

The Impact of Surgical Correction of Adult Spine Deformity on Radiological Parameters and Its Correlation With Clinical Outcomes

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Abstract- To evaluate the correlations between changes in radiological parameters and clinical outcomes following adult spinal deformity (ASD) surgery. Radiological assessments are necessary for evaluation of deformity magnitude and choosing the appropriate surgical approach. Some studies have demonstrated the correlation between radiological parameters and pain and disability among patients. However, few studies have evaluated changes in both coronal and sagittal radiological parameters following the surgical treatment of ASD and its correlation with clinical outcomes. Radiological parameters include: pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS), lumbar lordosis (LL), and PI minus LL (PI-LL), and Cobb's angle and three clinical outcome measures include: visual analog scale (VAS), Oswestry Disability Index (ODI), and Short Form-36 health survey (SF-36), were assessed at baseline and 6 and 12 months after surgery. A total of 95 patients were included. Mean VAS scores and ODI significantly improved from 7.09 ± 2.1 and 61.07 ± 13.6 to 2.64 ± 1.6 and 31.8 ± 16.1 respectively, after surgery (both $P < 0.001$). All items of the SF-36 survey, as well as all radiologic measures, improved significantly following surgery (both $P < 0.001$). We found a significant negative correlation between pre-operative SS and VAS scores ($r = -0.307$, $P = 0.002$). Energy ($r = -0.262$, $P = 0.010$) and social functioning ($r = -0.248$, $P = 0.015$) scales of SF-36. PI-LL was positively associated with ODI ($r = 0.223$, $P = 0.030$) before surgery and energy scale ($r = -0.262$, $P = 0.010$) of SF-36 after surgery. Surgical treatment of patients with ASD improves clinical outcomes, and in line with previous studies, restoration of sagittal alignment has a more important role in the enhancement of patients' function and quality of life.

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Introduction

Adult spine deformity (ASD) is becoming a major health problem, especially among elderly patients. Abnormal alignment of the spine in the ASD consists of decreased lordosis or even kyphosis and coronal malalignment of the spine as scoliosis. Progressive asymmetrical degeneration of spine anatomical elements is considered the main etiology of the disease (1).

Patients with ASD usually complain about pain, neurologic symptoms, and disability (2,3). Conservative management is the first-line treatment strategy. However, many patients with ASD do not respond to conservative management, and they will eventually need surgical treatment (3).

Radiological assessments are necessary for evaluation of deformity magnitude and choosing the appropriate

surgical approach. Some previous studies have demonstrated that radiological parameters are correlated with pain and disability (4-7). Moreover, it has been shown that malalignment in the sagittal plane is closely related to disability, while the role of coronal balance was neglected in many studies (5,8).

Few studies have evaluated changes in both coronal and sagittal radiological parameters following the surgical treatment of ASD and its correlation with clinical outcomes (9-12). Most of these studies were retrospective and had small sample sizes. We prospectively evaluated changes in radiological and clinical outcomes following surgical correction of spine deformity in a larger population of ASD patients.

Materials and Methods

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Correlation between radiological parameters and clinical outcome after adult spine deformity correction

We conducted a prospective study from January 2016 to January 2018 to evaluate surgical outcomes in 95 patients with ASD. The exclusion criteria were: (1) any history of idiopathic, congenital, iatrogenic spine disorder (2), neuromuscular diseases (3), spinal trauma (4), previous spine surgery.

Surgery

All patients underwent a thorough clinical examination prior to the surgery, and their demographics, clinical and radiological characteristics were recorded. Surgeries performed by the same surgical team. Based on the extent of spine deformity, laminectomy, foraminal and extraforaminal decompression and instrumented fusion with coronal and sagittal deformity correction were performed.

Image analysis

For each patient, preoperative and postoperative x-ray and magnetic resonance imaging (MRI) of the spine were extracted from the hospital picture archiving and communication system (PACS). The following radiologic measures were calculated (10,13). Cobb's angle, pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS), lumbar lordosis (LL), and PI minus LL (PI-LL). Scoliosis was defined as Cobb's angle greater than 10 degrees.

Clinical measures

Three self-assessment questionnaires were filled out by the patients at baseline and after surgery during follow up. The magnitude of pain was assessed by visual analog scale (VAS) by asking patients to mark the severity of their pain in a horizontal line (0-10) (14). The functional ability of patients was screened by the Oswestry Disability Index (ODI), the gold standard functional tool in patients with low back pain (15). Short Form-36 health survey (SF-36) was used for quality of life assessment (16) Eight dimensions of health (physical functioning, role limitations due to physical health, role limitations due to emotional problems, Energy, emotional well-being, social functioning, pain, and general health) are assessed by this questionnaire. Based on patient's health status, a score ranging from 0 to 100 may be possible for each item. Higher scores indicate better quality of life.

