



# Revision adult spinal deformity surgery: Does the number of previous operations have a negative impact on outcome?

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## Abstract

**Purpose** To study the effect of the number of previous operations on the outcome of revision adult spinal deformity (ASD) surgery.

**Methods** One hundred and thirty-seven consecutive patients who underwent revision ASD surgery were classified as follows: those who had one previous operation (group 1), had two previous operations (group 2) and had three or more previous operations (group 3). Perioperative complications and additional surgeries were reviewed. Back pain, leg pain, ODI scores and radiographic measurements were obtained.

**Results** Preoperatively, the patients in group 3 had worse ODI (60.0 vs. 48.1 and 47.9,  $p < 0.01$ ) but not back pain or leg pain. Group 2 and group 3 had worse coronal plumb line (38.4 and 35.8 mm vs. 18.2 mm,  $p < 0.05$ ) and SVA (99.7 and 153.9 mm vs. 67.8 mm,  $p < 0.05$ ). Group 3 had worse PI–LL mismatch (40.1° vs. 25.3° and 26.2°,  $p = 0.08$ ). Minor and major perioperative complication rates were 27.5% in group 1, 31.1% in group 2 and 39.0% in group 3 ( $p > 0.05$ ). At mean 30-month follow-up, the additional surgery rates were 7.8, 17.8 and 22.0%, respectively ( $p = 0.07$ ). The patients in all groups had improved back pain, leg pain and ODI scores. The net improvements on back pain, leg pain and ODI were not statistically different between the groups.

**Conclusions** Revision ASD patients who had two or more previous operations present with more coronal and sagittal imbalance and worse functional status. Patients who had three or more previous operations have relatively higher reoperation rate but similar perioperative complication rate and similar clinic improvements.

**Graphical abstract** These slides can be retrieved under Electronic Supplementary Material.

**Key points**

1. Revision surgeries are performed in 9% to 45% of adult patients who have undergone spine deformity surgery.
2. Revision ASD patients who had two or more previous operations present with worse coronal and sagittal imbalance and worse functional status.
3. Patients who had three or more previous operations have relatively higher reoperation rate but similar peri-operative complication rate and similar clinic improvements.

**Take Home Messages**

1. ASD patients who had multiple previous surgeries tend to present with worse functional status, and worse coronal and sagittal imbalance.
2. If these patients undergo revision surgery, they are more likely to encounter further revision surgeries.
3. However, majority of these patients can still anticipate improvement of their clinical symptoms at long term follow-up.

	Group 1	Group 2	Group 3	p value
Coronal Plumb Line (mm)	18.2	38.4	35.8	<0.05
SVA (mm)	67.8	99.7	153.9	<0.05
PI-LL (°)	25.3	26.2	40.1	= 0.08

Peri-operative surgical or medical complications	Group 1	Group 2	Group 3	p value
Minor	7.8%	13.3%	8.8%	>0.05
Major	19.6%	17.8%	20.3%	>0.05
Overall	27.5%	31.1%	39%	>0.05

	Group 1	Group 2	Group 3	p value
Back pain improved (VAS)	2.6	2.5	2.1	>0.05
Leg pain improved (VAS)	2.9	2.1	1.8	>0.05
ODI improved	15.0	8.3	17.9	>0.05

**Keywords** Adult spinal deformity · Revision surgery · Outcome

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s00586-018-5747-1>) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

## Introduction

Surgical correction of adult spinal deformity (ASD) is a complex procedure, and perioperative and late complications are not uncommon. An overall complication rate of up

to 70% has been reported [1–3]. Meanwhile, revision rates following primary spinal fusion procedures range from 9% to 45% and longer follow-up is associated with higher revision rates [4–6]. Revision ASD surgeries are often due to pseudoarthrosis, adjacent segment disease, implant failure or infection [7, 8].

Revision ASD surgeries are technically more challenging than primary ASD surgery. Most previous studies focused on the risk factors for revision surgery and the comparison of complications between primary and revision ASD surgeries [1, 8–10]. However, little is known about the effect of the number of previous operations on the patients' outcome after revision ASD surgery. The purpose of this study is to review a series of consecutive revision ASD surgeries and to study the effect of the number of previous operations on the patients' outcome.

## Materials and Methods

### Patients

After IRB approval, a single center's prospectively collected database was retrospectively reviewed to identify all the ASD patients who had operations between May 2010 and December 2013. The patients' demographic data such as age, gender, body mass index (BMI), primary diagnosis and the history of previous spine surgery were collected. The patients were then classified into three groups based on their number of previous spine operations: group 1, patients who had one previous operation; group 2, patients who had two previous operations; and group 3, patients who had three or more previous operations.

