Spine

SURGERY

SPINE Volume 37, Number 23, pp 1975–1982

Rates and Causes of Mortality Associated With Spine Surgery Based on 108,419 Procedures

A Review of the Scoliosis Research Society Morbidity and Mortality Database

Justin S. Smith, MD, PhD,* Dwight Saulle, MD,* Ching-Jen Chen, BA,* Lawrence G. Lenke, MD,† David W. Polly, Jr, MD,‡ Manish K. Kasliwal, MD,* Paul A. Broadstone, MD,§ Steven D. Glassman, MD,¶ Alexander R. Vaccaro, MD, PhD,‖ Christopher P. Ames, MD,** and Christopher I. Shaffrey, MD*

Study Design. A retrospective review of a prospectively collected database.

Objective. To assess rates and causes of mortality associated with spine surgery.

Summary of Background Data. Despite the best of care, all surgical procedures have inherent risks of complications, including mortality. Defining these risks is important for patient counseling and quality improvement.

Methods. The Scoliosis Research Society Morbidity and Mortality database was queried for spinal surgery cases complicated by death from 2004 to 2007, including pediatric (younger than 21 yr) and adult (21 yr or older) patients. Deaths occurring within 60 days and complications within 60 days of surgery that resulted in death were assessed.

Results. A total of 197 mortalities were reported among 108,419 patients (1.8 deaths per 1000 patients). Based on age, rates of death per 1000 patients for adult and pediatric patients were 2.0 and 1.3, respectively. Based on primary diagnosis (available for 107,996 patients), rates of death per 1000 patients were as follows: 0.9 for degenerative (n = 47,393), 1.8 for scoliosis (n = 26,421), 0.9 for spondylolisthesis (n = 11,421), 5.7 for fracture (n = 6706), 4.4 for kyphosis (n = 3600), and 3.3 for other (n = 12,455). The most common causes of mortality included: respiratory/pulmonary causes (n = 83), cardiac causes (n = 41), sepsis (n = 35), stroke (n = 15), and intraoperative blood loss (n = 8). Death occurred prior to hospital discharge for 109 (79%) of 138 deaths for which this information was reported. The specific postoperative day (POD) of death was reported for 94 (48%) patients and included POD 0 (n = 23), POD 1–3 (n = 17), POD 4–14 (n = 30), and POD >14 (n = 24). Increased mortality rates were associated with higher American Society of Anesthesiologists score, spinal fusion, and implants ($P < 0.001$). Mortality rates increased with age, ranging from 0.9 per 1000 to 34.3 per 1000 for patients aged 20 to 39 years and 90 years or older, respectively.

Conclusion. This study provides rates and causes of mortality associated with spine surgery for a broad range of diagnoses and includes assessments for adult and pediatric patients. These findings may prove valuable for patient counseling and efforts to improve the safety of patient care.

Key words: adult, complications, mortality, pediatric, spine surgery. **Spine 2012;37:1975–1982**

All surgical procedures have inherent risks of complications, and among the most profound is the risk of death. Defining the rates and causes of mortality associated with surgical procedures is valuable for patient counseling, surgical planning, and efforts to improve the safety of patient care. However, estimation of mortality rates is complicated by several factors, the most significant of which is the relative rarity of this event for most procedures. In addition, for data to be generalizable, estimations of mortality rates should include a broad range of surgeons, medical centers, geographic regions, and patient populations in order to mitigate potential confounding effects of these factors.

The spine may be afflicted by a remarkably broad spectrum of pathologies, and a similarly broad range of surgical procedures have been developed to address these conditions. Treatments can range from a relatively straightforward lumbar microdiscectomy to complex reconstructions for spinal deformities, and the acuity can range from purely elective to urgent or emergent. For procedures that are very commonly

From the *Department of Neurosurgery, University of Virginia Medical Center, Charlottesville, VA; †Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, MO; ‡Departments of Orthopedic Surgery and Neurosurgery, University of Minnesota, Minneapolis, MN; §Spine Surgery Associates, Chattanooga, TN; ¶Leatherman Spine Center, Louisville, KY; ‖Department of Orthopaedic Surgery, Thomas Jefferson University, Philadelphia, PA; and **Department of Neurosurgery, University of California San Francisco, San Francisco, CA.

Acknowledgment date: January 12, 2012. First revision date: February 26, 2012. Acceptance date: March 29, 2012.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work.

One or more of the author(s) has/have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this manuscript: e.g., honoraria, gifts, consultancies, royalties, stocks, stock options, decision-making position.

