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The Impact of Relative Curve Correction on Postoperative Shoulder Balance in Adolescent Idiopathic Scoliosis

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ABSTRACT

Background: Postoperative shoulder asymmetry frequently emerges as a prevalent adverse outcome following the surgical rectification of adolescent idiopathic scoliosis (AIS).

Objective: This study aimed to evaluate the influence exerted by the degree of rectification of the primary thoracic (MT) and proximal thoracic (PT) curvatures in correlation with one another on the equilibrium of the shoulders following surgical intervention.

Patients and methods: Fifteen patients harbouring AIS curvatures underwent correction via pedicle screw/rod constructs. The determinants of postoperative shoulder disparity were pinpointed through univariate examination. Furthermore, to ascertain the autonomous predictors of shoulder asymmetry, a multivariate assessment was conducted employing the classification and regression tree technique.

Results: Post-surgical observation revealed that a third of the patients (33.3%) experienced shoulder imbalance. In instances where the correction of the PT Cobb angle surpassed 52%, the majority (57%) exhibited shoulder equilibrium. In a similar vein, when the correction of the PT curve was inferior to 52% and the correction of MT curve did not exceed 67%, a significant 86% of the subjects achieved shoulder balance. Conversely, with the PT curve correction falling below 52% and the MT curve correction exceeding 67%, only half of the patients attained balanced shoulders.

Conclusions: Within the context of AIS deformities, a pronounced rectification of the main thoracic curve (67%) accompanied by a concurrent 'under-correction' (<52%) of the upper thoracic curve precipitated a disparity in shoulder height in half of the patients, irrespective of UIV placement.

Keywords: AIS, Curve correction, Deformity, Lenke type, Shoulder balance, Scoliosis, Shoulder imbalance, Surgery, Upper instrumented vertebra.

INTRODUCTION

The term scoliosis is derived from the Greek word “skoliosis,” signifying crookedness. This condition represents a multifaceted three-dimensional distortion of the spinal architecture marked by a lateral displacement exceeding 10 degrees, accompanied by vertebral rotation, and is frequently linked with a diminished natural kyphotic curvature of the spine, known as Hypokyphosis [1].

Scoliosis is divided into 3 broad categories: Idiopathic, Congenital, and Neuromuscular. Idiopathic scoliosis (IS) was classified according to the age of onset by James in England in 1954. These include Infantile (birth to 3 years), Juvenile (4-9 years), and AIS (10 years old) [2].

Epidemiological research has revealed that the prevalence of idiopathic scoliosis stands at about 2% in individuals presenting with a Cobb angle of 11°, while it ranges from approximately 0.3% to 0.5% in subjects possessing a Cobb angle of 20°. The proportion of patients with adolescent idiopathic scoliosis who require treatment is only 0.1% to 0.3% [3].

AIS predominantly impacts females, exhibiting a female-to-male ratio ranging from 1.5:1 to 3:1, a demographic that typically exhibits a greater concern for physical appearance compared to their male counterparts [4].

The advancement of AIS can lead to disruptions in bodily structure and function that influence both morphology and physiology [5].The foremost objective in surgically managing AIS is to secure a stable, evenly aligned spine through the rectification of its intricate 3D aberration, and to halt any additional progression of the deformity by accomplishing a robust arthrodesis. The technique of posterior surgical instrumentation involves the utilization of rods secured by pedicle screws, which are embedded within the vertebrae [6].

Surgical intervention continues to be regarded as a potent therapeutic approach for managing AIS, particularly in cases where the scoliotic curvature exceeds 45°. Despite its effectiveness, the surgical approach has been subject to criticism due to inadequate deformity correction, significant blood loss, elevated rates of complications, and the potential necessity for subsequent surgeries [7]. Constructs utilizing pedicle screws have demonstrated superior efficacy in addressing and rectifying the 3D complexities of scoliotic spinal deformations when contrasted with hook or hybrid constructs [8].

Comprehensive evaluations have been conducted on the effectiveness of posterior-only fusion in treating severe thoracic AIS. Studies by Luhmann and Lenke have scrutinized the outcomes of combined anterior and posterior fusion versus posterior fusion alone in severe AIS cases. Their findings suggest that outcomes for patients subjected to pedicle screw-only instrumentation were comparably effective to those receiving combined treatments (60.7% vs. 58.5%) [9].

