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DEFORMITY

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

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Study Design. Retrospective review.

Objective. Our objective was to assess the short-term complication rate in patients undergoing treatment of thoracolumbar fixed sagittal plane deformity (FSPD).

Summary of Background Data. The reported morbidity and mortality for the surgical treatment of thoracolumbar FSPD is varied and based on studies with small sample sizes. Further studies are needed to better assess FSPD complication rate, and the factors that influence it.

Methods. The Scoliosis Research Society (SRS) Morbidity and Mortality Database was queried to identify cases of thoracolumbar FSPD from 2004 to 2007. Complications were analyzed based on correction technique, surgical approach, surgeon experience (SRS membership status used as a surrogate), patient age, and history of prior surgery.

Results. Five hundred and seventy-eight cases of FSPD were identified. Osteotomies were performed in 402 cases (70%), including 215 pedicle subtraction osteotomies (PSO), 135 Smith–Petersen osteotomies (SPO), 19 anterior discectomy with corpectomy procedures (ADC), 18 vertebral column resections (VCR), and 15 unspecified osteotomies. There were 170 complications (29.4%) in 132 patients. There were three deaths (0.5%). The most common complications were durotomy (5.9%), wound infection (3.8%), new neurologic deficit (3.8%), implant failure (1.7%), wound hematoma (1.6%), epidural hematoma (1.4%), and pulmonary embolism (1.0%). Procedures including an osteotomy had a higher complication rate (34.8%) than cases not including an osteotomy (17.0%, $P < 0.001$), and this remained significant after adjusting for the effects of patient age, surgeon experience, and history of prior surgery ($P = 0.003$, odds ratio = 2.070, 95% CI = 1.291–3.321). Not significantly associated with complication rate were patient age ($P = 0.68$), surgeon experience ($P = 0.18$), and history of prior surgery ($P = 0.10$). Complication rates were progressively higher from no osteotomy (17.0%), to SPO (28.1%), to PSO (39.1%), to VCR (61.1%).

Conclusion. The short-term complication rate for treatment of FSPD is 29.4%. The complication rate was significantly higher in patients undergoing osteotomies, and more aggressive osteotomies were associated with progressively higher complication rates.

Key words: fixed sagittal plane deformity, complications, pedicle subtraction osteotomy, vertebral column resection, Smith–Petersen osteotomy. **Spine 2011;36:958–964**

Fixed sagittal plane deformity (FSPD) is a condition that is increasingly being encountered by spine surgeons as the population ages. FSPD can result from a variety of conditions. The most common etiology is iatrogenic, where kyphosis can develop after a multilevel lumbar fusion. In patients with osteoporosis, multiple compression fractures

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can occur and over time this may lead to fixed deformity. Other causes include advanced disc degeneration of multiple levels and ankylosing spondylitis.

There have been multiple surgical procedures described for the treatment of FSPD. These have included Smith–Petersen osteotomy (SPO), pedicle subtraction osteotomy (PSO), and vertebral column resection (VCR) procedures. The technique used to correct FSPD depends on factors such as the severity of the deformity, the flexibility of the deformity, and whether the kyphosis is more of a rounded, long sweeping kyphosis or a short, angular one.[1] An SPO can provide ~10° of correction, whereas a PSO can provide ~35° of correction, and a VCR can provide 40° or more of correction.[1,2]

The complication rate associated with the surgical correction of FSPD reported in the literature is variable.[2–9] The greatest shortcoming in each of the reported series has typically been the relatively low numbers of patients included.[3,6,7,9–12] Furthermore, the series reported have been typically based on surgical procedures performed by experienced surgeons at major medical centers, and do not necessarily reflect the outcome of a more general spine surgeon population. Although FSPD is not exceedingly common, it is important for the general spine surgeon to be familiar with the extent of morbidity associated with these procedures for the purpose of patient counseling. Furthermore, knowledge of the morbidity may result in the possible decision to a refer FSPD patients to a facility or surgeon where the treatment of FSPD is performed on a regular basis.

The Scoliosis Research Society (SRS) has been collecting data on short-term surgical complications for over 40 years. Thus far, this database has been used to report the morbidity and mortality (M&M) of scoliosis surgery[13,14] and Scheuermann's kyphosis.[15] The SRS database has not been queried to formally report the short-term M&M of FSPD. The main objective of this study was to report the SRS short-term complication rate in patients undergoing treatment of thoracolumbar FSPD and to assess factors that may influence this rate.