Address correspondence and reprint requests to Christopher I. Shaffrey, MD, Department of Neurosurgery, University of Virginia Medical Center, PO Box 800212, Charlottesville, VA 22908; E-mail: cis8z@virgina.edu

DOI: 10.1097/BRS.0b013e318257fada

performed, the literature offers estimates of mortality.[1–13] However, for less common procedures, such as those for spinal deformity, the available literature is limited.[14–18] In addition, estimates of mortality for pediatric patients, especially for less common procedures, are very limited.[19,20]

The Scoliosis Research Society (SRS) has been collecting morbidity and mortality (M&M) data from its members for more than 30 years. Given the relative infancy of modern surgical treatments of spinal deformity, the founding members of the SRS recognized the importance of collecting and assessing M&M as a means of improving future care, and this tradition has continued to the present and has become a hallmark of membership. Our objective in this study was to use the significant breadth and volume of cases reported to the SRS M&M database from a recent time period in order to provide rates and causes of mortality associated with spine surgery.

MATERIALS AND METHODS

Patient Population

Surgeons must complete 5 years of candidate membership prior to application for active membership in the SRS. Candidate members are required to collect and submit data on all spine cases performed, including all associated M&M. Reported complications do not influence whether a candidate is offered membership, because the SRS Membership Committee is only provided with indication as to whether each candidate member has completed the required case submission process and not the number or types of complications for each candidate. Active members, including North American and non-North American surgeons, are also encouraged to submit their cases. De-identified data are collected using a questionnaire developed by the SRS M&M Committee in the 1990s and updated to a secure Internet-based data entry form in 2001. The M&M data in the SRS database predominantly reflect short-term complications associated with the perioperative period, and the means of data collection do not permit entry of long-term complications. 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&M database was queried for all cases reported from the years 2004 through 2007. Extracted data included patient age, sex (only collected for the year 2007), American Society of Anesthesiologists (ASA) grade (only collected for the year 2007), membership status of the operating surgeon, diagnosis, whether the surgery was primary *versus* revision, whether a spinal fusion was performed, whether implants were used, and whether the case was complicated by death and if so, the reported cause of mortality. Deaths occurring within 60 days and complications within 60 days of surgery that resulted in death were assessed in this study. Patients were stratified on the basis of age as either pediatric (younger than 21 yr) or adult (21 yr of age or older).

The SRS M&M database design 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 de-identified data (IRB#29045).

Statistical Analyses

Statistical analysis was performed using SPSS v19.0 software (SPSS Inc., Chicago, IL). Frequency distributions and summary statistics were calculated for clinical and demographic data. Mortality rates were calculated and were reported as rates of death per 1000 patients. For categorical variables, cross-tabulations were generated and Fisher exact tests were used to compare distributions. Nonparametric testing, specifically the independent-samples Mann-Whitney *U* test, was used for statistical assessment of the relationship between ASA grade and mortality. All statistical analyses were 2-sided. *P* value of less than 0.05 was considered significant.

RESULTS

A total of 108,419 surgical cases were reported to the SRS M&M database from 2004 to 2007. The mean patient age was 47 years (median: 48, range: 1 mo to 97 yr), with 76% of cases performed in adult and 24% in pediatric patients. Active North American members contributed the majority of cases (71%), followed by candidate members (23%) and non-North American members (6%). A total of 197 deaths were reported for an overall mortality rate of 1.8 deaths per 1000 patients. Among adult (n = 82,082) and pediatric (n = 25,432) patients, the rates of death per 1000 patients were 2.0 and 1.3, respectively ($P = 0.020$). Rates of death for adult and pediatric patients, stratified on the basis of diagnosis, are summarized in Table 1. Compared with pediatric patients, the rates of death for adult patients were significantly higher for surgical treatment of scoliosis (all subtypes combined; $P = 0.002$), neuromuscular scoliosis ($P = 0.028$), and idiopathic scoliosis ($P < 0.001$). There were no significant differences in the rates of death between adult and pediatric patients for the surgical treatment of congenital scoliosis ($P = 1.00$), spondylolisthesis ($P = 1.00$), fracture ($P = 0.26$), or kyphosis ($P = 0.074$). Mortality rate per 1000 patients was further stratified by age groups and ranged from 0.9 for patients 20 to 39 years of age to 34.3 for patients 90 years of age or older (Figure 1).

The mortality rates were further analyzed for age subgroups for the pediatric patients. The numbers of deaths per 1000 cases for pediatric patients aged 0 to 5, 6 to 10, 11 to 15, and 16 to 20 years were 2.02, 1.91, 1.19, and 0.95, respectively ($P = 0.50$). Patients aged 0 to 10 and 11 to 20 years had rates of death of 1.95 and 1.10, respectively, per 1000 patients ($P = 0.17$).

