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Clinical Results and Functional Outcomes of Primary and Revision Spinal Deformity Surgery in Adults

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Background: Few studies have examined the postsurgical functional outcomes of adults with spinal deformities, and even fewer have focused on the functional results and complications among older adults who have undergone primary or revision surgery for spinal deformity. Our goal was to compare patient characteristics, surgical characteristics, duration of hospitalization, radiographic results, complications, and functional outcomes between adults forty years of age or older who had undergone primary surgery for spinal deformity and those who had undergone revision surgery for spinal deformity.

Methods: We retrospectively reviewed the cases of 167 consecutive patients forty years of age or older who had undergone surgery for spinal deformity performed by the senior author (K.M.K.) from January 2005 through June 2009 and who were followed for a minimum of two years. We divided the patients into two groups: primary surgery (fifty-nine patients) and revision surgery (108 patients). We compared the patient characteristics (number of levels arthrodesed, type of procedure, estimated blood loss, and total operative time), duration of hospitalization, radiographic results (preoperative, six-week postoperative, and most recent follow-up Cobb angle measurements for thoracic and lumbar curves, thoracic kyphosis, and lumbar lordosis), major and minor complications, and functional outcome scores (Scoliosis Research Society-22 Patient Questionnaire and Oswestry Disability Index).

Results: The groups were comparable with regard to most parameters. However, the revision group had more patients with sagittal plane imbalance and more frequently required pedicle subtraction osteotomies ($p < 0.01$). Patients in the primary group required more correction in the coronal plane than did patients in the revision group, whereas patients in the revision group required more correction in the sagittal plane. We found no significant difference between the two groups in the rate of major complications or in the Scoliosis Research Society-22 Patient Questionnaire functional outcome scores. There were significant improvements in many functional outcome scores in both groups between the preoperative and early (six-week) postoperative periods and between the early postoperative period and the time of final follow-up.

Conclusions: Revision surgery for spinal deformity in adults, although technically challenging and considered to present a higher risk than primary surgery, was shown to have a complication rate and outcomes that were comparable with those of primary spinal deformity surgery in adults.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Spinal deformities are prevalent in adults, affecting 3% to 50% of the population, depending on the age group examined[1,2]. The major goals of surgery are to alleviate pain, improve function, and halt deformity progression. However, surgical treatment in this population is often associated with a relatively high risk of serious complications, and most studies have focused on those high complication rates[3-22].

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TABLE I Patient Characteristics and Comorbidities

Parameter	Primary Group (N = 59)	Revision Group (N = 108)	P Value
Age* *(yr)*	60 (40 to 87)	60 (40 to 80)	1.0
Female patients *(no. [%])*	46 (78)	82 (76)	0.77
Duration of follow-up* *(mo)*	48 (24 to 76)	51 (24 to 77)	0.32
Active smokers *(no. [%])*	5 (9)	17 (16)	0.21
Comorbidities *(no. [%])*			
Osteoporosis	15 (25)	22 (20)	0.40
Spinal canal stenosis	34 (58)	59 (55)	0.58
Hypertension	22 (37)	58 (54)	0.06
Diabetes	2 (3)	10 (9)	0.17
History of cancer	5 (9)	17 (16)	0.19

*The values are given as the mean and range.

The indications for surgery in adult patients with spinal deformity are often pain and disability[5]. Because radiographic findings alone cannot be used to predict the level of disability and the need for surgery in this population[4], investigating how surgery influences health-related quality-of-life measures becomes important. However, most reports have focused on traditional radiographic benchmarks, and few studies of adult patients have attempted to correlate clinically relevant functional outcomes with radiographic measurements[4,6,10,12,23].

Recent data show that revision surgery is performed in 9% to 19% of adult patients who have undergone spine deformity surgery[24,25]. There is a paucity of studies on radiographic and functional outcomes of patients who have undergone revision surgery[16].

Our goal was to compare patient characteristics, surgical characteristics, duration of hospitalization, radiographic results, complications, and functional outcomes between adults forty years of age or older who had undergone primary surgery for spinal deformity and those who had undergone revision surgery. We hypothesized that, although patients treated with revision surgery for spinal deformity may have more complications than those treated with primary surgery, the long-term radiographic and functional outcomes of the two patient groups would be comparable.