### Surgical technique

The surgical technique was tailored to each specific patient. In most cases, it involved a staged procedure first with removal of hardware and biopsies to rule out infection. This was followed by a second- and/or third-stage procedure performed 5 days to 6 weeks later of either an anterior reconstruction and realignment at the lumbosacral junction then a posterior multilevel instrumentation correction and fusion with multilevel Smith-Petersen osteotomies. Occasionally, particularly for those with significant sagittal imbalance at the thoracolumbar junction, a pedicle subtraction osteotomy was performed.

### Radiographic measurements

Radiographic data collection consisted of standing coronal and sagittal radiographs obtained in free standing posture. All images were downloaded from PACS systems (DICOM

format) or digitized through a scanner and then analyzed using dedicated software (Surgimap, Nemaris, Inc., New York, USA). Measurements included various spinopelvic parameters, such as coronal Cobb angle, global coronal balance (coronal offset between C7 vertebral body and the center of S1 endplate), sagittal vertical axis (SVA), thoracic kyphosis, lumbar lordosis, pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS) [11].

### Clinical outcome measurements

Surgical procedure, perioperative complications, length of hospital stay, readmissions, follow-up complications, etc., were obtained from medical records. The visual analog scale (VAS) for back pain, leg pain and Oswestry Disability Index (ODI) was obtained from the patients' medical records pre-operatively and at the latest follow-up visit.

### Statistical analysis

Descriptive statistics, including means and standard deviations, were calculated for continuous variables. Nominal variables were analyzed using Chi-square test. Student t test was used for quantitative variables, and the level of significance was set at  $p \leq 0.05$ .

## Results

Data were retrospectively reviewed from 137 consecutive patients who underwent revision ASD surgeries. There were 51 patients who had one previous operation (group 1), 45 patients who had two previous operations (group 2) and 41 patients who had three or more previous operations (group 3). On average, the patients in group 3 had four previous operations (range 3–10). The patients' gender, age, BMI and follow-up intervals were not different between the groups ( $p > 0.05$ ) (Table 1). The patients' primary diagnoses were adjacent segment degeneration, pseudoarthrosis, scoliosis, kyphosis, loose/painful hardware, flat back, stenosis, etc. There was no difference regarding the patients' primary diagnoses between the three groups (Table 2).

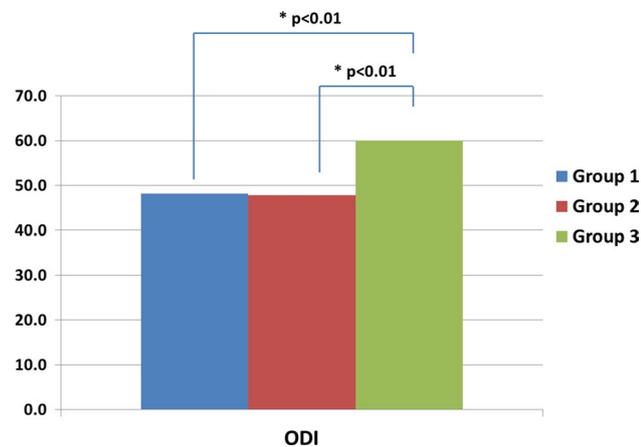
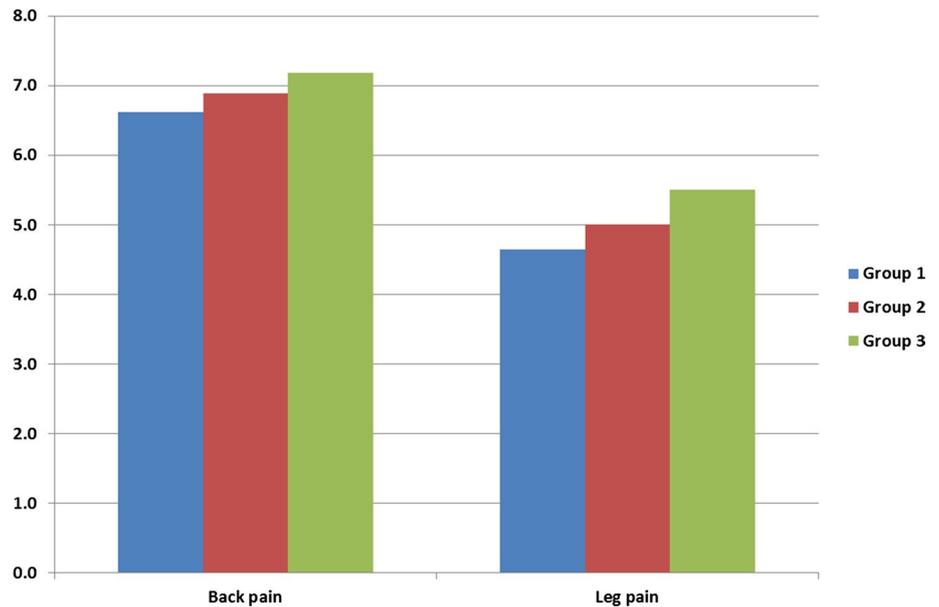
**Table 1** Overview of patients in these three groups