Causes of mortality were reported for 191 (97%) of the cases complicated by death. Reported causes of mortality, stratified on the basis of primary diagnosis, are summarized in Table 2. The most common causes of mortality included respiratory/pulmonary causes (n = 83), cardiac causes (n = 41), and sepsis (n = 35). Other less common causes of death included stroke (n = 15), operative blood loss (n = 8), and multisystem organ failure (n = 3). Further stratification of

TABLE 1. Rates of Death Based on Patient Age and Primary Diagnosis*

Diagnosis	No. of Cases	No. of Deaths	Deaths per 1000 Cases
Adult (≥21 yr)			
Degenerative disease	46,434	44	1.0
Cervical	11,674	19	1.6
Thoracic	524	4	7.6
Lumbar	33,910	21	0.6
Spinal level not recorded	326	0	…
Scoliosis	5801	20	3.5
Neuromuscular	292	4	13.7
Degenerative	2533	8	3.2
Idiopathic	2488	7	2.8
Post-traumatic	30	0	…
Congenital	137	0	…
Other	139	1	7.2
Type not recorded	182	0	…
Spondylolisthesis	10,529	10	1.0
Fracture	6025	37	6.1
Kyphosis	2012	13	6.5
Other	11,089	39	3.5
Metastatic tumor†	726	16	22.0
Acute osteodiscitis†	866	10	11.5
Not recorded	192	0	…
Total	82,082	163	2.0
Pediatric (<21 yr)			
Degenerative disease‡	654	0	…
Scoliosis	20,424	27	1.3
Neuromuscular	4855	17	3.5
Congenital	2045	6	2.9
Idiopathic	11,741	2	0.2
Post-traumatic	35	0	…
Other	1464	2	1.4
Type not recorded	284	0	…
Spondylolisthesis	827	0	…
Fracture	623	1	1.6
Kyphosis	1555	3	1.9
Other	1273	1	0.8
Not recorded	76	0	…
Total	25,432	32	1.3

**Age not recorded for 905 patients, including 2 cases of mortality (1 patient each with diagnosis of neuromuscular scoliosis and other. These patients are not included in this table.*

†Selected subgroups within the primary diagnosis of other.

‡Cases reported as pediatric degenerative disease predominantly consisted of disc herniations, stenosis, or degenerative disc disease, with the vast majority involving the lumbar region.

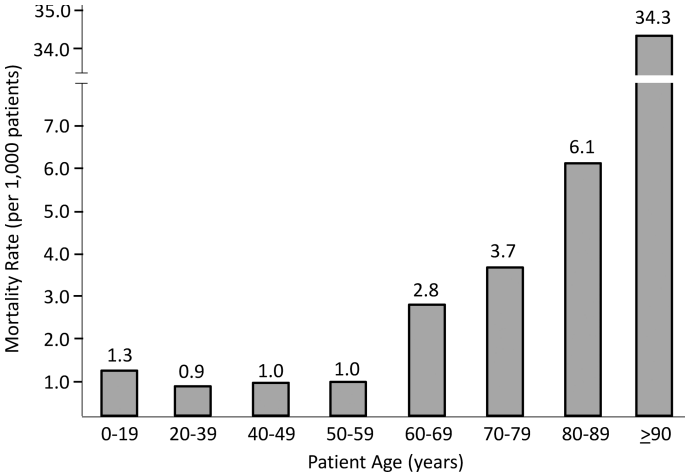

Figure 1. Rates of mortality per 1000 patients treated surgically for spinal pathology, stratified on the basis of patients' age. Each age grouping had more than 10,000 patients, except for the group of 80 to 89 years (n = 3430) and the group of 90 years or older (n = 175). Note the break in the *Y*-axis to accommodate the mortality rate for the group of 90 years or older.

respiratory/pulmonary and cardiac causes of death is provided in Table 2. Compared with pediatric patients, the rate of cardiac-related deaths for adults was significantly higher ($P = 0.041$). The rates of death related to respiratory/pulmonary conditions ($P = 0.072$), sepsis ($P = 0.24$), stroke ($P = 0.76$), and intraoperative blood loss ($P = 0.40$) did not differ significantly between adult and pediatric patients.

For a subset of patients, the timing of death relative to the surgical procedure was reported. Death occurred prior to hospital discharge for 109 (79%) of 138 deaths for which this information was reported. The specific postoperative day (POD) of death relative to surgery was reported for 94 (48%) patients and was POD 0 (day of surgery) for 23, POD 1–3 for 17, POD 4–14 for 30, and after POD 14 for 24 patients. The mean POD of death did not differ significantly between pediatric and adult patients (16.7 *vs*. 13.4, respectively; $P = 0.72$).

Associations between rates of mortality and clinical, surgical, and membership status parameters are summarized in Table 3. The rate of mortality did not significantly differ on the basis of patient's sex or whether the surgery was primary *versus* revision. Significantly higher mortality rates were associated with higher ASA grade ($P < 0.001$), cases requiring spinal fusion ($P < 0.001$), and cases requiring use of spinal implants ($P < 0.001$). Membership status was significantly associated with the rates of mortality per 1000 patients, with active North American members having the lowest rate (1.4), followed by candidate members (2.4) and then non-North American members (4.3; $P < 0.001$).

