Risk factors for revision surgery following primary adult spinal deformity surgery in patients 65 years and older

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OBJECTIVE Surgical correction of adult spinal deformity (ASD) is a complex undertaking with high revision rates. The elderly population is poorly studied with regard to revision surgery, yet senior citizens constitute a rapidly expanding surgical demographic. Previous studies aimed at elucidating appropriate risk factors for revision surgery have been limited by small cohort sizes. The purpose of this study was to assess factors that modify the risk of revision surgery in elderly patients with ASD.

METHODS The PearlDiver database (2005–2012) was used to determine revision rates in elderly ASD patients treated with a primary thoracolumbar posterolateral fusion of 8 or more levels. Analyzed risk factors included demographics, comorbid conditions, and surgical factors. Significant univariate predictors were further analyzed with multivariate analysis. The causes of revision at each year of follow-up were determined.

RESULTS A total of 2293 patients who had been treated with posterolateral fusion of 8 or more levels were identified. At the 1-year follow-up, 241 (10.5%) patients had been treated with revision surgery, while 424 (18.5%) had revision surgery within 5 years. On univariate analysis, obesity was found to be a significant predictor of revision surgery at 1 year, while bone morphogenetic protein (BMP) use was found to significantly decrease revision surgery at 4 and 5 years of follow-up. Diabetes mellitus, osteoporosis, and smoking history were all significant univariate predictors of increased revision risk at multiple years of follow-up. Multivariate analysis at 5 years of follow-up revealed that osteoporosis (OR 1.98, 95% CI 1.60–2.46, $p < 0.0001$) and BMP use (OR 0.70, 95% CI 0.56–0.88, $p = 0.002$) were significantly associated with an increased and decreased revision risk, respectively. Smoking history trended toward significance (OR 1.37, 95% CI 1.10–1.70, $p = 0.005$). Instrument failure was consistently the most commonly cited reason for revision. Five years following surgery, it was estimated that the cohort had 68.8% survivorship.

CONCLUSIONS For elderly patients with ASD, osteoporosis increases the risk of revision surgery, while BMP use decreases the risk. Other comorbidities were not found to be significant predictors of long-term revision rates. It is expected that within 5 years following the index procedure, over 30% of patients will require revision surgery.

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KEY WORDS adult spinal deformity; elderly; revision; spine fusion; posterolateral

SURGICAL correction of adult spinal deformity (ASD) is a complex undertaking that ranks among the most morbid of orthopedic procedures. The challenges that arise from surgical management of this pathology have resulted in high complication rates,^{3,4,34–36} particularly in elderly patients.⁹ Specifically, revision rates often range from 8%–45% following primary spine fusion procedures, increasing with greater follow-up.^{23,27,32,38} The elderly population is of particular interest given the rapidly

rising need for care for this population; with improving healthcare and life expectancy, larger numbers of elderly patients are considering surgical spine treatment.¹¹ Revision surgery in this patient population can pose a difficult problem, requiring physicians to weigh the pros and cons to determine an adequate solution. In patients with ASD, revisions are often due to pseudarthrosis,^{8,14,20–22,27,32,33} implant failure,^{27,38} adjacent segment disease,^{8,15,22,27,33,38} or infection,^{22,24,27,32,38} resulting in increased healthcare costs

ABBREVIATIONS ASD = adult spinal deformity; BMI = body mass index; BMP = bone morphogenetic protein; COPD = chronic obstructive pulmonary disease; CPT = current procedural terminology; ICD-9 = *International Classification of Diseases, 9th Revision*.

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and procedural morbidity. These issues highlight the need for identifying revision risk factors in order to influence clinical decision-making and improve patient education.

Previous studies aimed at investigating predictive risk factors for reoperation following spine surgery have mostly focused on procedures for lumbar stenosis.^{5,10,12} Unfortunately, there are few studies^{25,27,38} that have investigated predictive risk factors for revision surgery following an index procedure for patients with ASD, with none focusing primarily on an elderly population, likely because of low cohort sizes at individual institutions.