MATERIALS AND METHODS

The SRS M&M database was queried for cases of FSPD reported from the years 2004 to 2007. A period of 5 years of candidate membership in the SRS must be completed before application for full active membership. During the time interval assessed in this study (2004–2007), candidate members were required to submit all spinal procedures at least annually. Full active members were encouraged to submit their cases as well. Whether candidate members ultimately achieved full membership was not impacted by the numbers or types of complications reported.

During the 2004 to 2007 time interval, information collected in the SRS M&M database included: age, year of surgery, SRS membership status, type of scoliosis/deformity, history of prior surgery, use of fusion, use of osteotomy, type of osteotomy, fusion type, implant type, surgical approach, use of neurologic monitoring, and complications.

Complications for cases of FSPD were tabulated and stratified based on correction technique, surgical approach, SRS membership status (as a surrogate for experience), patient age, and history of prior surgery. Correction technique was categorized into: PSO, SPO, VCR, anterior discectomy with corpectomy (ADC), osteotomy performed but not otherwise specific, and no osteotomy. Surgical approach was categorized into anterior-only, posterior-only, or combined anterior and posterior. Complications for this database were short-term due to the annual reporting requirement, without reporting of additional follow-up. Statistical analyses of these data sets were performed using univariate and multivariate analyses. All statistical analyses were two-sided, and statistical significance was based on a $P < 0.05$.

RESULTS

A total of 108,419 surgical cases were submitted in the years 2004 to 2007. Of these cases, 578 (0.5%) were performed specifically for FSPD. Cases of FSPD were classified based on etiology and included 410 (71%) postsurgical, 120 (21%) degenerative, 6 (1%) postinfection, 2 (<1%) dysplastic, and 40 (7%) uncategorized cases. The mean age of FSPD patients in this series was 56.4 years (median = 58 years), with 418 (72%) patients ≤ 65 years of age (Table 1). Overall, 71% of the cases were revisions, and full active and candidate members performed 69% and 31% of the cases, respectively. Of the 578 cases, surgical approach information was available for 536, and included anterior-only approach for 47 (9%), posterior-only approach for 372 (69%), and combined anterior and posterior approaches for 117 (22%).

Osteotomies were performed in 402 of the 578 cases (70%), and included 215 PSOs (37%), 135 SPOs (23%), 19 ADCs (3%), 18 VCRs (3%), and 15 unspecified osteotomies (3%). Correction did not include an osteotomy in 176 cases (30%). The proportion of younger patients (≤65 years old) treated with an osteotomy (72%) was significantly greater than the proportion of older patients (>65 years old) treated with an osteotomy (63%; $P = 0.041$, Table 1). Among the subtypes of osteotomies, there were no significant differences in mean patient age.

There were a total of 170 complications (29.4%) in 132 patients (Table 2). The most common complications were dural tears (5.9%), wound infection (3.8%), new neurologic deficit (3.8%), pulmonary complications other than pulmonary embolus (2.1%), implant failure (1.7%), wound hematomas (1.6%), epidural hematomas (1.4%), and nonfatal pulmonary embolus (1.0%). There were three deaths (0.5%), with one each resulting from multisystem organ failure, myocardial infarction, and pulmonary embolism. These three patients were 42, 56, and 73 years of age, respectively.

The overall complication rate was significantly higher for cases that included an osteotomy, compared with cases that did not include an osteotomy (34.8% *vs.* 17.0%, $P < 0.001$). With regard to specific complications, patients whose procedure included an osteotomy had significantly higher rates of dural tear and new neurologic deficit compared with patients whose procedure did not include an osteotomy ($P = 0.013$ and 0.031, respectively, Table 2). Total rates of complications differed significantly among the no osteotomy, SPO, PSO, VCR, and ADC groups ($P < 0.001$). The total complication

TABLE 1. Correction Technique for Fixed Sagittal Plane Deformity, Stratified Based on Patient Age, Revision Status, and Surgeon Membership Status (Surrogate for Experience)