DISCUSSION

The rate at which mortality occurs in association with spinal procedures is difficult to estimate, owing to its relatively uncommon occurrence. This study capitalizes on the collective and long-standing efforts of the membership of the SRS to report M&M for spinal procedures. Among a broad range of

TABLE 2. Reported Causes of Mortality, Stratified on the Basis of Primary Diagnosis*

Reported Causes of Mortality	Primary Diagnosis (No. of Cases)*						Total (107,996)
	Degenerative (47,393)	Scoliosis (26,421)	Spondylolisthesis (11,421)	Fracture (6706)	Kyphosis (3600)	Other (12,455)	
Respiratory/pulmonary	**17**	**18**	**3**	**19**	**8**	**18**	**83**
Respiratory failure	1	6		7	1	8	(23)
PE	5		1	2	2	1	(11)
Presumed PE	3	2		1	2	1	(9)
Pneumonia	1	2		2	2	2	(9)
Aspiration	2	2	1	1	1	2	(9)
ARDS		2		1			(3)
Other	3						(3)
Not specified	2	4	1	5		4	(16)
Cardiac	**12**	**8**	**6**	**7**	**2**	**6**	**41**
Myocardial infarction	8		2	3	1	2	(16)
Cardiac arrest	3	3	1	4		2	(13)
Cardiac arrhythmia		1	1		1	1	(4)
Not specified	1	4	2			1	(8)
Sepsis	**8**	**7**		**6**	**3**	**11**	**35**
Stroke	**5**	**3**	**1**	**2**		**4**	**15**
Operative blood loss	**1**	**5**			**1**	**1**	**8**
MSOF				**2**	**1**		**3**
Other		**4**		**1**		**1**	**6**
Not indicated/unknown	**1**	**3**		**1**	**1**		**6**
Total	**44**	**48**	**10**	**38**	**16**	**41**	**197**
Deaths per 1000 cases	**0.9**	**1.8**	**0.9**	**5.7**	**4.4**	**3.3**	**1.8**

Bold values reflect the total mortalities for the main diagnosis categories and the indented (nonbold values) are subcategories.

**The 423 cases for which primary diagnosis was not reported are not included. Among these cases, there were no mortalities reported.*

PE indicates pulmonary embolism; ARDS, acute respiratory distress syndrome; MSOF, multisystem organ failure.

spinal disorders and procedures, the overall rate of mortality was 1.8 per 1000 patients. This rate was higher for adults than for pediatric patients (2.0 *vs.* 1.3 per 1000 patients, respectively) and varied on the basis of diagnosis, ranging from 0.9 per 1000 patients for degenerative conditions to 5.7 per 1000 patients with spine fractures. Furthermore, we have assessed the rates of mortality on the basis of clinical and surgical factors as well as membership status of the contributing surgeons. Collectively, these findings may prove valuable for patient counseling and efforts to improve the safety of patient care.

Prior efforts have documented the general validity of the SRS M&M data, based on comparison of the rates of complications in the database with rates reported in the literature for the most common procedures and complications.[21] Validation of the database for common procedures and complications has enabled assessments of less common procedures and rare complications.[22–33] As with any large data set, there are potential limitations to the data integrity; however, it is the authors' opinion that major complications, such as mortality, are likely the most reliably reported in the database and the least prone to recall bias. In addition, in contrast to the determination of some other complications, such as dysphagia after anterior cervical surgery, the occurrence of death is not subject to interpretation.

Many previous reports that provide rates of mortality in spine surgery are limited by insufficient numbers of patients to adequately estimate uncommon events or by confinement of patient populations to a single surgeon or institution.[34–38] For select diagnoses, the literature offers mortality rates for comparison with this study, and in general the rates are

TABLE 3. Rates of Mortality Stratified on the Basis of Clinical, Surgical, and Membership Status Parameters

Parameters	N	No. of Deaths	Mortality (per 1000 cases)	*P*
Sex (year 2007 only)				0.18
Male	9967	19	1.9	
Female	12,802	17	1.3	
ASA grade (year 2007 only)				**<0.001**
1	11,101	3	0.3	
2	7408	8	1.1	
3	3879	13	3.4	
4	463	10	21.6	
5	6	2	333.3	
Spinal fusion performed				**<0.001**
Yes	72,534	176	2.4	
No	35,877	21	0.6	
Not recorded	8	0	0	
Implants				**<0.001**
Yes	74,114	170	2.3	
No	34,305	27	0.8	
Revision surgery				0.84
Yes	16,503	32	1.9	
No	91,916	165	1.8	
Membership status				**<0.001**
North American member	76,748	110	1.4	
Candidate member	24,901	59	2.4	
Non-North American member	6534	28	4.3	
Other/not recorded	236	0	0	

