	Whether routine screening performed not indicated
Piasecki *et al*[47]	Combined anterior/posterior reconstruction for adult spinal deformity	66	DVT 9.1% PE 7.6% PE death 0%	Mechanical prophylaxis with foot pumps	Prospective; all patients screened with LE Doppler, MRV, and chest CT
Pateder *et al*[46]	Adult spinal deformity surgery	361	PE 2.4% PE death 0%	Compression stockings and pneumatic compression; either warfarin or LMWH starting on postoperative day 1	No routine LE Doppler or CT imaging; rates reflect clinically symptomatic events
Schizas *et al*[48]	Vast majority were spinal fusion cases	270	PE 2.2% PE death 0%	Compression stockings and LMWH	Prospective; no routine LE Doppler or CT imaging; rates reflect clinically symptomatic events
Nicol *et al*[54]	Lumbar spine surgery	1111	DVT 0.27% PE 0%	No prophylaxis, aspirin, or LMWH	No routine LE Doppler or CT imaging; rates reflect clinically symptomatic events
Present study	All spine surgery	108,419	DVT 0.1% PE 0.14% PE death 0.03%	Mixed	Mixed

LE indicates lower extremity; DVT, deep venous thrombosis; PE, pulmonary embolus; LMWH, low-molecular-weight heparin; CT, computed tomography; MRV, magnetic resonance venogram; IVC, inferior *vena cava*.

the SRS. The total dataset has >108,000 cases enrolled for the 4-year period assessed in the present study. Presuming that each case required a 10-minute effort by the surgeon, this dataset represents a contribution of 18,000 man-hours. If a conservative estimate of the time value of the surgeons is made at $250 per hour, this dataset represents a $4.5 million dollar investment. To gain higher quality data of this scale would cost substantially more. So, while there are limitations in the dataset, the authors feel that it is a useful estimate of general information about current practice and complication rates for acute complications. At a minimum it is useful in discerning new trends, and for informing clinicians and patients about these particular risks.

■ Conclusion

The overall major complication rates for first-time LD, ACDF, and LSD based on the SRS M and M database are similar to those in previously reported smaller series. These data not only provide surgeons with potentially useful information for preoperative patient counseling but also serve to validate the SRS M and M database as a resource to study other less common spinal procedures and rare complications. Our data also provide general

benchmarks of clinically evident PE and DVT rates as a basis for ongoing efforts to improve safety of care.

■ Key Points

- The overall complication rates of 9692 lumbar discectomies, 6735 anterior cervical discectomies and fusions, and 10,329 LSDs reported to the Scoliosis Research Society M and M database were 3.6%, 2.4%, and 7.0%, respectively.
- The overall major complication rates for first-time LD, ACDF, and LSD based on the SRS M and M database are similar to those in previously reported smaller series, supporting the validity of this database as a resource to study other less common spinal disorders and complications.
- Based on 108,419 spinal surgery cases reported to the SRS M and M database, overall rates of clinically evident PE, death due to PE, and clinically evident DVT were 1.38, 0.34, and 1.18 per 1000 cases, respectively. Among 82,082 adults, the rate of PE ranged from 0.47 for LD to 12.4 for metastatic tumor.

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