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THE EFFECT OF PRE-AND POSTOP APICAL VERTEBRA ROTATION ON THE SHOULDER BALANCE AND SRS22-R SCORES IN ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Objective: To investigate the association between shoulder imbalance and AVR (apical vertebrae rotation) with AVR related ratios and how these radiological parameters effects patients postoperative functional and cosmetic outcomes by using SRS-22r scoring system.

Methods: Adolescent Idiopathic scoliosis patients (n: 48) treated with posterior spinal surgery and followed up for more than 1 years were evaluated retrospectively. The rotation angle of the apical vertebra was measured using Drerup's AVR measuring method in coronal plane radiograph. AVR improvement rate were calculated. Preoperative and postoperative follow-up shoulder balances were assessed by measuring CTAD (clavicular tilt angle difference) in the standing graphs.

Results: According to the Pearson Correlation test there was a statistically mild negative correlation between postoperative shoulder balance and age of operation. There was an inverse moderate correlation between early postoperative apical vertebral rotation and postoperative shoulder balance. According to other tests (Benferroni ve Pillai's Trace), AVR of patients with shoulder imbalance seems to have not improved in the postoperative period. Shoulder imbalance was found to be statistically significant in patients with poorly corrected postoperative AVR. Patients with good shoulder balance appeared to be composed of patients who showed better AVR recovery significantly in the early postoperative period.

Conclusion: Using early postoperative AVR recovery in evaluating the surgical outcomes of patients with adolescent idiopathic scoliosis and the evaluation of follow-up progression may provide important contributions to orthopedic surgery. Nevertheless, there is a need for large populations and long follow-up studies to support this thinking.

Key words: SRS-22r, Adolescent Idiopathic Scoliosis, shoulder balance, pain score, Lenke, Apical Vertebrae Rotation

Level of Evidence: Retrospective clinic study, Level III

INTRODUCTION

The main purpose of surgical treatment for idiopathic scoliosis patients is to establish natural cosmesis and improve self-image. The success of surgical treatment is assessed with radiographic parameters and functional outcomes. Generally, patients are satisfied with a balanced spine, well-corrected rib hump, and balanced shoulders after the surgery.

Although it is very important to provide subjective shoulder balance, it is difficult to evaluate and perform it by using conventional surgical methods. For this reason, radiographic shoulder balance is often used instead of subjective shoulder balance and is also considered as a critical parameter when judging the success of corrective surgery. Although there are many studies investigated several factors related to postoperative shoulder imbalance, no definite conclusions have been made. Also a few studies have investigated relationship between AVR and AVR related ratios with shoulder imbalance in the literature. In these studies no definite conclusions have been made too [1,6]. Therefore, we aimed to investigate the association between shoulder imbalance and AVR with AVR related ratios.

During this investigation we used SRS-22r scoring system as a patient related

evaluating system to investigate how these radiological parameters effects patients postoperative functional outcomes, cosmetic outcomes and their opinion.

PATIENTS AND METHODS

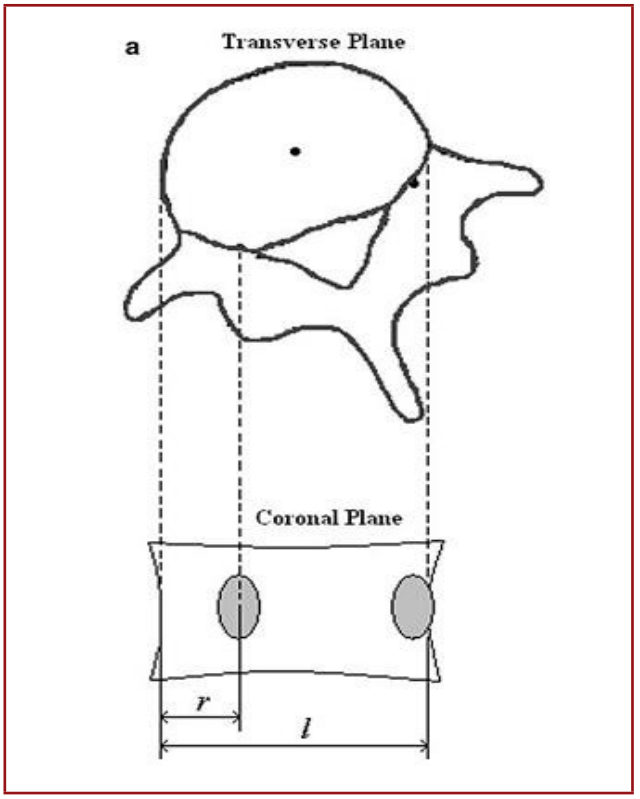
Adolescent Idiopathic scoliosis (AIS) patients (n: 48) who were treated with posterior spinal surgery and followed up for more than 1 years (13-55 months) and completed the SRS-22r outcomes questionnaire were evaluated retrospectively. There were 11 males and 37 females, ranging in age from 11 to 20 years with a mean age of 14.8 years at the time of surgery. We classified the patients' scoliotic curvatures by using Lenke classification system. The distribution of patients according to Lenke Classification system is shown in **Table-1**.