Significant P*-values are shown in bold face.*

ASA indicates American Society of Anesthesiologists.

comparable. For example, modern reports of cervical procedures in adults, predominantly for degenerative conditions, document mortality rates ranging from 1.0 to 4.3 per 1000 patients,[7–11,39] which is comparable with the rate of 1.6 per 1000 patients in this study. Modern reports of thoracic procedures in adults, primarily for degenerative conditions, indicate mortality rates ranging from 2.6 to 74 per 1000 patients,[1,40–43] which, although a broad range, is inclusive of the rate of 7.6 per 1000 patients in this study. Modern reports of mortality for lumbar degenerative procedures in adults document rates ranging from 0 to 5.2 per 1000 patients,[1,3,21,44] which is inclusive of the 0.6 per 1000 patients in this study.[2,4–6]

The SRS M&M data set includes a substantial number of pediatric patients and permits assessment of mortality rates for subtypes of scoliosis. Although there are few comparable reports in the literature for comparison, previous assessments of mortality for the most common form of pediatric deformity, adolescent idiopathic scoliosis, suggest that the rate is between 0 and 0.32 per 1000 patients,[19,20] which is comparable with the rate of 0.2 per 1000 patients in this study.

Based on the SRS M&M database, the rates of mortality are significantly higher for cases in which spinal fusion was performed or implants were used. It is important to recognize that these data do not necessarily suggest a causation link between death and the performance of fusion or use of implants but rather likely reflect greater complexity and inherent risk factors for cases that required spinal fusion or use of implants. In addition, the SRS M&M database also demonstrates significantly higher rates of mortality for candidate and non-North American members than for active North American members. Although the database does not permit detailed analysis of this association, differences in mortality rates between candidate and active North American members could reflect a combination of experience levels and case selection. Possible explanations for the more than 3-fold higher mortality rate of non-North American members compared with North American members could include differences in patient and case selection, experience levels, and available resources.

During the time period during which data were collected for this study, candidate members were required to submit all cases, and active and international members were strongly encouraged to report their cases. Although this may raise concerns of a bias toward reporting from younger surgeons and resulting mortality rates that represent a "worst case" scenario, more than 70% of the cases in this study were submitted by active North American members. In addition, concern may arise over under-reporting of major complications by candidate members who wish to become full members and by active members who may not be eager to share their less than optimal outcomes. However, in an effort to help mitigate these concerns, the SRS uses a de-identified submission process and only provides the membership committee with a simple listing of surgeons who have and have not provided case submissions.

This study has several strengths, including the large number of cases that include both low- and high-complexity procedures. Although most of the contributing surgeons are fellowship-trained spine surgeons or pediatric orthopedists, they represent a broad range of experience levels, which enhances the generalizability of the findings. The multicenter design, which includes private and academic practices predominantly from throughout North America, helps mitigate the effects of differences in patient populations and practice patterns and further enhances the generalizability of the results.

In addition, collection of clinical and surgical details, including patient age, ASA grade, performance of spinal fusion, and use of spinal implants, permits stratification of the mortality data based on these parameters. Data collection also included cause of mortality, which provides some insight into the events and pathologies that resulted in death.

This study also has limitations. Although the data were collected using a prospective approach, the study was designed and conducted retrospectively. Because of the de-identified data submission process, it is not possible to determine the number of deaths per institution or per surgeon, and there is currently no means of determining the completeness of the data submission, nor the accuracy of reporting. Risk stratification cannot be performed, because patient comorbidities were not collected. Although performance of a fusion and use of implants may serve as general surrogates for case complexity, the database does not otherwise provide an effective means of stratifying case complexity beyond the diagnosis. There is also the possibility of under-reporting the mortality rate due to the optional submission of data for noncandidate members. In addition, there is a tendency for retrospective reviews to underestimate complication rates compared with true prospectively acquired and documented studies. Furthermore, given that many of the patients likely did not undergo formal autopsy, it is possible in some cases that the reported causes of death may not fully or accurately reflect the true causes of death.

Perhaps the optimal mortality estimates would come from patient medical condition risk stratification and procedure stratified information, as has been done by the Society of Thoracic Surgeons.[45–48] Although the SRS M&M database does not allow this level of detail, it gives a crude age-based (adult *vs*. pediatric) and crude procedure-based rate (spinal surgery).

Mortality rates are affected by the patient's medical condition, the procedure being performed, the skill of the surgical team, and the skill of the team providing postsurgical care. All of these factors will most certainly affect mortality. Attempts at medical comorbidity stratification have been ongoing. To date, the ASA grade[49] and Charlson comorbidity indices[50] seem to have some utility for crude prognostication. Measurement of surgeon-controlled factors (learning curve/experience level) has not been well delineated in spine surgery to date. The variability of the skill and effect of the care team have yet to be investigated in detail in spine surgery as well. Although this study does not allow investigation of these factors in any detail, it gives a crude overall estimate of effect size that can inform future efforts.