Statistical analysis

All statistical analyses in this study were performed using the Statistical Package for the Social Sciences (SPSS Version 25.0). Mean±standard deviation (SD) or 95% confidence interval (95% CI) was used to describe

numerical variables. Changes in radiological and clinical outcomes were analyzed by paired sample t-test. The correlation between radiologic measures and clinical measures was examined by Pearson correlation test. Stepwise linear regression was used to determine whether any post-operative radiologic outcomes (PI-LL, SS, PT, LL, and Cobb's angle) can influence post-operation pain, function and, quality of life.

Results

Ninety-five eligible patients were included. Patients' baseline demographics and clinical findings are shown in Table 1.

Infection was found in 6 patients (6.3%) after surgery. Mean VAS scores and ODI significantly improved from 7.09 ± 2.1 and 61.07 ± 13.6 to 2.64 ± 1.6 and 31.8 ± 16.1 , respectively, after surgery ($P<0.001$). All items of the SF-36 survey significantly improved following spine surgery ($P<0.001$) (Figure 1). All radiological measures improved significantly following surgery (Table 2).

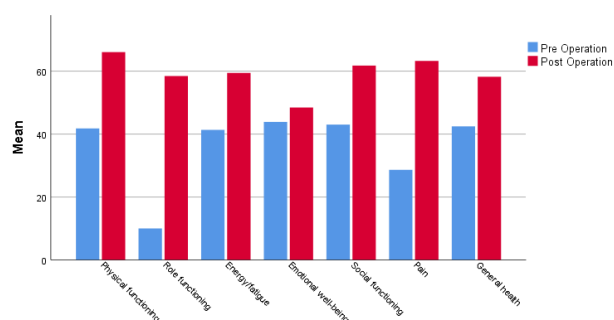


Figure 1. SF-36 items

Scoliosis was detected in 40 patients (42.1%) prior to surgery. The mean Cobb's angle was 27.3 range between 12 to 41. Patients' demographics and baseline VAS and ODI scores, as well as SF-36 scales, were not different between patients with and without scoliosis ($P>0.5$). Surgery led to the complete correction of scoliosis except in two patients.

After adjustment for baseline values, the intensity of post-operation pain and ODI were 2.61 (95% CI: 2.1-3.1) and 29.82 (95% CI: 24.6-35.1) in patients with scoliosis, and 2.67 (95% CI: 2.2-3.1) and 33.2 (95% CI: 28.8-37.6) in patients without scoliosis ($P=0.863$ and $P=0.329$ respectively). None of the SF-36 scales differed significantly between the scoliosis group after surgery.

Preoperative radiological parameter and clinical

measures correlation was evaluated. The VAS score was negatively correlated with SS ($r = -0.307, P = 0.002$). ODI was positively correlated with PI ($r = 0.260, P = 0.011$) and PI-LL ($r = 0.223, P = 0.030$). SS was negatively correlated with energy ($r = -0.262, P = 0.010$) and social functioning ($r = -0.248, P = 0.015$) scales of SF-36. There was a significant negative correlation between LL and social functioning ($r = -0.287, P = 0.005$).

Postoperative radiological parameters and clinical outcomes correlation were analyzed. A significant negative association between the VAS score and PI ($r = -$

$0.233, P = 0.026$) was found. PI-LL was positively correlated to the energy scale of SF-36 ($r = 0.203, P = 0.048$). No other significant correlation was found between radiological parameters and ODI and SF-36 scales. Stepwise linear regression revealed that none of the post-surgical radiological parameters could explain the variation observed in the VAS score and ODI after the surgery ($P > 0.05$). PI-LL was the only significant predictor of the Energy scale of SF36 ($B = 0.351, 95\% \text{ CI: } 0.224-0.799, P = 0.001$).

Table 1. Patients' baseline characteristics.