Materials and Methods

After receiving approval from our institutional review board, we retrospectively reviewed our prospectively collected database to identify consecutive patients who were forty years of age or older when they underwent spinal deformity surgery performed by the senior author (K.M.K.) from January 2005 through June 2009 and who had been followed for a minimum of two years. Of the 179 patients who met the other inclusion criteria, twelve were excluded from the study because they did not meet the two-year follow-up requirement. The age selection was somewhat arbitrary but was based on our experience that patients in this age group tend to have more comorbidities and different degenerative changes compared with those who are less than forty years old. We identified 167 patients and divided them into two groups for comparison: primary surgery (fifty-nine patients) and revision surgery (108 patients).

Characteristics and Complications

We used the clinical database and the patients' hospital charts to ascertain patient characteristics (age, sex, diagnoses, smoking status, duration of follow-up, and comorbidities), surgical characteristics (number of levels arthrodesed, type of procedure, estimated blood loss, and total operative time), duration of hospitalization, and major and minor complications.

In the primary group, the main indication for surgery was spinal deformity (including scoliosis and kyphosis) with pain and disability for which prolonged nonoperative treatment had failed. In the revision group, the main indications for surgery were progressive deformity, pseudarthrosis, instrumentation failure, and flatback deformity associated with pain and disability.

In the primary group, the diagnoses at the time of the primary surgery were coronal deformity (twenty-four patients), sagittal deformity (ten patients), and combined sagittal and coronal deformity (twenty-five patients). Of the twenty-four patients with coronal deformity, fourteen had adult idiopathic scoliosis and ten had degenerative scoliosis. Of the ten patients with sagittal deformity, two had idiopathic kyphosis and eight had degenerative kyphosis.

In the revision group, the diagnoses at the time of revision surgery were coronal deformity (eight patients), sagittal deformity (fifty-five patients), and combined sagittal and coronal deformity (forty-five patients). In the revision group, we were not always able to determine the exact cause of the original deformity because most patients had undergone the original surgery at another institution and many were not able to provide their index surgery records and/or initial radiographs.

Radiographic Measurements

Detailed radiographic measurements were performed on full-length standing anteroposterior and lateral radiographs obtained preoperatively, postoperatively, and at the time of final follow-up. In the coronal plane, we measured the Cobb angles for the thoracic and lumbar curves and the coronal vertical axis. In the sagittal plane, we measured thoracic kyphosis from T2 to T12, lumbar lordosis from L1 to S1, and the sagittal vertical axis.

Functional Outcome Measurements

Each patient was evaluated before surgery, at six weeks after surgery, and at the time of final follow-up with the use of health-related, quality-of-life measurement tools, namely the Scoliosis Research Society-22 Patient Questionnaire (SRS-22)[26,27] and the Oswestry Disability Index (ODI)[28]. The SRS-22 scale ranges from 1 to 5 points, with 5 points representing the most desirable outcome within each category. The ODI scale ranges from 0 to 100, where a score

TABLE II Surgical and Hospital-Stay Characteristics

Parameter	Primary Group (N = 59)	Revision Group (N = 108)	P Value
Levels arthrodesed* *(no.)*	7 (5 to 18)	6 (5 to 17)	0.12
Operative time* *(min)*	531 (232 to 690)	495 (270 to 660)	0.58
Estimated blood loss* *(L)*	2.6 (0.4 to 8.5)	3.6 (0.3 to 8.5)	0.11
Duration of stay* *(days)*	10 (3 to 71)	9 (1 to 41)	0.49
Ponte/Smith-Petersen osteotomy *(no. [%])*	42 (71)	62 (57)	0.07
Pedicle subtraction osteotomy *(no. [%])*	4 (7)	57 (53)	<0.01
Vertebral column resection *(no. [%])*	6 (10)	13 (12)	0.73

*The values are given as the mean and range.

of 0 to 20 corresponds to minimal disability; a score of 21 to 40, moderate disability; and a score of 41 to 60, severe disability.

Responses were tabulated for each of the five SRS-22 domains: pain, self-image, activity, mental health, and satisfaction.

Statistical Analysis

We analyzed the data with the use of standard computer software. Significance was assigned at $p < 0.05$. The Hotelling t-square test was used to compare continuous parameters, and the chi-square test was used to compare categorical parameters.

Source of Funding

No external funding was obtained for this study.

Results

Patient Characteristics

The primary and revision groups were not significantly different in terms of average age, sex, average duration of follow-up, percentage of active smokers, or comorbidities (Table I).

All patients in the primary and revision groups had one of three diagnoses: scoliosis (twenty-four [41%] and eight [7%] of the patients, respectively; $p < 0.01$), kyphosis (ten [17%] and fifty-four [50%] of the patients, respectively; $p < 0.01$), and kyphoscoliosis (twenty-five [42%] and forty-six [43%] of the patients, respectively; $p = 0.90$).