Crude comparisons with other reported rates of mortality may help provide perspective to the overall mortality rate of 1.8 per 1000 spine surgery cases reported in this study. In an assessment of hospital volume and surgical mortality in the United States, Birkmeyer *et al*[51] reported mortality rates for carotid endarterectomy (range of 1.5–1.7 per 1000 cases), elective repair of abdominal aortic aneurysm (range of 3.9–6.5 per 1000 cases), coronary artery bypass grafting (range of 45–56 per 1000 cases), esophagectomy for cancer (84–203 per 1000 cases), and pancreatic resection for cancer (range of 38–163 per 1000 cases). A systematic review of early postoperative mortality after joint arthroplasty by Singh *et al*[52] found an overall 90-day mortality rate of 7 per 1000 cases across all types of arthroplasties. *Yoho et al*[53] reviewed rates of mortality associated with cosmetic surgery and suggested that the true rate of mortality associated with liposuction may be as high as 1 per 1000 cases.

The results of this study have many potential applications. The rates of mortality can be used to help anchor benchmarks for future quality improvement. In addition, the reported causes of mortality may prove helpful in focusing future quality improvement efforts in areas of higher risk. For example, the most common reported causes of death were respiratory/pulmonary related, suggesting possible opportunities for improvement of postoperative critical care. Furthermore, the data provide an important reminder for surgeons, patients, and society that spine surgery, regardless of complexity and medical and surgical advances, does have inherent risk of mortality.

CONCLUSION

Based on 108,419 spine surgery cases from the SRS M&M database, the overall rate of mortality within 60 days of surgery was 1.8 per 1000 patients. This rate was higher for adults than for pediatric patients (2.0 *vs*. 1.3 per 1000 patients, respectively) and varied on the basis of diagnosis, ranging from 0.9 per 1000 patients with degenerative conditions and spondylolisthesis to 5.7 per 1000 patients with spine fractures. The most common causes of death were respiratory/pulmonary causes, cardiac causes, sepsis, stroke, and intraoperative blood loss. Increased mortality rates were associated with higher ASA score, spinal fusion, and implants ($P < 0.001$). Mortality rates increased with age, ranging from 0.9 per 1000 to 34.3 per 1000 for patients aged 20 to 39 years and 90 years or older, respectively. These findings may prove valuable for patient counseling and efforts to improve the safety of patient care.

➢ Key Points

- Based on 108,419 spine surgery cases from the SRS M&M database, the overall rate of mortality within 60 days of surgery was 1.8 per 1000 patients, with higher rates for adults than for pediatric patients (2.0 *vs*. 1.3 per 1000 patients, respectively).
- Mortality rates varied on the basis of diagnosis, ranging from 0.9 per 1000 patients for degenerative conditions and spondylolisthesis to 5.7 per 1000 patients with spine fractures.
- The most common causes of death were respiratory/pulmonary causes, cardiac causes, sepsis, stroke, and intraoperative blood loss.
- Increased mortality rates were associated with higher ASA score, spinal fusion, and implants ($P < 0.001$) but not with patient sex or whether the surgery was a revision ($P > 0.05$).
- Mortality rates increased with age, ranging from 0.9 per 1000 to 34.3 per 1000 for patients aged 20 to 39 years and 90 years or older, respectively.