Posterior reduction and fusion was applied all of the patients by three different surgeons. In 36 patients polyaxial screw-rod system, in 8 patients polyaxial pedicle screw-rod system and polyester sub laminar clamp combination and in 4 patients polyaxial pedicle screw-rod system and pedicle or sub laminar hook combination was used. Selective posterior fusion was applied 46 of the 48 patients. Implantation was not extended to a level higher than T3 at any of the patients.

The rotation angle of the apical vertebra was measured by using Drerup's apical vertebra rotation measuring method in coronal plane radiographs **(Figure-1)**. In this formula 'r' indicates the distance between lateral border of the vertebra and the center of the pedicle which exists at convex side of the scoliotic curvature. The symbol 'l' indicates the length of horizontal border of the vertebral corpus (18). For the patients whose apex come across to a disc space, we separately calculated the AVR values of the vertebrae above and below the apical disc space. After these calculations the largest value was used for statistical examination. AVR recovery rate was calculated according to the following formula using pre- op and follow-up AVR values.

Preoperative and postoperative follow-up shoulder balances were assessed by measuring CTAD (clavicular tilt angle difference) in the standing graphs **(Figure-2)**. The reason of choosing this measurement method was that it is the most accurate method of measuring shoulder balance in standing ortho-radiographs in which both shoulders were not visible like our retrospectively evaluated patients. Patients with a clavicular tilt angle difference greater than 4.5 degrees were considered to have an unstable shoulder balance. The clavicular tilt angle is the angle between the horizontal plane and the line drawn along the proximal contour of the clavicle. Shoulder balance is negative for the patients whose right shoulder is high and it is positive for the patients whose left shoulder is high [1].

All patients were investigated by using SRS-22r scoliosis patient evaluation questionnaire for clinical evaluation [2]. According to the answers given to this questionnaire, scoring was done on subjects such as function, pain, external appearance, mental health and satisfaction after surgical treatment. These scores were noted for each patient. The average score, which evaluates patient's clinical scores, totally was also calculated and used in the study.



AVR= ((r/l) x 100) – 10
AVR improvement rate (%) = [(Pre-op AVR – follow-up AVR value) / Pre-op AVR)] X 100

Figure-1. Drerup's apical vertebra rotation measuring method [9,30].

Table-1. Distribution of patients according to Lenke Classification system

	A			B			C		
	(+)	(-)	N	(+)	(-)	N	(+)	(-)	N
I	1		12	3	2	7			6
II	1	2		1	1				
III	1			1					
IV									1
V									5
VI							1		3

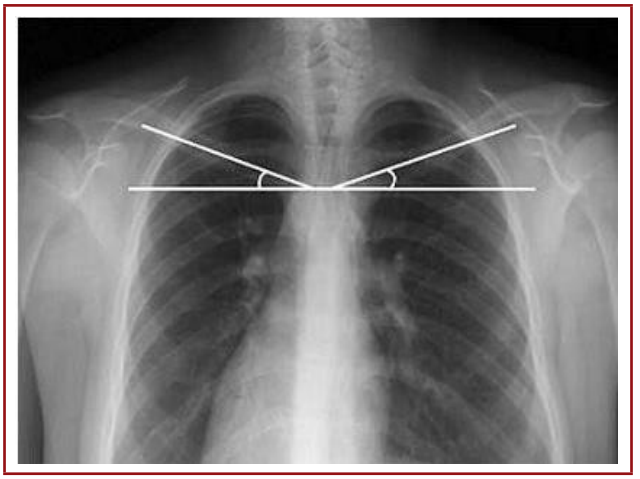


Figure-2. Clavicular tilt angle measuring [1]

RESULTS

None of the patients had pseudarthrosis and paralysis. None of the patients experienced complication due to primary instrumentation. The average time from surgery to last follow-up was 34.6 months (range, 13–55 months).