Patients frequently express apprehension regarding their bodily aesthetics prior to and subsequent

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to undergoing surgical procedures. The balance of the shoulders, as evaluated through the Walter Reed Visual Assessment Scale (WRVAS), is consistently cited as a significant issue by individuals diagnosed with AIS, thereby affirming the instrument's applicability in the assessment of scoliotic distortions [10].

An examination encompassing 112 patients diagnosed with AIS who underwent surgical procedures disclosed that prior to surgery, shoulder asymmetry presented a challenge in 75% of the instances. Postoperatively, a disconcerting 24% continued to experience issues related to shoulder imbalance [5].

Particularly disheartening are instances where patients, despite having satisfactory shoulder balance before surgery, encounter unexpected postoperative imbalances. Clinical assessments, radiographic evaluations, and clinical photography all serve as methods to quantify shoulder balance, with its achievement being a principal objective of corrective surgery [11].

Amidst the considerable importance patients attribute to their aesthetic form, gaining a comprehensive insight into the determinants of shoulder equilibrium could offer substantial value in dialogues preceding surgical interventions with both patients and their kin. However, the factors precipitating postoperative shoulder disequilibrium and the methodologies for its preclusion post-corrective procedure remain contentious. Investigations leveraging pre- and post-operative radiographic analyses have indicated multiple variables influencing the ultimate shoulder balance post-AIS surgical intervention.

The study carried out by **Lee *et al.*** [12] illuminated the correlation between post-surgical shoulder disequilibrium and higher Risser scores, enhanced postoperative proximal wedge angles, as well as a heightened ratio of postoperative proximal thoracic curve (PTC) to main thoracic curve (MTC). Concurrently, **Yagi *et al.*** [13] discerned that both the clavicle chest cage angle difference (CCAD) and the apical vertebral rotation (AVR) of the MTC emerge as singular predictive factors for postoperative shoulder imbalance (PSI) in AIS patients undergoing surgical interventions.

Namikawa *et al.* [14] posited that for averting postoperative shoulder disequilibrium, an adequate correction of the PTC, in congruence with the MTC correction, is imperative. Concerning the prognostic indicators for postoperative shoulder disequilibrium, **Liu *et al.*** [15] revealed that CCAD serves as a dependable metric for assessing postoperative shoulder imbalance in AIS patients undergoing selective posterior fusion for Lenke 5C curvatures, a finding corroborated by **Han *et al.*** [16] for patients with Lenke 1 AIS.

With the advancement of spinal column instrumentation, the methodologies for selecting fusion levels in idiopathic scoliosis correction have undergone significant evolution. Contemporary pedicle screw and rod assemblies empower surgeons with the capability to enact substantial curvature adjustments. However, should the correction focus solely on the main thoracic curve to the neglect of the proximal segment, a resultant shoulder height imbalance is possible.

A range of strategies to diminish postoperative shoulder disequilibrium has been delineated, yet this complication persists, manifesting in upwards of 25% of idiopathic scoliosis cases [11]. The choice of the UIV is championed as a critical factor in the prevention of postoperative shoulder imbalance. It is advocated that the PT curve be instrumented especially when MT curve correction could exacerbate any preexisting disequilibrium [17, 18].

A multitude of academics highlight the paramount importance of UIV determination in the alleviation of shoulder imbalance, frequently recommending the selection of a superiorly located UIV (usually T2 or T3) particularly in instances where patients afflicted with right sided Lenke 1 and 2 curvatures exhibit a preoperative elevation of the left shoulder [19].

In the year 2008, **Ilharreborde *et al.*** [18] expounded on their methodology for UIV selection, which takes into consideration the stiffness of the PT curve, the inclination of T1 and the shoulder, as well as the anticipated effects following the correction of the MT curve. Similarly, other scholars advocate for the adoption of higher proximal fusion levels in situations characterized by an elevated left shoulder prior to the surgical intervention [19, 20].