References

1. Dekutoski MB, Norvell DC, Dettori JR, et al. Surgeon perceptions and reported complications in spine surgery. *Spine (Phila Pa 1976)* 2010;35(suppl):S9–21.
2. Li G, Patil CG, Lad SP, et al. Effects of age and comorbidities on complication rates and adverse outcomes after lumbar laminectomy in elderly patients. *Spine (Phila Pa 1976)* 2008;33:1250–5.
3. Deyo RA, Cherkin DC, Loeser JD, et al. Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure. *J Bone Joint Surg Am* 1992;74: 536–43.
4. Juratli SM, Mirza SK, Fulton-Kehoe D, et al. Mortality after lumbar fusion surgery. *Spine (Phila Pa 1976)* 2009;34:740–7.
5. Deyo RA, Mirza SK, Martin BI, et al. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. *JAMA* 2010;303:1259–65.
6. Schoenfeld AJ, Ochoa LM, Bader JO, et al. Risk factors for immediate postoperative complications and mortality following spine surgery: a study of 3475 patients from the National Surgical Quality Improvement Program. *J Bone Joint Surg Am* 2011;93:1577–82.
7. Shamji MF, Cook C, Pietrobon R, et al. Impact of surgical approach on complications and resource utilization of cervical spine fusion: a nationwide perspective to the surgical treatment of diffuse cervical spondylosis. *Spine J* 2009;9:31–8.
8. Patil PG, Turner DA, Pietrobon R. National trends in surgical procedures for degenerative cervical spine disease: 1990–2000. *Neurosurgery* 2005;57:753–8; discussion 753–8.
9. Wang MC, Chan L, Maiman DJ, et al. Complications and mortality associated with cervical spine surgery for degenerative disease in the United States. *Spine (Phila Pa 1976)* 2007;32:342–7.
10. Alosh H, Riley LH III, Skolasky RL. Insurance status, geography, race, and ethnicity as predictors of anterior cervical spine surgery rates and in-hospital mortality: an examination of United States trends from 1992 to 2005. *Spine (Phila Pa 1976)* 2009;34: 1956–62.
11. Fountas KN, Kapsalaki EZ, Nikolakakos LG, et al. Anterior cervical discectomy and fusion associated complications. *Spine (Phila Pa 1976)* 2007;32:2310–7.
12. Kalanithi PS, Patil CG, Boakye M. National complication rates and disposition after posterior lumbar fusion for acquired spondylolisthesis. *Spine (Phila Pa 1976)* 2009;34:1963–9.
13. Verlaan JJ, Diekerhof CH, Buskens E, et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. *Spine (Phila Pa 1976)* 2004;29:803–14.
14. Smith JS, Shaffrey CI, Glassman SD, et al. Risk-benefit assessment of surgery for adult scoliosis: an analysis based on patient age. *Spine (Phila Pa 1976)* 2011;36:817–24.
15. Drazin D, Shirzadi A, Rosner J, et al. Complications and outcomes after spinal deformity surgery in the elderly: review of the existing literature and future directions. *Neurosurg Focus* 2011;31:E3.
16. Etame AB, Wang AC, Than KD, et al. Outcomes after surgery for cervical spine deformity: review of the literature. *Neurosurg Focus* 2010;28:E14.
17. Pateder DB, Gonzales RA, Kebaish KM, et al. Short-term mortality and its association with independent risk factors in adult spinal deformity surgery. *Spine (Phila Pa 1976)* 2008;33:1224–8.
18. Cho KJ, Suk SI, Park SR, et al. Complications in posterior fusion and instrumentation for degenerative lumbar scoliosis. *Spine (Phila Pa 1976)* 2007;32:2232–7.
19. Coe JD, Arlet V, Donaldson W, 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 (Phila Pa 1976)* 2006;31:345–9.
20. Upasani VV, Caltoum C, Petcharaporn M, et al. Does obesity affect surgical outcomes in adolescent idiopathic scoliosis? *Spine (Phila Pa 1976)* 2008;33:295–300.
21. Smith JS, Fu KM, Polly DW Jr, et al. 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. *Spine (Phila Pa 1976)* 2010;35:2140–9.
22. Fu KM, Smith JS, Polly DW, et al. Morbidity and mortality associated with spinal surgery in children: a review of the Scoliosis Research Society morbidity and mortality database. *J Neurosurg Pediatr* 2011;7:37–41.
23. Fu KM, Smith JS, Polly DW Jr, et al. Correlation of higher preoperative American Society of Anesthesiology grade and increased morbidity and mortality rates in patients undergoing spine surgery. *J Neurosurg Spine* 2011;14:470–4.
24. Fu KM, Smith JS, Polly DW Jr, et al. Morbidity and mortality in the surgical treatment of six hundred five pediatric patients with isthmic or dysplastic spondylolisthesis. *Spine (Phila Pa 1976)* 2011;36:308–12.
25. Fu KM, Smith JS, Polly DW Jr, et al. Morbidity and mortality in the surgical treatment of 10,329 adults with degenerative lumbar stenosis. *J Neurosurg Spine* 2010;12:443–6.
26. Hamilton DK, Smith JS, Sansur CA, et al. Rates of new neurological deficit associated with spine surgery based on 108,419 procedures: a report of the scoliosis research society morbidity and mortality committee. *Spine (Phila Pa 1976)* 2011;36:1218–28.
27. Reames DL, Smith JS, Fu KM, et al. Complications in the surgical treatment of 19,360 cases of pediatric scoliosis: a review of the Scoliosis Research Society Morbidity and Mortality database. *Spine (Phila Pa 1976)* 2011;36:1484–91.
28. Sansur CA, Reames DL, Smith JS, et al. Morbidity and mortality in the surgical treatment of 10,242 adults with spondylolisthesis. *J Neurosurg Spine* 2010;13:589–93.
29. Sansur CA, Smith JS, Coe JD, et al. Scoliosis Research Society morbidity and mortality of adult scoliosis surgery. *Spine (Phila Pa 1976)* 2011;36:E593–7.
30. Smith JS, Sansur CA, Donaldson WF III, et al. Short-term morbidity and mortality associated with correction of thoracolumbar fixed sagittal plane deformity: a report from the scoliosis research society morbidity and mortality committee. *Spine (Phila Pa 1976)* 2011;36:958–64.
31. Smith JS, Shaffrey CI, Sansur CA, et al. Rates of infection after spine surgery based on 108,419 procedures: a report from the Scoliosis Research Society Morbidity and Mortality Committee. *Spine (Phila Pa 1976)* 2011;36:556–63.
32. Williams BJ, Sansur CA, Smith JS, et al. Incidence of unintended durotomy in spine surgery based on 108,478 cases. *Neurosurgery* 2011;68:117–23; discussion 123–4.
33. Williams BJ, Smith JS, Fu KM, et al. Does BMP increase the incidence of perioperative complications in spinal fusion? A comparison of 55,862 cases of spinal fusion with and without BMP. *Spine (Phila Pa 1976)* 2011;36:1685–91.
34. Ebersold MJ, Pare MC, Quast LM. Surgical treatment for cervical spondylitic myelopathy. *J Neurosurg* 1995;82:745–51.
35. Halvorsen CM, Lied B, Harr ME, et al. Surgical mortality and complications leading to reoperation in 318 consecutive posterior decompressions for cervical spondylotic myelopathy. *Acta Neurol Scand* 2011;123:358–65.
36. Fritzell P, Hagg O, Nordwall A. Complications in lumbar fusion surgery for chronic low back pain: comparison of three surgical techniques used in a prospective randomized study. A report from the Swedish Lumbar Spine Study Group. *Eur Spine J* 2003;12: 178–89.
37. Wiese M, Kramer J, Bernsmann K, et al. The related outcome and complication rate in primary lumbar microscopic disc surgery depending on the surgeon's experience: comparative studies. *Spine J* 2004;4:550–6.
38. Benz RJ, Ibrahim ZG, Afshar P, et al. Predicting complications in elderly patients undergoing lumbar decompression. *Clin Orthop Relat Res* 2001;384:116–121.
39. Shamji MF, Cook C, Tackett S, et al. Impact of preoperative neurological status on perioperative morbidity associated with anterior and posterior cervical fusion. *J Neurosurg Spine* 2008;9: 10–6.
40. Memtsoudis SG, Vougioukas VI, Ma Y, et al. Perioperative morbidity and mortality after anterior, posterior, and anterior/posterior spine fusion surgery. *Spine (Phila Pa 1976)* 2011;36:1867–77.
41. Chen TC. Surgical outcome for thoracic disc surgery in the postlaminectomy era. *Neurosurg Focus* 2000;9:e12.