Parameter	Value
Age (mean±SD)	56.44 ± 9.0
Gender (male%)	23 (24.2%)
Smokers n (%)	23 (24.2%)
Diabetes n (%)	22 (23.1%)
Number of levels involved	<3 levels
	>3 levels
VAS	7.09 ± 2.1
ODI	61.07 ± 13.6
	Physical functioning
SF-36	Role functioning
	Energy/fatigue
	Emotional well-being
	Social functioning
	Pain
	General health
	Cobb's angle
Radiologic measures	Pelvic incidence
	Pelvic tilt
	Sacral slope
	Lumbar lordosis
PI-LL	16.94±15.2

ODI= Oswestry Disability Index, SF-36= 36-Item Short Form Survey, SD= standard deviation, VAS= visual analog scale

Table 2. Radiological outcomes after surgery

Parameter	Preoperation	Postoperation	P
Cobb's angle	9.98±2.5	3.82±1.0	<0.001
Pelvic incidence	57.8±14.5	58.1±14.5	0.8
Pelvic tilt	20.42±5.1	15.7±3.9	<0.001
Sacral slope	37.5±9.4	42.3±10.6	<0.001
Lumbar lordosis	40.9±10.2	48.0±12.0	<0.001
PI-LL	16.94±15.2	9.97±9.6	<0.001

Discussion

This study evaluated changes in clinical and radiological measures following spine surgery in 95 patients with ASD. In line with previous studies, surgical correction of ASD improve both clinical and radiological outcomes (17-19). Deformity correction is potentially demanding, and complication rates are relatively high (20). Surgical site infection is an important complication of surgery, which can increase the risk of morbidity, re-

operation, and mortality in these patients. In the present study, the rate of infection was 6.3%. This result is comparable with previous studies reported infection rates of 5.5% and 5.4% in surgically treated ASD patients (21,22).

Six radiological parameters include: Cobb's angle, PT, SS, PI, LL, and (PI-LL) were evaluated in this study. Cobb's angle is a radiologic measure used to determine the magnitude of spine curvature in the coronal plane. Scoliosis is a spinal deformity in the coronal plane and is

defined as Cobb's angle measured greater than 10 degrees (4). The relation between coronal alignment and surgical outcomes was assessed in some earlier studies. The majority of these studies found no significant association between Cobb's angle and functional outcomes (7,23,24). Scoliosis was detected in 42.1% of our patients. Scoliotic deformity corrected in all patients except two. We found no significant difference between patients with and without scoliosis regarding pain, disability, and quality of life. Moreover, there was no significant correlation between Cobb's angle and VAS score, ODI, and SF-36.

In this study, the surgical treatment of ASD caused a significant decrease in PT and PI-LL and a significant increase in SS and LL. PT, SS, and PI are key pelvic radiologic measures that are closely related to sagittal spinal alignment (25,26). PI has an important role in sagittal balance and is especially linked to LL (27,28). According to the Scoliosis Research Society (SRS)-Schwab classification, PT, the sagittal vertical axis (SVA), and PI-LL are major three sagittal modifiers (28). PI-LL values greater than 10-11 degrees are considered abnormal (28).

Restoration of sagittal balance is important for retrieving function and reducing pain in ASD patients (24). Several studies have evaluated the association between sagittal radiological parameters and clinical outcomes (7,10). Simon *et al.*, demonstrated that SS, LL, and spinosacral angle were negatively correlated with physical components of SF-36 (7). The Association between SVA and severity of pain was reported by some authors (5,29). In a study, higher PT, PI-LL, and SVA were associated with higher post-operation disability measured with ODI (18). Likewise, Inami *et al.*, shown that PT and PI-LL were significantly associated with ODI (9). A recent meta-analysis of surgical correction of degenerative sagittal imbalance, including ten studies (327 patients), revealed that changes in ODI are closely related to changes in LL (19). Some studies reported that mismatch between PI and LL (PI-LL) has the strongest association with disability and poor quality of life (30).

In our study, a negative correlation between pre-operative SS and VAS score, and energy and social functioning scales of SF-36 was observed. This means that patients with lower SS had more pain and worse quality of life. Therefore, SS increase after surgery may have a modifying role in pain relief and quality of life improvement. In contrast to the abovementioned studies, we had not found a significant correlation between PT and clinical outcomes (9,18). PI-LL was positively associated with ODI before surgery and the energy scale of SF-36 after surgery. The direct correlation of PI-LL

and ODI observed in this study confirms findings from previous studies, which argued that higher PI-LL is associated with more disability (9,19). LL was negatively correlated with social functioning. The adverse correlation of PI-LL and LL with these two scales of SF-36 is in contrast to results from earlier studies (30).

Prospective design and evaluation of a wide range of clinical and radiological measures are the strength of our study. However, a short duration of follow-up and a relatively small sample size is the major limitations to this study.

In conclusion, this study showed that the surgical correction of ASD improves both radiological parameters and clinical outcomes. Sagittal alignment has a more important role in the enhancement of patients' function and quality of life. However, for better evaluation, a large multicenter randomized control trial study is required.

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