The primary aim of this study is 2-fold: to characterize reoperation rates in elderly patients treated with 8-level or greater posterior fusion procedures for deformity and to assess the relative contribution of specific patient and surgery characteristics in determining the risk of eventual reoperation.

Methods

Data for the current study were acquired from the PearlDiver Patient Records Database (PearlDiver Inc.), which is a for-fee database. Data were acquired from the database using *International Classification of Diseases, 9th Revision* (ICD-9), diagnosis and procedure codes or current procedural terminology (CPT) codes. In total, procedural volumes, demographic information, and specific diagnoses can be accessed from over 40 million individual patient records from 2005 to 2012. Access to the database was granted by PearlDiver Technologies for the purpose of academic research. The database was stored on a password-protected server maintained by PearlDiver.

Patients with ASD who had been treated with a posterolateral fusion of 8 or more levels were considered for this study. Specifically, ICD-9 procedure codes for thoracolumbar and lumbosacral posterior fusions (81.05, 81.07, and 81.08) were queried. The resultant group of patients was narrowed to include only those who were also coded as having undergone a fusion of 8 levels or greater (81.64). Fusions extending to the cervical spine were excluded (81.01, 81.02, 81.03). Other exclusion criteria included any diagnoses of traumatic spine fracture, bone metastasis, primary bone cancer, or spine infection either on the day of surgery or prior to surgery (Appendix Table 1) and shoulder, knee, or hip replacement at any point following the index procedure. The latter exclusion criteria were used to avoid general revision surgery coding for revision procedures associated with other common surgical procedures. Patients who had undergone a revision fusion procedure were excluded as well. ICD-9 procedure codes for revision surgery are detailed in Table 1. Lastly, only patients 65–84 years of age were selected, specifically those with a diagnosis of kyphosis or scoliosis on the same day as their index procedure. This resulted in a total of 2293 patients who were included for subsequent analysis.

Following a basic demographic assessment of the cohort, queries were attempted for the number of reoperations or revision spine surgeries after the index procedure at 1, 2, 3, 4, and 5 years of follow-up. The full cohort was then dichotomized based on several potential predictor variables. Demographic predictor variables included pa-

tient age (dichotomized by a cutoff of 75 years) and sex. Comorbidities included diabetes mellitus, chronic obstructive pulmonary disease (COPD), peripheral vascular disease, obesity, smoking history, and osteoporosis. Surgical and postsurgical factors that were assessed included transfusion on the day of surgery, coding of a concomitant anterior approach, length of stay longer than 7 days, and bone morphogenetic protein (BMP) use. Following dichotomization, the number of revisions occurring in each subgroup at each time point was recorded. After determining which univariate variables were predictive of eventual revision, significant predictors were further analyzed with aggregate multivariate analysis.

The reason for revision or reoperation was determined by querying the number of patients who had 1 of 5 possible diagnoses entered on the same day as their revision surgery. The 5 diagnoses that were specifically queried were pseudarthrosis, instrument failure, thoracolumbar fracture, spine infection, or new neurological deficit (Table 2). New neurological deficit was queried by assessing the number of patients who had developed a neurological deficit at the time of their revision but did not have any motor or sensation deficit recorded on the day of or prior to the index procedure. The 5 diagnoses were not mutually exclusive.

Statistics

The proportion of revision surgeries in dichotomized subgroups were compared using Pearson chi-square analysis at each time point. Significant univariate predictors were further assessed by multivariate analysis to calculate the adjusted odds ratio (OR) for other significant univariate variables predictive of 5-year revision rates.

Survival analysis was then performed, with revision surgery as the primary outcome. Survivorship was defined as not having a revision surgery during the specified follow-up time. The survival function was calculated using the Kaplan-Meier method. Follow-up time was calculated by censoring patients when treated with a revision surgery or when an active record was not present. Follow-up time was estimated at 3-month intervals for the first 5 years postoperatively. Patients who were lost to follow-up between time points contributed half the interval time (e.g., 1.5 months) to follow-up.

For all analyses, $p < 0.005$ was considered significant because of the large cohort sizes and multiple comparisons. Statistical analyses were performed using Stata 11.0 (StataCorp LP).