42. Faciszewski T, Winter RB, Lonstein JE, et al. The surgical and medical perioperative complications of anterior spinal fusion surgery in the thoracic and lumbar spine in adults. A review of 1223 procedures. *Spine (Phila Pa 1976)* 1995;20:1592–9.
43. Taylor RS, Taylor RJ, Fritzell P. Balloon kyphoplasty and vertebroplasty for vertebral compression fractures: a comparative systematic review of efficacy and safety. *Spine (Phila Pa 1976)* 2006;31:2747–55.
44. Oldridge NB, Yuan Z, Stoll JE, et al. Lumbar spine surgery and mortality among Medicare beneficiaries, 1986. *Am J Public Health* 1994;84:1292–8.
45. Jin R, Furnary AP, Fine SC, et al. Using Society of Thoracic Surgeons risk models for risk-adjusting cardiac surgery results. *Ann Thorac Surg* 2010;89:677–682.
46. O'Brien SM, Shahian DM, Filardo G, et al. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 2—isolated valve surgery. *Ann Thorac Surg* 2009;88(suppl):S23–42.
47. Shahian DM, O'Brien SM, Filardo G, et al. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 3—valve plus coronary artery bypass grafting surgery. *Ann Thorac Surg* 2009;88(suppl):S43–62.
48. Shahian DM, O'Brien SM, Filardo G, et al. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 1—coronary artery bypass grafting surgery. *Ann Thorac Surg* 2009;88(suppl):S2–22.
49. Dripps RD. New classification of physical status. *Anesthesiology* 1963;24:111.
50. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–83.
51. Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. *N Engl J Med* 2002;346:1128–37.
52. Singh JA, Kundukulam J, Riddle DL, et al. Early postoperative mortality following joint arthroplasty: a systematic review. *J Rheumatol* 2011;38:1507–13.
53. Yoho RA, Romaine JJ, O'Neil D. Review of the liposuction, abdominoplasty, and face-lift mortality and morbidity risk literature. *Dermatol Surg* 2005;31:733–43; discussion 743.