	No. of Procedures (%) by Patient Age Group*		Mean Age (median)	Percent Revision Cases	Membership Status of Surgeon (%)	
	<65 yr Old	>65 yr Old			Full Active	Candidate
No Osteotomy	117 (28)	57 (37)	56.7 (60)	55	73	27
Osteotomy	301 (72)	97 (63)	56.3 (58)	78	68	32
Pedicle subtraction osteotomy	157 (38)	56 (36)	57.3 (58)	80	66	34
Smith-Petersen osteotomy	103 (25)	30 (19)	54.8 (57)	78	68	32
Anterior discectomy/corpectomy	16 (4)	3 (2)	56.7 (56)	74	78	22
Vertebral column resection	14 (3)	4 (3)	58.1 (58)	78	94	6
Unspecified osteotomy	11 (3)	4 (3)	53.5 (57)	73	47	53
Combined Osteotomy and No Osteotomy Groups	418	154	56.4 (58)	71	69	31

**Age was not reported for 6 of the total 578 patients. A significantly higher proportion of osteotomies were performed in patients <65 yr old compared with patients > 65 yr old (P = 0.041).*

TABLE 2. Complications Associated with the Surgical Treatment of 578 Patients with Fixed Sagittal Plane Deformity, Stratified Based on Corrective Technique*

	No. by Type of Osteotomy (%)						
Complication	No Osteotomy, n = 176 (%)	Osteotomy, n = 402 (%)	SPO (n = 135)	PSO (n = 215)	VCR (n = 18)	ADC (n = 19)	Not Specified (n = 15)
Death*	1 (0.6)	2 (0.5)	1 (0.7)	1 (0.5)	0	0	0
Dural Tear†	4 (2.3)	30 (7.5)	9 (6.7)	15 (7.0)	2 (11.1)	2 (10.5)	2 (13.3)
Wound Infection	5 (2.8)	17 (4.2)	3 (2.2)	12 (5.6)	1 (5.6)	1 (5.3)	0
Superficial	2 (1.1)	5 (1.2)	0	4 (1.9)	0	1 (5.3)	0
Deep	3 (1.7)	12 (3.0)	3 (2.2)	8 (3.7)	1 (5.6)	0	0
New Neurological Deficit‡	2 (1.1)	20 (5.0)	5 (3.7)	15 (7.0)	0	0	0
Implant Failure	3 (1.7)	7 (1.7)	1 (0.7)	6 (2.8)	0	0	0
Wound Hematoma	2 (1.1)	7 (1.7)	2 (1.5)	5 (2.3)	0	0	0
Epidural Hematoma	1 (0.6)	7 (1.7)	3 (2.2)	3 (1.4)	1 (5.6)	0	0
Nonfatal PE	0	6 (1.5)	1 (0.7)	4 (1.9)	1 (5.6)	0	0
Pulmonary (not PE)	4 (2.3)	8 (2.0)	2 (1.5)	5 (2.3)	0	1 (5.3)	0
DVT	0	4 (1.0)	0	2 (0.9)	2 (11.1)	0	0
Visual Loss	1 (0.6)	0	0	0	0	0	0
Other	7 (4.0)	32 (8.0)	11 (8.1)	16 (7.4)	3 (16.7)	1 (5.3)	1 (6.7)
Total§	30 (17.0)	140 (34.8)	38 (28.1)	84 (39.1)	11 (61.1)	6 (31.6)	3 (20.0)

There were a total of 170 complications in 132 patients.

**Causes of death: multisystem organ failure (no osteotomy), myocardial infarction (SPO), pulmonary embolism (PSO)*

†Dural tear rate significantly higher in osteotomy group vs. group without osteotomy (P = 0.013).

‡New neurological deficit rate significantly higher in osteotomy group vs. group without osteotomy (P = 0.031).

§Overall complication rate significantly higher in osteotomy group vs. group without osteotomy (P < 0.001). Total rates of complications significantly different among no osteotomy, SPO, PSO, VCR, and ADC groups (P < 0.001, Pearson χ^2).

SPO indicates Smith–Peterson osteotomy; PSO, pedicle subtraction osteotomy; VCR, vertebral column resection; ADC, anterior discectomy with corpectomy; PE, pulmonary embolism; DVT, deep venous thrombosis.

rates were progressively higher from no osteotomy (17.0%), to SPO (28.1%), to PSO (39.1%), to VCR (61.1%; Table 2). There were no statistically significant differences in the rates of mortality based on whether an osteotomy was performed or based on osteotomy type.