Results

Of the 2293 patients included in this study, 944 (41.2%) were 65–69 years old, 732 (31.9%) were 70–74 years old, 457 (19.9%) were 75–79 years old, and 160 (7.0%) were 80–84 years old. A total of 1810 (78.9%) patients were female. The median Charlson Comorbidity Index score was 5 (mean 5.87 ± 3.32). Of note, 24.6% of patients had diabetes, 36.2% had COPD, 44.9% had osteoporosis, 23.0% had peripheral vascular disease, 19.9% were obese, and 34.9% had a smoking history. Concerning the surgical procedure itself, 1009 (44.0%) patients had a transfusion on the same

TABLE 1. CPT and ICD-9 codes for revision spine surgery

Category	ICD-9 or CPT Code	Definition
Revision surgery	P78.69	Removal of implanted devices from bone, other bones
	P81.30	Refusion of spine, not otherwise specified
	P81.34	Refusion of dorsal & dorsolumbar spine, ant column, ant technique
	P81.35	Refusion of dorsal & dorsolumbar spine, pst column, pst technique
	P81.36	Refusion of lumbar & lumbosacral spine, ant column, ant technique
	P81.37	Refusion of lumbar & lumbosacral spine, pst column, lat transverse process technique
	P81.38	Refusion of lumbar & lumbosacral spine, ant column, pst technique
	P81.39	Refusion of spine not elsewhere classified
	P86.22	Excisional debridement of wound, infection, or burn
	CPT-22010	Open incision & drainage of deep abscess (subfascial), pst spine; cervical, thoracic, or cervicothoracic
	CPT-22015	Open incision & drainage of deep abscess (subfascial), pst spine; lumbar, sacral, or lumbosacral
	CPT-22830	Exploration of spinal fusion
	CPT-22850	Removal of pst nonsegmental instrumentation
	CPT-22852	Removal of pst segmental instrumentation
Deformity	737.1, 737.10, 737.19	Kyphosis (acquired)
	737.3, 737.30, 737.39	Kyphoscoliosis & scoliosis
	737.4, 737.40, 737.41, 737.43	Curvature of spine associated w/ other conditions
	737.8	Other curvatures of spine
	737.9	Unspecified curvature of spine

ant = anterior; pst = posterior.

day, 490 (21.4%) were treated with a combined anteroposterior approach, and 983 (42.9%) were treated with BMP.

Revision rates stratified by follow-up time in the overall cohort and also by potential predictor variables are summarized in Table 3. Within 1 year of follow-up, 241 patients (10.5%) were treated with revision surgery. This number increased to 354 (15.4%), 394 (17.2%), 417 (18.2%), and 424 (18.5%) within 2, 3, 4, and 5 years of follow-up, respectively. When univariate statistics were considered, diabetes, obesity, smoking, and osteoporosis were found to be significant predictors of increased revisions within

1 year of follow-up. Of note, this was the only time point at which obesity was predictive. BMP use was associated with a decreased likelihood of revision surgery at 4 and 5 years of follow-up.

Multivariate adjusted ORs for each of the aforementioned univariate predictors are provided in Table 4. Significant adjusted ORs were observed with osteoporosis (OR 1.98, 95% CI 1.60–2.46, $p < 0.0001$) and BMP use (OR 0.70, 95% CI 0.56–0.88, $p = 0.002$). Smoking history trended toward significance (OR 1.37, 95% CI 1.10–1.70, $p = 0.005$). Diabetes mellitus ($p = 0.013$) and obesity ($p =$