	Group 1	Group 2	Group 3	<i>p</i> value
No. of patients	51	45	41	> 0.05
Gender (female: male)	40:11	32:13	29:12	> 0.05
Mean age (year)	60	63	58	> 0.05
Mean BMI	27.7	28.0	27.5	> 0.05
Mean follow-up (mo)	27.6	30.2	30.9	> 0.05

**Table 2** Patients’ primary diagnosis in these three groups

Primary diagnosis	Group 1 (%)	Group 2 (%)	Group 3 (%)	<i>p</i> value
Adjacent segment degeneration	27.5	42.2	29.3	> 0.05
Pseudoarthrosis	23.5	22.2	31.7	> 0.05
Other	49.0	35.6	39.0	> 0.05

**Fig. 1** Preoperative back pain and leg pain in these three groups (*p* > 0.05)



**Fig. 2** Preoperative scores in these three groups (*p* < 0.01)

Preoperatively, the patients’ back pain and leg pain VAS scores were not statistically different between the groups (*p* > 0.05) (Fig. 1). However, the patients in group 3 had significantly worse ODI scores (60.0, compared with 48.1 in group 1 and 47.9 in group 2, *p* < 0.01) (Fig. 2).

The patients in group 2 and group 3 had significantly worse coronal plumb line (38.4 mm and 35.8 mm, respectively, compared with 18.2 mm in group 1, *p* < 0.05) and SVA (99.7 mm and 153.9 mm, respectively, compared with 67.8 mm in group 1, *p* < 0.05). The patients in group 3 had relatively worse PI–LL mismatch (40.1°, compared with 25.3° in group 1 and 26.2° in group 2, *p* = 0.08) (Table 3).

Minor and major perioperative surgical and medical complications occurred in 14 patients (27.5%) in group 1, 14

**Table 3** Preoperative coronal plumb line, SVA and PI–LL mismatch in these three groups

	Group 1	Group 2	Group 3	<i>p</i> value
Coronal plumb line (mm)	18.2	38.4	35.8	< 0.05
SVA (mm)	67.8	99.7	153.9	< 0.05
PI–LL (°)	25.3	26.2	40.1	= 0.08

**Table 4** Perioperative surgical or medical complications (up to 90 days post-op)

Perioperative surgical or medical complications	Group 1 (%)	Group 2 (%)	Group 3 (%)	<i>p</i> value
Minor	7.8	13.3	9.8	> 0.05
Major	19.6	17.8	29.3	> 0.05
Overall	27.5	31.1	39	> 0.05

patients (31.1%) in group 2 and 16 patients (39.0%) in group 3 (*p* > 0.05) (Table 4). Minor complications included: dural

tear, superficial wound infection, wound seroma, orthostatic spinal headache and pacemaker malfunction. Major complications included: deep wound infection, neurological deficit, deep venous thrombosis, pulmonary embolism, ileus, proximal junctional kyphosis, screw malposition, pedicle fracture, sacral fracture, deep wound seroma, hardware failure, pseudomeningocele and cardiac arrest.

At mean 30-month follow-up, four patients in group 1 (7.8%), eight patients in group 2 (17.8%) and nine patients in group 3 (22.0%) had additional surgeries ( $p > 0.05$ ). The primary reasons for additional surgery were adjacent segment degeneration, proximal junctional kyphosis and hardware failure. In groups 1 and 2, the primary reason for additional surgery is adjacent segment degeneration (2/4 and 5/8, respectively). In group 3, the primary reason for additional surgery is hardware failure (5/9). However, the difference between the groups is not statistically significant ( $p > 0.05$ ).

In group 1, the patients' back pain improved 2.6 points (6.5 vs. 3.9,  $p < 0.01$ ), leg pain improved 2.9 points (4.8 vs. 1.9,  $p < 0.01$ ) and ODI scores improved 15.0 points (47.9 vs. 32.9,  $p < 0.01$ ). In group 2, the patients' back pain improved 2.5 points (7.1 vs. 4.6,  $p < 0.01$ ), leg pain improved 2.2 points (5.4 vs. 3.2,  $p < 0.01$ ) and ODI scores improved 8.3 points (48.1 vs. 39.8,  $p = 0.10$ ). In group 3, the patients' back pain improved 2.1 points (7.2 vs. 5.1,  $p < 0.01$ ), leg pain improved 1.8 points (5.6 vs. 3.8,  $p = 0.08$ ) and ODI scores improved 18.0 points (63.4 vs. 45.4,  $p < 0.01$ ). The net improvements on back pain, leg pain and ODI scores were not statistically different between the groups ( $p > 0.05$ ) (Table 5).