Of the 22 neurologic deficits reported, 18 patients (3.1%) had nerve root deficits, and 4 (0.7%) had incomplete spinal cord deficits. Of the 18 patients with new nerve root deficits, intraoperative neuromonitoring was performed with somatosensory-evoked potentials (SSEP) in 16, with electromyography (EMG) in 14, and with motor-evoked potentials (MEP) in 7. Only 2 of the 18 nerve root deficits had abnormalities detected with neuromonitoring intraoperatively, all of which had combined monitoring. Four cases had implants removed. Nine of the eighteen nerve root deficits had partial recovery and nine had complete recovery (Table 3).

Of the four patients with new spinal cord deficits, all had been monitored intraoperatively with both SSEP and EMG monitoring, and three of the four also had MEP monitoring. None of these patients had a wakeup test performed. Only one of these patients had abnormalities detected intraoperatively by neuromonitoring. Two patients had partial recovery and two had complete recovery of their deficits (Table 3). None of these patients had their implants removed.

Factors potentially associated with the occurrence of complications were assessed with univariate binomial logistic regression (Table 4). Cases in which an osteotomy was performed had significantly higher rates of complications, compared with those that did not include an osteotomy (P = 0.003, odds ratio [OR] = 2.066, 95% confidence interval [CI] = 1.289–3.311). In addition, cases performed with an anterior-only approach had significantly fewer complications, compared with cases performed with a posterior-only approach (6.4% and 23.9%, respectively, P = 0.021, OR = 0.289, 95% CI = 0.101–0.827). Patient age, whether treated as a continuous variable or a discreet variable (<65 years *vs.* ≥ 65 years), was not significantly associated with the rate of complications (P = 0.68 and 0.31, respectively). Patients <65 years old and those ≥ 65 years of age had complication rates of 24.0% and 20.1%, respectively. Full active members did not have significantly different complication rates compared to candidate members (20.8% and 25.9%, respectively, P = 0.18). Revision cases did not have a significantly different complication rate compared with primary cases (24.5% and 18.2%, respectively, P = 0.10). Cases that involved combined anterior and posterior approaches did not have a significantly different complication rate compared with cases having a posterior-only approach (27.4% and 23.9%, respectively, P = 0.45).

Multivariate analysis was performed to assess for potential confounding effects on the association between performance of an osteotomy and a higher rate of complications. On binomial logistic regression, procedures with an osteotomy (*vs.* those without an osteotomy) had significantly higher rates of complications (P = 0.003, OR = 2.070, 95% CI = 1.291–3.321), after adjusting for the effects of patient age (continuous variable, P = 0.75), membership status of the surgeon (active *vs.* candidate, P = 0.31), and history of prior surgery (revision *vs.* primary, P = 0.23).

Multivariate forward and backward conditional logistic regression analyses were performed to assess for independent predictors of increased complications. The best-fitting final model included only whether an osteotomy was performed (P = 0.002, OR = 2.149, 95% CI = 1.332–3.468). All other variables included in the analyses were excluded from the final model, including: patient age (continuous variable, P = 0.63), history of prior surgery (revision *vs.* primary, P = 0.35), membership status of the surgeon (active *vs.* candidate, P = 0.15), and surgical approach (anterior-only *vs.* combined anterior-posterior or posterior-only, P = 0.12).

TABLE 3. Rates of New Neurological Deficit Associated with the Surgical Treatment of 578 Patients with Fixed Sagittal Plane Deformity, Stratified Based on Corrective Procedure, Type of Deficit, and Degree of Recovery

	No. of Procedures	No. of New Deficits	Degree of Recovery, No. (%)	
			Partial	Complete
No osteotomy	176			
Nerve root deficit		2	1 (50)	1 (50)
Smith–Peterson osteotomy	135			
Nerve root deficit		3	1 (33)	2 (67)
Incomplete spinal cord deficit		3	2 (67)	1 (33)
Pedicle subtraction osteotomy	215			
Nerve root deficit		13	7 (54)	6 (46)
Incomplete spinal cord deficit		1	0	1 (100)

No new neurological deficits were reported for procedures that included vertebral column resection (n = 18) or anterior discectomy with corpectomy (n = 19).