PATIENTS AND METHODS

This is a Prospective study from 2022 till 2024, with a follow up range from one to two years conducted in the Department of Orthopedic Surgery, Benha University Hospital, Egypt. This study focused on fifteen patients with AIS who were treated through posterior spinal fusion using a pedicle screws-only configuration, utilizing a posterior-only approach. An in-depth review of both radiological and clinical photographs was conducted to assess the effect of correction levels of MT and PT curves on postoperative shoulder balance.

Inclusion criteria: Children within the age range of 10 to 18 years, diagnosed with AIS, who underwent surgical treatment involving posterior spinal fusion and instrumentation. This included all Lenke AIS classification types, with the requirement that participants agreed to partake in the research and provided informed consent.

Exclusion criteria: Cases with congenital or neuromuscular scoliosis and those younger than 10 years or older than 18 years, ensuring a focused

examination on the specific demographic of adolescent idiopathic scoliosis and the surgical outcomes related to spinal curve correction and its impact on postoperative shoulder alignment.

Ethical considerations: The study was done after being accepted by The Research Ethics Committee, Benha University. All patients provided written informed consents prior to their enrolment. The consent form explicitly outlined their agreement to participate in the study and for the publication of data, ensuring protection of their confidentiality and privacy. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean ± standard deviation (SD), median and interquartile range (IQR). Qualitative data were expressed as frequency and percentage. Chi-square (x^2) test of significance was used in order to compare proportions between qualitative parameters.

RESULTS

Fifteen patients, with an average age of 14.3 years were qualified for the study based on the inclusion criteria. The majority (86.6%) had UIV set at T3-T4, while the remaining 13.3% were instrumented up to T2, as detailed in table (1). Postoperative assessments revealed that 33.3% of these patients experienced shoulder imbalance. Notably, when the PT Cobb angle underwent correction exceeding 52%, a balanced shoulder condition was observed in 57% of cases.

Table (1): Description of UIV in all studied patients

		Studied patients (N = 15)	
UIV	**T2**	2	13.3%
	T3	8	53.3%
	T4	5	33.3%

In a parallel fashion, equilibrium was attained in 86% of the subjects when the correction applied to the PT curve remained below 52%, and the adjustment of the MT curve did not surpass 67%. In contrast, a balance achievement rate of 50% was observed when the PT curve's correction was maintained below 52%, albeit with the MT curve experiencing corrections that exceeded 67%. Notably, these results were steadfast, unaffected by the specific selection of the UIV level, as documented in table (2).

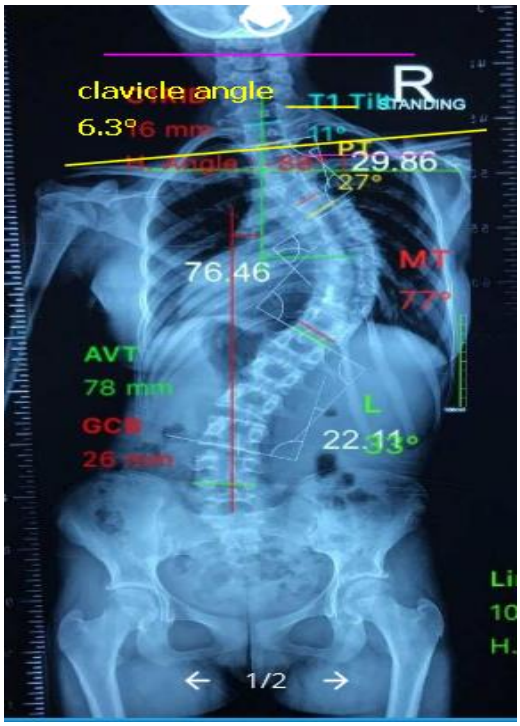
Table (2): Correlation between MTA & PTA % of correction in relation to each other and post-operative clinical shoulder balance in the studied patients

		Post-op clinical shoulder balance				X^2	P-value
		Balanced		Not balanced			
% of correction	**PTA < 52% & MTA < 67%**	5	85.7 %	1	14.3 %	1.28	0.525 NS
	PTA < 52% & MTA > 67%	1	50%	1	50%		
	PTA > 52% & MTA < 67%	0	0%	0	0%		
	PTA > 52% & MTA > 67%	4	57%	3	43%		

Case presentation

A female patient 15 years old presented with a type 2 A N Lenke curve pattern. Her proximal thoracic and main thoracic curves were 27° and 77° respectively, which proximal thoracic wasn't changed on Lt. side-bending films and the main thoracic curve was reduced to 62° on Rt side- bending films.