In the revision group (108 patients), the patients had had on average two previous surgical procedures (range, one to fourteen). Forty-six (43%) of the patients had a diagnosis of pseudarthrosis, most commonly at the L5-S1 level, after their initial procedure. Instrumentation had failed in fifty-six (52%) of the patients, and eighteen patients (17%) had flatback deformity.

Surgical and Hospital-Stay Characteristics

In the primary group, there were seven anterior and posterior combined procedures and fifty-two posterior-only procedures as the index surgery. In the revision group, there were seven combined anterior and posterior procedures and 101 posterior-only procedures as the index surgery. We found no significant difference in the proportion of circumferential surgical procedures between the two groups ($p = 0.42$).

There was no significant difference between the two groups in the number of levels arthrodesed, average blood loss, average operative time, or average duration of hospital stay (Table II). In both groups, the most commonly arthrodesed levels were T11 to the pelvis and the most commonly instrumented upper-end vertebra was T11. Arthrodesis to the sacrum was performed in forty-seven patients (80%) in the primary group and in eighty-seven patients (81%) in the revision group; this difference was not significant ($p = 0.98$).

TABLE III Comparison of Radiographic Measurements

	Primary Group (N = 59)			Revision Group (N = 108)		
Parameter*	Preoperative	6-Wk Postoperative	Final Follow-up	Preoperative	6-Wk Postoperative	Final Follow-up
Thoracic curve *(°)*	36 (14 to 67)	17 (2 to 47)	16 (1 to 45)	32 (2 to 90)	22 (1 to 70)	22 (1 to 57)
Lumbar curve *(°)*	48 (23 to 79)	22 (5 to 58)	23 (4 to 49)	35 (2 to 70)	23 (2 to 58)	22 (1 to 57)
Thoracic kyphosis *(°)*	42 (7 to 126)	48 (23 to 77)	54 (23 to 86)	39 (5 to 86)	46 (6 to 84)	52 (13 to 81)
Lumbar lordosis *(°)*	−38 (−88 to 14)	−50 (−75 to −21)	−53 (−78 to −28)	−27 (−61 to 33)	−48 (−78 to −27)	−50 (−80 to −20)
Coronal vertical axis *(cm)*	3.0 (0 to 17.4)	2.6 (0 to 10)	2.3 (0 to 11)	3.2 (0 to 22)	1.8 (0 to 7.3)	2.2 (0 to 29)
Sagittal vertical axis *(cm)*	6.7 (−6 to 29.3)	4.0 (−5 to 18.5)	3.3 (−8.6 to 15.4)	11.4 (−3.2 to 35)	4.9 (−7.3 to 25)	5.1 (−5.7 to 26)

*The values are given as the mean and range.

TABLE IV Reoperations in Primary and Revision Groups

Reason	Reoperations *(No.)*	
	Primary Group (N = 59)	Revision Group (N = 108)
Infection	4	3
Neurologic complications	0	4
Proximal junctional kyphosis	2	2
Distal junctional kyphosis	1	2
Additional sagittal correction	1	1
Persistent radiculopathy	2	3
Painful instrumentation	0	2
Junctional fracture	1	4
Pseudarthrosis	1	4

We found no significant difference between the two groups in frequency of Ponte or Smith-Petersen osteotomies[29] ($p = 0.07$) or vertebral column resections[30] ($p = 0.73$), but there were significantly more pedicle subtraction osteotomies[31,32] performed in the revision group ($p < 0.01$).

Radiographic Outcomes

Radiographs of patients who underwent primary or revision surgery (see Appendix) showed that major correction was achieved in each group (Table III). There was only a slight deterioration (up to 6°) in correction between the six-week postoperative radiographs and those at the time of final follow-up. The patients who underwent primary surgery required more correction in the coronal plane than did those who had revision surgery, whereas the revision group required more correction in the sagittal plane (Fig. 1).

Major and Minor Complications

In the primary group, the major complication rate was 20%, with a total of twelve major complications occurring in twelve of the fifty-nine patients in the primary surgery group. These complications included deep wound infection (four); retroperitoneal hematomas requiring evacuation (two); postoperative motor deficit, mesenteric artery ischemia, pneumothorax requiring chest tube placement, and acute renal failure (one each); and long-term complications consisting of pseudarthrosis and junctional fracture (one each).