TABLE 4. Univariate Assessment of Parameters Potentially Associated with the Occurrence of Complications Associated with the Surgical Correction of 578 Patients with Fixed Sagittal Plane Deformity

	P	OR	OR 95% CI
Osteotomy performed (*vs.* no osteotomy)	0.003	2.066	1.289–3.311
Patient age (continuous variable)	0.68	1.003	0.989–1.017
Patient age (≥65 yr *vs.* <65 yr)	0.31	1.264	0.804–1.989
Full active member (*vs.* candidate member)	0.18	0.751	0.495–1.142
Revision surgery (*vs.* primary surgery)	0.10	1.461	0.927–2.303
Anterior approach alone (*vs.* posterior- alone approach)	0.021	0.289	0.101–0.827
Anterior-posterior combined approach (*vs.* posterior-alone approach)	0.45	1.197	0.747–1.918

Analyses performed using binary logistic regression analysis, with each patient coded as either having had one or more complications (yes) or having had no complications (no).

OR indicates odds ratio; CI, confidence interval.

DISCUSSION

This is the largest study to date that provides complication rates associated with the surgical treatment of FSPD. This report provides separate complication rates based on whether a corrective osteotomy was performed as part of the procedure, and demonstrates a significantly higher rate of complications when an osteotomy is used. In addition, the numbers of cases in this series enabled assessment of complication rates based on type of osteotomy performed, and clearly demonstrate a progressive increase in complications with more aggressive osteotomies (SPO to PSO to VCR). Also documented is a modestly, but significantly, higher rate of osteotomy use in younger compared with older patients. Notably, univariate analyses demonstrated that rates of complications were not significantly associated with patient age, surgeon experience, or history of prior surgery. In addition, of the parameters assessed, the only factor with statistically significant, independent association with the rate of complications was whether an osteotomy was performed. Collectively, these data document the M&M that are inherent to the surgical correction of FSPD and provide potentially useful information for surgical planning, preoperative patient counseling, and for on-going efforts to improve the safety of patient care.

In this series, osteotomies were associated with higher rates of complications. It should be recognized that these osteotomies offer the potential for powerful deformity correction and are often used in patients with the most complex and rigid deformities that likely could not be readily corrected otherwise. It is important to appreciate the significantly higher complication rates associated with osteotomies and employ them judiciously.

Age has been shown to have an increased correlation with complications in patients undergoing deformity surgery.[16] In this series, age did not correlate with a higher rate of complications. However, there was a significantly greater tendency to perform osteotomies in patients ≤65 years of age (Table 1). Thus, the lack of correlation between age and complication rate in this study may be confounded by the fewer osteotomy procedures that were performed in older patients. However, among the subtypes of osteotomies performed, there were no significant differences in mean patient age.

The data presented in this study demonstrate a higher rate of complications in patients who underwent a revision procedure (24.5% *vs.* 18.2%). Although this difference did not reach statistical significance ($P = 0.10$), it is important to recognize that patients with a previous history of spinal surgery typically present a greater challenge to the surgeon. Careful technique should be used when performing revision surgery to help reduce the already established increased risk of dural tears and other complications during these cases.[17,18]

Membership status was used in this study as a surrogate for surgeon experience. Not surprisingly, candidate members had a modestly higher rate of complications (25.9% *vs.* 20.8%), but this difference did not reach statistical significance ($P = 0.18$). This may suggest a short but steep learning curve for these techniques or may suggest that many of the complications occur independent of surgeon experience.

An anterior-only approach was associated with a significantly lower rate of complications (6.4%) compared with posterior-only (23.9%) or combined anterior–posterior (27.4%) approaches. It is possible that the lower rate of complications with the anterior-only approach may result from its application to less complex deformities or potentially more healthy patients, although this cannot be confirmed based on information available in the database.