TABLE 2. Reasons for revision surgery

Reasons For Revision	ICD-9 Code	Definition
Pseudarthrosis	733.82	Nonunion of fracture (including pseudarthrosis of spine)
Instrument failure	996.49	Other mechanical complication of other internal orthopedic device, implant, & graft
Thoracolumbar fracture	805.2, 805.4, 805.6, 805.8	Closed fracture of thoracic, lumbar, sacral, coccygeal, unspecified spine w/o spinal cord injury
	806.20–.29, 806.4, 806.60–.62, 806.69, 806.8	Closed fracture of thoracic, lumbar, sacral, coccygeal, unspecified spine w/ spinal cord injury
Neurological deficit	344.1	Paraplegia
	344.30–.32	Monoplegia of lower limb
	344.60–.61	Cauda equina syndrome
	353.1	Lumbosacral plexus lesions
	353.3	Thoracic root lesions
	353.4	Lumbosacral root lesions
Infection	324.1	Intraspinal abscess
	998.5	Postop infection not elsewhere classified
	998.51	Infected postop seroma
	998.59	Other postop infection
	996.67	Infection & inflammatory reaction due to other internal orthopedic device, implant, & graft

TABLE 3. Predictors of revision rate

Category	Total	1 Yr	2 Yrs	3 Yrs	4 Yrs	5 Yrs
No. of revision patients (%)	2293	241 (10.5)	354 (15.4)	394 (17.2)	417 (18.2)	424 (18.5)
Demographics						
Age in yrs						
<75	1676	196 (10.8)	287 (15.8)	318 (17.6)	339 (18.7)	345 (19.1)
≥75	617	45 (9.3)	67 (13.9)	76 (15.7)	78 (16.1)	79 (16.4)
Sex						
F	1810	181 (10.8)	266 (15.9)	303 (18.1)	323 (19.3)	329 (19.6)
M	483	60 (9.7)	88 (14.3)	91 (14.7)	94 (15.2)	95 (15.4)
Comorbid conditions						
Diabetes mellitus						
No	1728	163 (9.4)	246 (14.2)	270 (15.6)	291 (16.8)	296 (17.1)
Yes	565	78 (13.8)*	108 (19.1)	124 (21.9)*	126 (22.3)*	128 (22.6)*
COPD						
No	1462	144 (9.8)	212 (14.5)	233 (15.9)	243 (16.6)	246 (16.8)
Yes	831	97 (11.7)	142 (17.1)	161 (19.4)	174 (20.9)	178 (21.4)
Peripheral vascular disease						
No	1765	177 (10.0)	261 (14.8)	286 (16.2)	304 (17.2)	308 (17.4)
Yes	528	64 (12.1)	93 (17.6)	108 (20.4)	113 (21.4)	116 (22.0)
Obesity						
No	1836	174 (9.5)	266 (14.5)	299 (16.3)	318 (17.3)	322 (17.5)
Yes	457	67 (14.7)*	88 (19.2)	95 (20.8)	99 (21.7)	102 (22.3)
Smoking history						
No	1492	135 (9.0)	216 (14.5)	232 (15.5)	244 (16.4)	248 (16.6)
Yes	801	106 (13.2)*	138 (17.2)	162 (20.2)*	173 (21.6)*	176 (22.0)*
Osteoporosis						
No	1263	110 (8.7)	151 (12.0)	167 (13.2)	175 (13.8)	178 (14.1)
Yes	1030	131 (12.7)*	203 (19.7)*	227 (22.0)*	242 (23.5)*	246 (23.9)*
Surgical factors						
Same-day transfusion						
No	1284	134 (10.4)	204 (15.9)	226 (17.6)	242 (18.8)	245 (19.1)
Yes	1009	107 (10.6)	150 (14.9)	168 (16.7)	175 (17.3)	179 (17.7)
Circumferential approach						
No	1803	194 (10.8)	291 (16.1)	325 (18.0)	343 (19.0)	350 (19.4)
Yes	490	47 (9.6)	63 (12.8)	69 (14.1)	74 (15.1)	74 (15.1)
BMP use						
No	1310	156 (11.9)	224 (17.1)	250 (19.1)	265 (20.2)*	272 (20.8)*
Yes	983	85 (8.6)	130 (13.2)	144 (14.6)	152 (15.5)	152 (15.5)
Length of stay >7 days						
No	1427	145 (10.2)	215 (15.1)	233 (16.3)	245 (17.2)	252 (17.6)
Yes	866	96 (11.1)	139 (16.0)	161 (18.6)	172 (19.9)	172 (19.9)

* Significant difference between the 2 subgroups at the indicated time point ($p < 0.005$).