Her thoracic kyphosis angle and lumbar lordosis were 37°, 58° respectively. Her shoulder balance as regards clavicle angle was 6.3° right up and T1 tilt 11°. Her clinical photogrammetric analysis was SHA: 8°, AHA: 11°, right up. Postoperatively, her curves corrected to 13° and 15° respectively. Her thoracic kyphosis and lumbar lordosis were corrected to 25° and 50° respectively. Her shoulder balance as regards clavicle angle was 0.2° (balanced) and T1 tilt 0°. Her clinical photogrammetric analysis was SHA: 0°, AHA: 0°, balanced.



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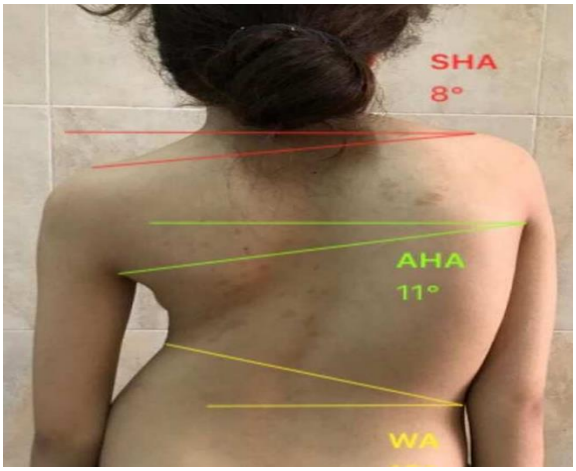

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Figure (1): (A) Pre-operative standing posteroanterior view, (B) Post-operative standing posteroanterior view, (C) Pre-operative clinical photogrammetric posterior view, (D) Post-operative clinical photogrammetric posterior view.

DISCUSSION

The quest for aesthetic symmetry post-scoliosis corrective surgery underscores the significance of achieving shoulder balance, a frequent source of patient dissatisfaction post-procedure, and prompting extensive research efforts to refine surgical outcomes. In our analysis of AIS subjects, we discerned that a relative "under-correction" of PT curve (below 52% Cobb angle adjustment) coupled with substantial correction of MT curve (exceeding 67% Cobb angle adjustment) culminated in a 50% incidence of postoperative shoulder height disparity, irrespective of UIV selection. Conversely, exceeding a 52% correction threshold for the PT curve resulted in shoulder height disparities in 43% of instances. Furthermore, when under-correction of both the PT curve (below 52%) and MT curve (below 67%) was observed, only 14% exhibited shoulder imbalance, highlighting the critical nature of relative corrections between the PT and MT curves for symmetric shoulder heights post-surgery. This elucidates the pivotal role of proportional corrections between the PT and MT curves in fostering postoperative shoulder symmetry. **Sielatycki *et al.*** [21] explored how disproportionate corrections between the PT and MT curves contribute to shoulder imbalance, underscoring the consequence of under-correction of the PT curve and over-correction of the MT curve. Unlike **Sielatycki *et al.*** [21] who focused on anterior photographs of patients with Lenke 1 and 2 curves, our study utilized posterior photographs and encompassed all Lenke curve types, discovering a higher threshold for what constitutes overcorrection of the MT curve.

The literature emphasized the criticality of UIV level selection to achieve symmetrical shoulder heights post-correction [17-19], advocating for higher UIV selection in patients predisposed to shoulder imbalance. The methodologies of **Ilharreborde *et al.*** [18] propose UIV determination algorithms based on curve flexibility and predicted shoulder height impacts, emphasizing the strategic management of the PT curve through higher UIV selections.

Despite conventional wisdom, our findings indicated that UIV selection alone does not predict shoulder balance, echoing the sentiment that radiographic markers such as T1 tilt and clavicle angle, while previously correlated with shoulder balance perceptions [22, 23], were not predictive in our analysis. This underscores the nuanced understanding that achieving an optimal PT curve correction, particularly when the MT curve undergoes significant correction, is paramount, necessitating targeted compression/distraction manoeuvres.