The short-term complication rate for SPOs in this study was 28.1%. This is comparable to that reported by Cho *et al* in 2005, in which they reported an early complication rate of 37% for SPO based on 30 patients.[19] In this series, 3.7% of the patients undergoing an SPO developed a new neurologic deficit, which is comparable to the rate of 3.3% (1 in 30 patients) reported by Cho *et al*.[19]

In this series, the rate of complications for PSO's was 39.1%. Prior reports of early complication rates of PSO's range from 37% to 59%.[3,19,20] These rates were based on studies of fewer than 35 patients. In a meta-analysis from

Van Royen *et al*, the mortality rate with PSO's in this meta-analysis was 1.3%, which is comparable to this series in which it was 0.5%.[21]

In this series, procedures with a PSO were found to have almost twice the rate of new neurologic deficits compared with procedures with an SPO (7.0% *vs.* 3.7%). The SRS PSO neurologic complication rate is comparable to that of Cho *et al*, who reported a rate of 7.3% (3 of 41 patients),[19] however, a neurologic complication rate as high as 14.3% (5 of 35 patients) from the same institution has also been reported.[20]

The overall complication rate in this series for procedures including a VCR was 61.1%. VCR complication rates have been reported by Suk *et al* in two papers.[2,4] The first paper which assessed 16 patients with rigid scoliosis had an overall complication rate of 25%.[2] The second study assessed complication rates in 25 patients undergoing VCR for the treatment of fixed lumbosacral deformity and reported a rate of 20%. In addition, Wang *et al* reported an overall complication rate of 30.7% based on a retrospective review of 13 patients treated with a VCR[22] The range of complication rates for VCR, from those of Suk to those of this study, may reflect the limited sample sizes. In addition, the higher rate of complications in this series may be more reflective of rates based on a multicenter series.

Although the VCR group had the greatest rate of complications in this series, surprisingly, there were no neurologic complications in this group. It is also remarkable that none of the mortalities occurred in the VCR group. Perhaps with a greater sample size, more neurologic deficits and mortality would be identified, because VCR is the most complex of the osteotomy types. Nevertheless, it is important to note that the complications in this group were not insignificant. Specifically, among the VCR complications were two dural tears, an epidural hematoma, a deep wound infection, two deep venous thromboses, a pulmonary embolus, and a malpositioned implant.

The strength of the SRS database as a resource for spine research includes the large number of patients treated, and the representation of surgeons with a broad range of experience from multiple institutions. Limitations of this database include the lack of reporting of long-term follow-up, no information on number of levels fused, lack of pain and functional outcome data, and the potential inaccuracy of the true complication rate secondary to under-reporting of events. Despite these acknowledged limitations, the SRS database provides spine surgeons with the largest repository of information to study short-term complications undergoing spinal surgery.

CONCLUSION

On the basis of a series of 578 patients treated for FSPD, the overall complication rates associated with cases including an osteotomy were significantly higher than cases that did not include an osteotomy (34.8% *vs.* 17.0%, $P < 0.001$). In addition, this study demonstrates a progressive increase in complications with more aggressive osteotomies, from SPO (28.1%), to PSO (39.1%), to VCR (61.1%). In this series, patient age, surgeon experience (using SRS membership status as a surrogate), and whether the patient had a history of prior surgery were not significantly associated with the rate of complications. Collectively, these data document the M&M that are inherent to the surgical correction of FSPD and provide potentially useful information for surgical planning, preoperative patient counseling, and for on-going efforts to improve the safety of patient care.

➢ Key Points

- ❑ The overall complication rate, based on 578 cases from the Scoliosis Research Society Morbidity and Mortality Database, for the treatment of fixed sagittal plane deformity (FSPD) is 29.4%.
- ❑ The mortality rate associated with surgical correction of FSPD was 0.5%, with deaths resulting from multisystem organ failure, myocardial infarction, and pulmonary embolism.
- ❑ Surgical procedures for correction of FSPD that included an osteotomy had a higher rate of complications (34.8%) than cases not including an osteotomy (17.0%, $P < 0.001$), and this remained significant after adjusting for the effects of patient age, surgeon experience, and history of prior surgery ($P = 0.003$).
- ❑ Factors not significantly associated with complication rate included: patient age ($P = 0.68$), surgeon experience ($P = 0.18$), and history of prior surgery ($P = 0.10$).
- ❑ Complication rates were progressively higher from no osteotomy (17.0%), to Smith–Peterson osteotomy (28.1%), to pedicle subtraction osteotomy (39.1%), to vertebral column resection (61.1%).