In the revision group, the rate of major complications was 21%, with a total of twenty-three major complications occurring in twenty-one of the 108 patients. These complications included deep wound infection (three); postoperative motor deficit (four); epidural hematoma (three); vascular injury, pulmonary embolism, pneumonia, pneumothorax requiring chest tube placement, and acute renal failure (one each); and long-term complications consisting of pseudarthrosis and junctional fractures (four each). There was no perioperative mortality in either group. We found no significant difference between the two groups in the rate of the development of major complications ($p = 0.88$) or in the rate of pseudarthrosis ($p = 0.46$).

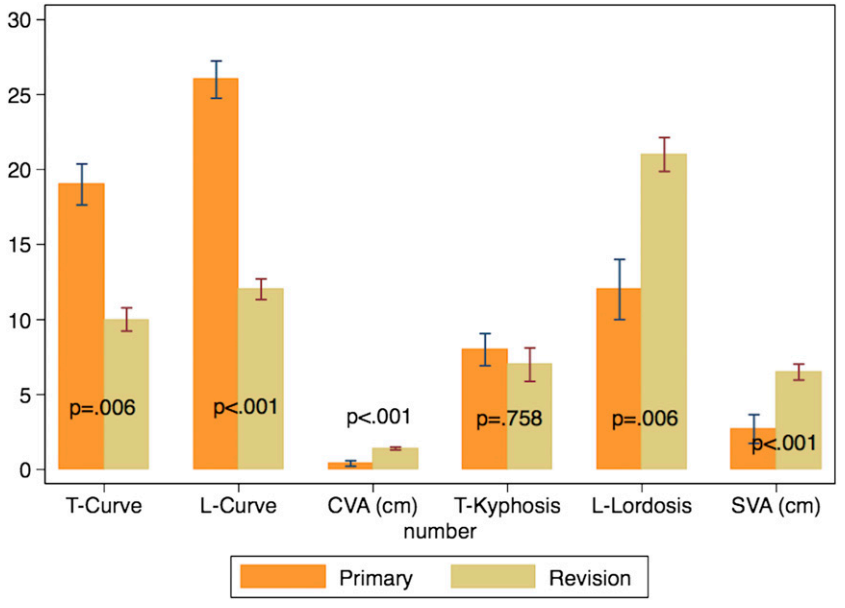

Fig. 1

A bar chart comparing the magnitude of correction achieved in the primary group with that of the revision group between the preoperative and six-week postoperative periods. Corrections of interest in the coronal plane were the thoracic Cobb angle (T-Curve), lumbar Cobb angle (L-Curve), and coronal vertical axis (CVA). Corrections of interest in the sagittal plane were the thoracic kyphosis Cobb angle (T-Kyphosis), lumbar lordosis Cobb angle (L-Lordosis), and sagittal vertical axis (SVA). The bars represent the mean values, and the I bars represent the standard deviation.

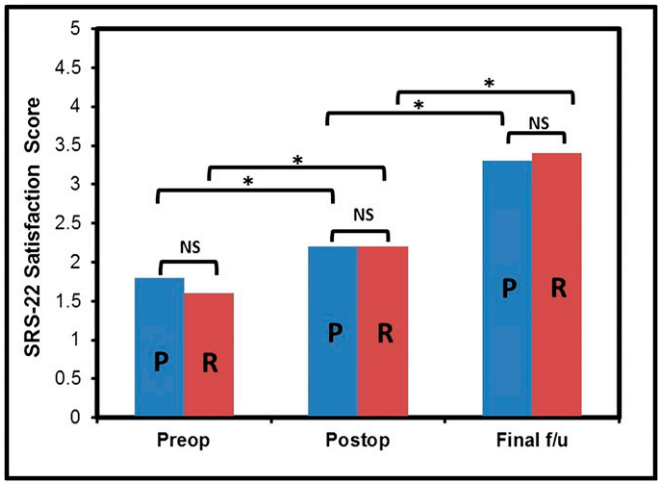

Fig. 2

A bar chart comparing SRS-22 satisfaction scores. There was no significant difference between the primary (P) and revision (R) groups preoperatively (Preop), six weeks postoperatively (Postop), or at the time of final follow-up (Final f/u). There was a significant improvement in the satisfaction scores of patients in both groups between the preoperative and postoperative stages, and between the postoperative and final follow-up stages. * = significant, and NS = not significant. The bars represent the mean values.

Minor complications occurred in fifteen patients in the primary group and in thirty-seven patients in the revision group, which was not a significant difference ($p = 0.24$). Common minor complications in both groups included dural tears, excessive bleeding, sensory deficits postoperatively, superficial wound complications, and vertebral fractures not requiring revision surgery.