0.038) did not prove to be significant. A survival function for the full cohort is provided in Fig. 1. Of note, at 1 year, 3 years, and 5 years following surgery, it was estimated that 87.3%, 73.9%, and 68.8% of patients, respectively, would not have had a revision surgery.

Five specific diagnoses were separately queried in revision cases to determine the reasons for revision surgery (Fig. 2). Instrument failure was consistently the most com-

monly cited reason for revision, with 129 (53.5%) patients having undergone revision for this reason at 1 year and 264 (62.3%) patients at 5 years. Infection was the next most common reason for revision surgery, with 58 (24.1%) patients at 1 year and 90 (21.2%) patients through 5 years.

Discussion

At 5 years of follow-up, the proportion of patients

TABLE 4. Adjusted OR for univariate variables predictive of 5-year revision rates*

Variable	Adjusted OR	95% CI Lower	95% CI Upper	p Value
Diabetes mellitus	1.36	1.07	1.73	0.013
Obesity	1.32	1.01	1.72	0.038
Smoking history	1.37	1.10	1.70	0.005
Osteoporosis	1.98	1.60	2.46	<0.0001
BMP use	0.70	0.56	0.88	0.002

* Boldface type indicates statistical significance.

who had undergone a revision surgery following 8-level or greater spine fusion was 18.5%, up from 10.5% at the 1-year follow-up. Obesity was a significant univariate predictor of increased revisions at 1 year of follow-up, while BMP use was predictive of decreased revisions at 4 and 5 years of follow-up. Multivariate analysis revealed that when adjusting for significant univariate predictors, only osteoporosis (OR 1.98) and BMP use (OR 0.70) were significant predictors of revision, with smoking history (OR 1.37) trending toward significance. Overall, instrument failure was the most common reason for revision surgery, representing a coded diagnosis at the time of revision surgery in over 50% of cases at every follow-up time point. Five years following surgery, it was estimated that the cohort had 68.8% survivorship.

Risk factor analysis for outcomes following index spine procedures can differ greatly depending on the outcome of choice. Identifying risk factors for pseudarthrosis, implant failure, or deformity progression is distinct from categorizing predictors of eventual revision, as increasing age or comorbidities play a significant role in determining the health risks of further surgery. For example, although patients with rod fracture, a common reason for revision, tend to be older and have a higher body mass index (BMI),³⁷ increasing age and comorbidities have been shown to be significant predictors of both increasing^{10,26,27,38} and decreasing risk of revision.¹² Regarding age, a study by Deyo et al. found that patients who were 70 years of age or younger were almost twice as likely to

have surgery as those 80 years or older (14.2% vs 7.0%), a significant finding in a population restricted to elderly patients treated for lumbar stenosis.¹² In contrast, a study by Zhu et al. found that patients aged 20–29 years and 30–39 years were significantly less likely to have a revision surgery following an index procedure for ASD than those older than 40 years.³⁸ Furthermore, a study by Hart et al. found that age was not a significant predictor of whether a surgeon decided to perform revision surgery in patients with proximal junctional failure following ASD correction.¹⁸ Conclusions from these 3 studies are difficult to compare since they are derived from different age groups, pathologies, and socioeconomic groups. Results in the present study agreed with the findings of Hart et al.,¹⁸ which stated that age was not a significant predictor of increased risk of revision.

Comorbid conditions remain important factors to consider when predicting future risk of revision surgery. In our study, obesity was a significant predictor of revision surgery at 1 year of follow-up, but it was not significant following multivariate analysis at 5 years of follow-up perhaps because of the higher risk of infections during the early postoperative period, a risk that is known to increase with elevated BMI in patients undergoing lumbar spine surgery.^{6,10,13,19,31} Smoking history did approach significance on multivariate analysis ($p = 0.005$), suggesting that this comorbidity may play a role in predicting an increased risk of revision surgery. A positive smoking history has been shown to predict reoperation following both ASD²⁷ and laminectomy¹⁰ procedures. Osteoporosis, a nontraditional comorbidity, has also been found to be a significant risk factor for eventual revision surgery, probably as a result of poor instrumentation purchase.¹⁷