When the patients were evaluated according to their CTAD values, 18 (37.5 %) had normal shoulder balance and 30 (62.5 %) had shoulder imbalance before the surgical treatment. At the last follow-up, 33 (68.75 %) of the 48 patients had good shoulder balance and 15 patients (21.25 %) had shoulder imbalance.

Seven of 18 patients (38.9 %) who had normal shoulder balance before surgery had shoulder imbalance at the last follow-up. Twenty-one (70 %) of 30 patients with preoperative shoulder imbalance had normal shoulder balance at the last follow-up.

The mean preoperative AVR (apical vertebral rotation) of the patients was 18.64 (0-45) degrees. Mean postoperative AVR value was 17.05 (2-40) and mean last follow-up AVR value was 14.51 (0-31).

The mean last follow-up AVR recovery rate of patients was 21.9% (0-75). Nineteen of the patients (39.6 %) were found to have no improvement in apical vertebral rotation at the last follow-up.

Clinical outcomes of the patients were assessed by Scoliosis Research Society (SRS-22r) questionnaire. Patients were evaluated as having the highest score 5 and the lowest score 1 for each subject and for total score on this questionnaire. Patients descriptive data analysis according to the response to SRS scoliosis patient questionnaire is shown in **Table-2**.

Pearson correlation test was used to statistically analyze the relationship between clinical and radiological outcomes with preoperative, early postoperative, and last follow-up radiological results. SRS questionnaire total score and other domains presents in the SRS questionnaire like activity-function, pain, external appearance, psychological status and treatment satisfaction were not statistically correlated with parameters such as age of operation, preoperative AVR and AVR recovery rate.

Preoperative AVR and AVR recovery rate parameters did not show a significant correlation with SRS- 22r scores according to Pearson Correlation Test.

According to the Pearson Correlation Test, there was a statistically mild negative correlation between postoperative shoulder balance and age of operation (r: -0,302) (better shoulder balance in younger patients).

There was an inverse moderate correlation between early postoperative apical vertebral rotation and postoperative shoulder balance (r: -0.426). There was a slight correlation between postop AVR improvement rate and postop shoulder balance in the same direction (r: 0.289). There was a negative correlation between the amount of last follow-up AVR and the SRS satisfaction score at the end of follow-up (r: -0, 290).

We performed repeated measured analysis by using general linear samples in order statistically to evaluate treatment outcome by using repeated measured radiological parameters analysis including subjective factors. We performed Pillai's Trace test by including subjective factors to these measures. Benferroni Test was performed in binary comparisons. According to these tests, AVR of patients with shoulder imbalance seems to have not improved in the postoperative period. Shoulder imbalance was statistically significant in patients with poorly corrected postoperative AVR. Patients who showed better AVR recovery significantly in the early postoperative period were also patients with good shoulder balance (statistically significant).

Table-2. Descriptive data analysis table arranged according to the patients' response to SRS scoliosis patient questionnaire

	N	Minimum	Maximum	Mean	Std. Deviation
FUNCTION	48	2.6	5.0	5.0	3.747
PAIN	48	2.2	5.0	5.0	4.141
APPEARANCE	48	1.2	4.8	4.8	3.583
MENTAL HEALTH	48	2.2	5.0	5.0	3.494
SATISFACTION	48	2	5	5	4.29
TOTAL	48	2.52	4.73	4.73	3.7979
Valid N (listwise)	48				

DISCUSSION

Adolescent idiopathic scoliosis is accepted as the most common spinal deformity. Efforts for better understanding and analyzing this structure have accelerated with the beginning of the understanding of the three-dimensional structure of the scoliosis. A number of new and effective radiological measurement methods and parameters have been widely used day by day for evaluating AIS with these improvements.

The most important factors determining success in scoliosis surgery are providing patient satisfaction, correcting rib hump and maintaining postoperative shoulder balance. Edgar and Mehta reported that among scoliosis patients who were depressed or insecure, rib prominence and asymmetry were reported as the most concerning deformity related factors [11]. Therefore, a number of studies have been carried out to determine the radiological parameters that will lead to the postoperative stabilization of the shoulder balance. The variability of findings in previous research attests to the challenges of defining, measuring, and correcting shoulder imbalance [10].

In this study, we aimed to determine whether parameters such as apical vertebra rotation and AVR recovery rate measured in the preoperative and postop period affect the shoulder balance and SRS-22r clinical scoring system in the postoperative period.