Reoperations numbered twelve in ten patients in the primary group and twenty-five in eighteen patients in the revision group ($p = 0.68$) (Table IV).

Functional Outcomes

Preoperatively, there were no significant differences between the groups in terms of the average ODI scores or the average scores of the five SRS-22 domains (see Appendix). By the time of final follow-up, patients in both groups had significant improvement in all SRS-22 domains, including satisfaction (Fig. 2), and a significant reduction in disability as measured by ODI (see Appendix). In the revision group, patient pain and self-image scores decreased between the early postoperative period and final follow-up, but activity, mental health, and satisfaction scores improved (see Appendix).

Discussion

To our knowledge, this series is the largest in which the radiographic and functional outcomes of revision surgery were compared with the outcomes of primary surgery in adult patients with spinal deformity who were forty years of age or older. In both patient groups, surgery led to marked improvements in radiographic results and in SRS-22 and ODI functional outcome scores.

Both the revision and the primary group demonstrated substantive improvement in functional outcomes in the early postoperative period and at the time of final follow-up. Patients in the revision group showed significant improvement in most functional outcome scores in the early postoperative period compared with their preoperative scores, and their ODI scores continued to decrease over time. Patients in the primary group experienced a small decline in pain and self-image subscores at the time of final follow-up compared with their six-week postoperative state. As was evident for the patients in the revision group, SRS-22 subscores for patients in the primary group indicated that their activity, mental health, and satisfaction improved from the postoperative period to the final follow-up evaluation, and their ODI scores continued to decrease over time.

Bridwell et al.[6] reported no significant deterioration in radiographic or clinical outcomes between two-year and three-to-five-year follow-up points in adult patients who had undergone primary surgical treatment for spinal deformity. In our study, we did not substratify our follow-up periods, so it is now difficult to compare our findings with those of Bridwell et al.[6].

Common indications for revision surgery in our study included progressive deformity, pseudarthrosis, and instrumentation failure, which are consistent with those reported in a recent study by Pichelmann et al.[25]. Furthermore, in our study, 43% of patients (forty-six of 108) in the revision group had had pseudarthrosis after their initial procedure, which is consistent with the 17% to 41% prevalence reported[14,15,25]. Of the 167 patients who underwent surgery in our study, 3% (one of fifty-nine patients in the primary group and four of 108 patients in the revision group) developed pseudarthrosis, which is a relatively low rate compared with rates presented in other reports[14,15,25]. However, that rate may change with longer follow-up.

Complications in adults after spinal deformity surgery are a clinically important and frequent problem (a rate of >40%)[5,10,12,33]. Glassman et al.[12] reported that the prevalence of major complications was approximately 10%. In our study, the overall rate of major complications was 20% in the primary group and 21% in the revision group. There was no significant difference between the primary and revision groups in terms of the prevalence of major and minor complications, which is consistent with the findings of previous reports[16,34]. In addition, we found no significant difference in the reoperation rate between the two groups.

Adult patients with spinal deformities who undergo revision surgery can be expected to experience satisfactory radiographic and functional outcomes similar to those undergoing primary surgery, in spite of the high rate of complications. Generally, the patients who had primary surgery in the present study required more correction in the coronal plane, and those treated with revision required more sagittal-plane correction. Patients should be extensively counseled on the pros and cons, potential risks, and expected outcomes of

these very complex surgical procedures. Very thorough preoperative counseling is an ethical and professional obligation.

The retrospective nature of our study could be perceived as a weakness; however, most data were collected prospectively. A second potential weakness is that all patients were from a single institution and treated by one surgeon who treats a large volume of adult patients with spinal deformity. This exclusivity may have biased the study, as most spine surgeons may not have the same degree of experience, especially with revision procedures. However, the exclusivity also conferred uniformity and, in addition, one might expect these types of surgical procedures to be performed at a tertiary care center by surgeons with similar experience. Third, the sample size was determined on the basis of the number of patients available rather than with a priori power calculation.

On the basis of this study, it appears that multiple failed spinal surgical procedures should not by themselves be considered a contraindication for performing another corrective procedure. In spite of the stigma associated with failed surgery in adult patients with spinal deformities, we believe that careful patient selection and appropriate and careful surgical techniques can result in satisfactory outcomes and an acceptable complication rate after these complex procedures.

Appendix

(eA) A table showing the mean SRS-22 and ODI functional outcome scores of the primary and revision groups preoperatively, at six weeks postoperatively, and at the time of final follow-up, and preoperative and postoperative radiographs of a patient from each group are available with the online version of this article as a data supplement at jbjs.org. ■

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