References

1. Bridwell KH. Decision making regarding Smith-Petersen vs. pedicle subtraction osteotomy vs. vertebral column resection for spinal deformity. *Spine* 2006;31(19 Suppl):S171–8.
2. Suk SI, Chung ER, Kim JH, et al. Posterior vertebral column resection for severe rigid scoliosis. *Spine* 2005;30(14):1682–7.
3. Bridwell KH, Lewis SJ, Edwards C, et al. Complications and outcomes of pedicle subtraction osteotomies for fixed sagittal imbalance. *Spine* 2003;28(18):2093–101.
4. Suk SI, Chung ER, Lee SM, et al. Posterior vertebral column resection in fixed lumbosacral deformity. *Spine* 2005;30(23):E703–10.
5. Keyoung HM, Kanter AS, Mummaneni PV. Delayed-onset neurological deficit following correction of severe thoracic kyphotic deformity. *J Neurosurg Spine* 2008;8(1):74–9.
6. Kim KT, Suk KS, Cho YJ, et al. Clinical outcome results of pedicle subtraction osteotomy in ankylosing spondylitis with kyphotic deformity. *Spine* 2002;27(6):612–18.
7. Kim KT, Lee SH, Suk KS, et al. Spinal pseudarthrosis in advanced ankylosing spondylitis with sagittal plane deformity: clinical characteristics and outcome analysis. *Spine* 2007;32(15):1641–7.
8. La Marca F, Brumblay H. Smith-Petersen osteotomy in thoracolumbar deformity surgery. *Neurosurgery* 2008;63(3 Suppl):163–70.
9. Berven SH, Deviren V, Smith JA, et al. Management of fixed sagittal plane deformity: results of the transpedicular wedge resection osteotomy. *Spine* 2001;26(18):2036–43.
10. Chang KW, Chen YY, Lin CC, et al. Closing wedge osteotomy versus opening wedge osteotomy in ankylosing spondylitis with thoracolumbar kyphotic deformity. *Spine* 2005;30(14):1584–93.
11. Wiggins GC, Ondra SL, Shaffrey CI. Management of iatrogenic flat-back syndrome. *Neurosurg Focus* 2003;15(3):E8.

12. Yang BP, Ondra SL, Chen LA, et al. Clinical and radiographic outcomes of thoracic and lumbar pedicle subtraction osteotomy for fixed sagittal imbalance. *J Neurosurg Spine* 2006;5(1):9–17.
13. 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* 2006;31(3):345–9.
14. MacEwen GD, Bunnell WP, Sriram K. Acute neurological complications in the treatment of scoliosis. A report of the Scoliosis Research Society. *J Bone Joint Surg Am* 1975;57(3):404–8.
15. Coe JD, Smith JS, Berven S, et al. Complications of spinal fusion for scheuermann kyphosis: a report of the scoliosis research society morbidity and mortality committee. *Spine (Phila Pa 1976)* 2010;35(1):99–103.
16. Daubs MD, Lenke LG, Cheh G, et al. Adult spinal deformity surgery: complications and outcomes in patients over age 60. *Spine* 2007;32(20):2238–44.
17. Mummaneni PV, Dhall SS, Ondra SL, et al. Pedicle subtraction osteotomy. *Neurosurgery* 2008;63(3 Suppl):171–6.
18. Khan MH, Rihn J, Steele G, et al. Postoperative management protocol for incidental dural tears during degenerative lumbar spine surgery: a review of 3,183 consecutive degenerative lumbar cases. *Spine* 2006;31(22):2609–13.
19. Cho KJ, Bridwell KH, Lenke LG, et al. Comparison of Smith-Petersen versus pedicle subtraction osteotomy for the correction of fixed sagittal imbalance. *Spine* 2005;30(18):2030–7, discussion 8.
20. Kim YJ, Bridwell KH, Lenke LG, et al. Results of lumbar pedicle subtraction osteotomies for fixed sagittal imbalance: a minimum 5-year follow-up study. *Spine* 2007;32(20):2189–97.
21. Van Royen BJ, De Gast A. Lumbar osteotomy for correction of thoracolumbar kyphotic deformity in ankylosing spondylitis. A structured review of three methods of treatment. *Ann Rheum Dis* 1999;58(7):399–406.
22. Wang Y, Zhang Y, Zhang X, et al. A single posterior approach for multilevel modified vertebral column resection in adults with severe rigid congenital kyphoscoliosis: a retrospective study of 13 cases. *Eur Spine J* 2008;17(3):361–72.