When we evaluate the studies done, we can see that the shoulder balance is handled in two group as clinical and radiological shoulder balance. Actually when we look at the anatomy of the shoulder, there is no direct contact between the spine and the shoulder [10]. This makes it difficult to understand the relationship between scoliosis and deterioration of the shoulder balance. This also prevents the development of radiologic parameters that will facilitate the work of surgeons to establish shoulder balance after scoliosis treatment, or to evaluate treatment efficacy. In addition the definition of PSI (postoperative shoulder imbalance) has not been clearly established before [18]. Additionally Akel et al. [1] showed that shoulder imbalance is also common in the normal population without scoliosis.

Subjective shoulder balance is most important, but it is hard to evaluate and achieve using conventional surgeries. In addition clinical shoulder imbalance does not correlate with radiographic shoulder imbalance [18]. Thus, radiographic shoulder balance is frequently evaluated instead of subjective shoulder balance and is considered a critical consideration when judging the success of corrective surgery [18]. It is not clear how shoulder imbalance can be measured accurately, but several studies have reported the effectiveness of various methods [12,20,29]. These reasons prevent to develop effective parameters for establishing postoperative shoulder balance.

Kuklo and colleagues reported that there is no objective measurement tool for clinical evaluation of the shoulder balance [14]. They also showed that clavicle angle was the most reliable parameter indicating shoulder balance and they mentioned upright proximal thoracic, or side-bending proximal thoracic Cobb, provided the best preoperative radiographic prediction of postoperative shoulder balance [14,15].

In another study, the best radiographic predictor of postoperative shoulder balance following posterior or anterior spinal fusion has not yet been determined [24]. Again, at the same study they found that the clavicle angle was the best predictor, reaching statistical significance and they mentioned the next best predictor was coracoid height [24]. Kwan et al reported that shoulder imbalance correlated with coracoid height difference (CHD), clavicle\rib intersection distance (CRID), clavicle angle (CA), radiographic shoulder height (RSH), T1 tilt and cervical axis [16].

In another study shoulder imbalance is found associated with T1 tilt, pre-operative shoulder height, first rib inclination, coracoid height difference, clavicle angle, radiological shoulder height, clavicle\rib intersection distance and pre-operative proximal thoracic (PT) curve [4,12]. There are, however, many studies suggesting that T1 tilt is not effective in determining shoulder balance.

In recent years, Ono et al. reported the concept of medial and lateral shoulder imbalance. Medial shoulder imbalance is produced by trapezius bulkiness. The lateral shoulder measurements were defined by the clavicle angle (CA). The position of the proximal spine as measured by T1 tilt, first rib angle, and proximal thoracic Cobb does not correlate well with lateral shoulder balance [20]. These measures correlate better with the medial trapezoidal prominence.

The fact that shoulder imbalance is also present in patients without scoliosis. Identification and measurement of shoulder imbalance has its own difficulties and lack of certain parameters that confirm this antiquity have created many difficulties to us about choosing parameters to use in our work. For these reasons, it become harder for us and for other authors to choose which parameters to use in their studies and for our study. Including all these facts, we used the CTAD, which is the most compatible with the clavicle angle that is the most correlated parameter with shoulder balance in the literature and provide the most accurate measurement of the shoulder balance in standing ortho-radiographs [1].

Rotation of apical vertebrae is primarily responsible for the thoracic cage deformity (rib hump) that represents one of the main cosmetic problems for scoliotic patients [21]. In our study, we evaluated the effects of this parameter on shoulder balance but many aspects are still open to debate. For instance, accuracy of radiographic measurements of vertebral rotation varies different studies [23]. Computed tomography gives the most exact information [17,28] but it is difficult to perform computed tomography for all patients. And it has high radiation exposure. For this reason, it is preferable to make measurements on plain radiographs in the routine.

There are also disadvantages of radiography measurement. Patient positioning during the X-ray may influence apical vertebral rotation measurement. This measurement is graded on an ordinal scale and may not be sensitive in detecting

smaller differences; although, this may not be clinically significant [8].

It can be difficult to evaluate and measure AVR after spinal instrumentation that covers osseous landmarks on standard X-rays [22-23]. The impact of AVR correction on the overall surgical outcome, that is, patients' satisfaction in the short term, was not proven [13].

Chang et al reported that AVR, AVT, and Cobb magnitude, as well as their respective ratios, did not, in fact, predict which patients would require surgery or have marginally acceptable outcomes [6].