## Discussion

The rate of ASD surgery has increased significantly over the last three decades likely due to many factors such as a growing aging population and the advancement in medical technologies and surgical techniques [12]. Surgical management of ASD is challenging to spine surgeons and is associated with relatively high rates of surgical and medical complications and the need for revision surgeries. Revision ASD surgery is technically even more challenging than primary surgery, and it is difficult to achieve deformity correction

after previous spine procedures such as decompression or fusion [1, 5].

Some published studies have compared the patients' outcome between primary versus revision ASD surgery; however, to the best of our knowledge, no studies have directly researched the impact of the number of previous operations on revision ASD patients' outcome. In this study, we collected 137 consecutive revision ASD patients' data and stratified the patients into three groups based on their number of previous operations (one previous operation, two previous operations and three or more previous operations). At baseline, there is no difference regarding the patients' gender, age, BMI and the average follow-up interval. The patients' back pain and leg pain were also similar among the three groups. However, the patients who had three or more previous surgeries had significantly worse ODI scores, suggesting that these patients were more functionally impaired compared to those who had two or one previous operation.

Radiographic measurement showed that patients who had two or more previous surgeries had worse coronal and sagittal imbalance. The patients who had three or more previous surgeries also had relatively worse PI–LL mismatch suggesting that these patients presented with worse sagittal malalignment despite the previous operations. A previous study by Fu et al. [9] showed that compared with patients undergoing primary scoliosis surgery, patients undergoing revision scoliosis surgery had more deterioration of coronal balance. Our study further suggests that the patients who had more previous operations tend to present with not only worse coronal balance but also worse sagittal balance.

Analysis of perioperative surgical and medical complications shows that the rates of minor complications did not differ between the groups. However, those patients who had three or more previous operations did have relatively higher rates of major and overall complications, but this difference did not reach statistical significance. Similarly, at mean 30-month follow-up, more patients in group 2 had additional surgeries than in group 1 and more patients in group 3 had additional surgeries than in group 2. Based on a prospectively collected multicenter database of adult deformity surgery, Glassman et al. [13] found that those patients who had previous scoliosis surgery are more likely to have complications (62% vs. 48%). Cho et al. [1] analyzed consecutive ASD patients who underwent multilevel revision surgery with a minimum 2-year follow-up, and they found that 34.4% of patients experienced major complications and the occurrence of a follow-up major complication has a negative impact on the patients' clinical outcome. Recently, Diebo et al. [10] performed a nationwide study of 10,912 patients who had primary or revision ASD surgeries, and they found that the revision group had a significantly higher complication rate than the primary group (66.47% vs. 52.03%). Our study further suggests that the patients who had more

**Table 5** Patients' net clinical improvement in these three groups at the latest follow-up

	Group 1	Group 2	Group 3	<i>p</i> value
Back pain improved (VAS)	2.6	2.5	2.1	> 0.05
Leg pain improved (VAS)	2.9	2.1	1.8	> 0.05
ODI improved	15.0	8.3	17.9	> 0.05

previous operations could be more likely to encounter perioperative complications and they are also more likely to have additional revision surgeries.

At mean 30-month follow-up, the patients in all three groups had significant improvement in their back pain, leg pain and ODI scores. The net improvement on back pain and leg pain was similar among the three groups. Although the preoperative ODI score was significantly higher in those patients who had three or more previous surgeries, the net improvement in ODI scores was similar among the groups. A previous study compared the clinical outcome between primary and revision scoliosis surgery and found that revision patients achieved the same clinical outcome as primary patients [9]. Our data further suggest that for patients who had multiple previous spine surgeries, they can still benefit from revision surgery despite their worse preoperative functional status.

This study is limited by virtue of the fact that this study is a single-center-based review with a limited number of patients in each group. We do not have enough power to subcategorize and study the possible effects of many other factors, such as the patients' comorbidities, the type of surgery, the change of pelvic and global alignment, on the patients' outcome [8, 14, 15]. A multicenter study with a much larger database will be needed to address these questions.

In conclusion, our study shows that revision ASD patients who had two or more previous operations present with more coronal and sagittal imbalance and worse functional status. Patients who had three or more previous operations have relatively higher reoperation rate but similar perioperative complication rate and similar clinic improvements at mean 30-month follow-up. Our findings also provide useful information for spine surgeons to educate patients who are undergoing revision ASD surgeries regarding the risk of morbidity and mortality and the clinical outcome that they can anticipate.

## Compliance with ethical standards

**Conflicts of interest** The authors declare that there is no direct conflict of interest associated with this manuscript.

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