Lastly, BMP use was associated with a lower risk of revision surgery at 4 and 5 years of follow-up, a relationship that persisted following adjustment for other significant univariate predictors. Previous studies have demonstrated that BMP use decreases the risk of revision surgery following single-level lumbar fusion⁷ and fusions of 8 levels or greater.³⁰ Our finding suggests that BMP use may ensure improved outcomes in the elderly deformity population, but further studies are needed to investigate how revision risk changes with shorter fusions and how complication

FIG. 1. Survivorship curve for all 2293 patients included in this study.

FIG. 2. Reasons for revision. For each reason, the proportion of the total number of revised patients for each year of follow-up is provided above each bar.

rates are affected by BMP use in the elderly deformity population.

Survivorship probability, as calculated by Kaplan-Meier estimates, fell within the range of previously reported values. Mok et al. estimated that survivorship without reoperation in patients with ASD was 86.4% at 1 year, 77.2% at 2 years, and 75.2% at 3 years.²⁷ In contrast, at a mean follow-up of 4.7 years, Pichelmann et al. reported a 9.0% revision rate,³² while at a mean follow-up of 6.9 years, Zhu et al. reported a 7.6% revision rate for 5-level or greater fusions at their respective institutions.³⁸ Notably, in our study, survivorship probabilities ranged from 87.3% at 1 year to 68.8% at 5 years.

In terms of reasons for revision surgery, our results agreed with those of previous studies. A large body of literature reveals the management of pseudarthrosis, implant failure, infection, and adjacent segment disease as an indication for reoperation following spine surgery.^{1,2,15,28,29} The study by Zhu et al. demonstrated that among 60 patients who had undergone revision surgery following the surgical management of ASD, implant breakage was the clear indication in 37% of the patients, while deformity progression, infection, and pseudarthrosis were the indications for further treatment in 16.1%, 14.5%, and 12.9% of revisions, respectively.³⁸ These results are similar to those found in the present study, as most patients had undergone revision surgery for implant failure. Unfortunately, we were unable to determine the incidence of proximal junctional kyphosis and deformity progression because of code restrictions.

The elderly population represents an important, but poorly studied, demographic. With the aid of a national database, we were able to more specifically characterize the reoperation rates observed in this patient population with an analysis of risk factors. Unfortunately, this study has several limitations, some of which are due to restrictions from using an administrative database. Firstly, our analysis is contingent upon accurately coded data. Mis-coding of surgical procedures and patient characteristics is not rare¹⁶ but ideally represents only a minority of cases in our series. Furthermore, specific codes cannot capture the full extent of clinical spine surgery, limiting accurate analysis of surgery-specific factors. For example, coding

for proximal junctional kyphosis and deformity progression was elusive within the ICD-9 coding system, preventing accurate determination of the relative incidence of each of these factors as a reason for revision surgery. Similarly, we were not able to assess functional outcomes and the rate at which elderly patients were offered revision surgery, facts that significantly limit interpretation of these data. Additionally, we were not able to stratify and control for an aggregate comorbidity index, a consideration that could affect risk factor assessment. Lastly, the quality of follow-up in such databases is difficult to assess. As a result, our reoperation rates probably underestimate true rates, as they are not censored for deaths.

Conclusions

Reoperation rates following posterolateral fusions of 8 levels or greater for deformity in elderly patients increased from 10.5% at 1 year of follow-up to 18.5% at 5 years of follow-up. Following multivariate analysis at 5 years of follow-up, osteoporosis (OR 1.98) and BMP use (OR 0.70) were associated with significantly increased and decreased rates of revision, respectively. Positive smoking history (OR 1.37) trended toward significance. Implant failure was the most commonly coded indication for revision surgery. It was estimated that the cohort had 68.8% survivorship 5 years following surgery.

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Disclosures

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Author Contributions

Conception and design: Puvanesarajah, Shen. Acquisition of

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Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Appendix Table 1. <http://thejns.org/doi/suppl/10.3171/2016.2.SPINE151345>.

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