In a study for the clinical evaluation of scoliosis patients Bengtsson et al [5] found that patients with severe scoliosis were characterized by insecurity and hypersensitivity, and that their psychosocial adjustment was negatively correlated with the severity of their deformity. In time, SRS scoring system was improve and started to be used in evaluating patient's preoperative perceptions about themselves and their postoperative outcomes. The SRS instrument is the only standard, well validated, disease-specific questionnaire for idiopathic scoliosis, and many authors think that the instrument is very useful despite culture-related differences in perception of the patient [3,25].

There are different SRS scoring instruments like SRS-24, SRS-30 and SRS-22r. The choice of SRS scoring system differs from country to country in routine use but main titles like function, pain, external appearance, mental health, and satisfaction with treatment doesn't differs.

In a study, D'Andrea *et al* examined 78 patients treated with anterior or posterior instrumentation with a minimum 2-year follow-up using the SRS-24 questionnaire, and reported little correlation between the radiographic assessment and the SRS-24 questionnaire scores [7]. In many studies self-image and patient satisfaction have been found to be associated with clinical deformity [5,10,19].

Wilson *et al* examined 265 patients in a multicenter study at 7 scoliosis centers and reported that coronal measures of thoracic and lumbar curve were correlated with the pain, self-image, and total SRS-24 scores (P 0.0001) [26].

Watanabe et al reported that of the scores of the individual SRS-24 domains and radiographic measurements, the scores of the general function, activity, and postoperative function domains did not reveal any correlations with radiographic parameters of spinal deformity. The pain domain score was positively correlated with the magnitude of correction angle of postoperative thoracic rotation angle.

The results of the study indicate that the patients with a greater Cobb angle or rotation angle in the thoracic curve had a negative self-image regarding back appearance at the final follow-up. In addition, satisfaction after surgery was correlated with improvement of patients' self- image based on the result of stepwise regression analysis [25].

In our study there was a slight correlation between postop AVR improvement rates, a rarely used parameter in previous studies that we thought is related to external appearance especially the improvement in the rib hump and postop shoulder balance, and SRS satisfaction scores in the same direction. Although these results are compatible with the study of Watanabe et al, there was mild correlation in our study and there was strong correlation in their study. We concluded that by using these data, the effect of AVR on SRS scores should be evaluated on larger patient populations preferably with the same or longer post-operative follow-up period, would give results that are more accurate.

An interesting result that has not been determined before in the literature was that there was a statistically mild negative correlation between postoperative shoulder balance and age of operation according to Pearson Correlation Test.

Another finding that did not present in the literature review was that an inverse moderate correlation was found between early postoperative apical vertebra rotation and postop shoulder balance. (Watanabe et al. concluded that there was strong inverse correlation between thoracal AVR and general self-image and pain scores at last follow-up).

In addition, a mildly similar correlation was found between postop AVR recovery rate and postop shoulder balance. We performed repeated measured analysis by using general linear samples in order to evaluate treatment outcome by using repeated measured radiological parameters analysis including subjective factors. We performed 'Pillai's Trace' test by including 'subjective factors' to these measures. 'Benferroni Test' was performed in binary comparisons. According to these tests, there was a significant correlation between AVR recovery rate and shoulder balance and patients with good shoulder balance showed better AVR recovery significantly in the early postoperative period. (Statistically significant). Therefore, we think that using early postoperative AVR recovery in evaluating the surgical outcomes of patients with adolescent idiopathic scoliosis and the evaluation of follow-up progression of this parameter may provide important contributions to orthopedic surgery. Therefore, there is a need for long follow-up and high patient population studies.

Yagi et al reported that apical rotation of the main curve is a significant predictor of postoperative shoulder imbalance [27]. This finding is similar with our and Watanabe and his collegues' findings. If any other studies made to support the same information, we could see that apical vertebra rotation, which is very important in determining the rib hump, became a widely used parameter to determine the postoperative shoulder balance.

The presence of different types of curvature in some of the patients and the short follow-up period are the limiting factors of this study. Shoulder imbalance is also seen in patients without scoliosis. Findings from previous studies on the definition and measurement of shoulder balance contradict each other. Additionally different opinions have been put forward in different studies on the reliability of

AVR measurement. In addition, implants used in surgery make it difficult to determine the landmarks that is used for AVR measurement on plain radiographs in the postoperative period. These reasons are restrictive factors for our study and for all studies done about this subject.

We are thinking that we should focus on studies to find a reliable and infallible method that can detect and use intraoperatively in order to ensure shoulder balance after scoliosis operations.

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