However, our study's methodology, including the selection of patients based on available photographs and the timing of these photographs post-surgery, may introduce biases and limit the observation of long-term outcomes. Additionally, our focus was solely on the coronal plane, not accounting for potential sagittal and axial plane interplays, nor did we differentiate between medial and lateral aspects of shoulder asymmetry, areas ripe for future investigation.

CONCLUSIONS

In adolescent idiopathic scoliosis (AIS) treatment, significant correction of the main thoracic curve (over 67% Cobb angle correction) while minimally adjusting the upper thoracic curve (below 52% Cobb angle correction) led to shoulder height imbalance in half of the patients, regardless of the upper instrumented vertebra (UIV) used. Contrastingly, correcting the PT curve by more than 52% resulted in imbalance in 43% of cases. When both the PT and MT curves were modestly corrected (PT below 52%, MT below 67%), imbalance occurred in only 14% of patients, indicating that the relative correction between PT and MT curves significantly affected postoperative shoulder balance more than UIV selection. Although, selecting a proximal UIV might be essential for maximizing PT curve correction, achieving optimal shoulder balance necessitates specific corrections to the PT curve, especially when a larger MT curve correction is planned.

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REFERENCES

1. **Asghar J, Samdani A, Pahys J *et al.* (2009)**: Computed tomography evaluation of rotation correction in adolescent idiopathic scoliosis: a comparison of an all pedicle screw construct versus a hook-rod system. Spine (Phila Pa 1976), 34: 804-7.
2. **Hresko M, Talwalkar V, Schwend R (2016)**: Early Detection of Idiopathic Scoliosis in Adolescents. J Bone Joint Surg Am., 98: e67.
3. **Stirling A, Howel D, Millner P *et al.* (1996)**: Late-onset idiopathic scoliosis in children six to fourteen years old. A cross-sectional prevalence study. J Bone Joint Surg Am., 78: 1330-6.
4. **Choudhry M, Ahmad Z, Verma R (2016)**: Adolescent Idiopathic Scoliosis. Open Orthop J., 10: 143-54.
5. **Kotwicki T, Chowanska J, Kinel E *et al.* (2013)**: Optimal management of idiopathic scoliosis in adolescence. Adolesc Health Med Ther., 4: 59-73.
6. **Tandon M, Dhingra A, Varma V (2020)**: Management of Patient with Scoliosis. Problem Based Learning Discussions in Neuroanesthesia and Neurocritical Care, 19: 291-330.
7. **Lonner B, Ren Y, Yaszay B *et al.* (2018)**: Evolution of Surgery for Adolescent Idiopathic Scoliosis Over 20 Years: Have Outcomes Improved? Spine (Phila Pa 1976), 43: 402-10.
8. **Lenke L, Betz R, Harms J *et al.* (2001)**: Adolescent idiopathic scoliosis: a new classification to determine

extent of spinal arthrodesis. J Bone Joint Surg Am., 83: 1169-81.

9. **Lenke L, Newton P, Sucato D *et al.* (2013)**: Complications after 147 consecutive vertebral column resections for severe pediatric spinal deformity: a multicenter analysis. Spine (Phila Pa 1976), 38: 119-32.
10. **Pineda S, Bago J, Gilperez C *et al.* (2006)**: Validity of the Walter Reed Visual Assessment Scale to measure subjective perception of spine deformity in patients with idiopathic scoliosis. Scoliosis, 1: 18.
11. **Smyrnis P, Sekouris N, Papadopoulos G (2009)**: Surgical assessment of the proximal thoracic curve in adolescent idiopathic scoliosis. Eur Spine J., 18: 522-30.
12. **Lee C, Hwang C, Lim E *et al.* (2016)**: A retrospective study to reveal factors associated with postoperative shoulder imbalance in patients with adolescent idiopathic scoliosis with double thoracic curve. J Neurosurg Pediatr., 25: 744-52.
13. **Yagi M, Takemitsu M, Machida M (2013)**: Chest cage angle difference and rotation of main thoracic curve are independent risk factors of postoperative shoulder imbalance in surgically treated patients with adolescent idiopathic scoliosis. Spine (Phila Pa 1976), 38: E1209-15.
14. **Namikawa T, Matsumura A, Kato M *et al.* (2015)**: Radiological assessment of shoulder balance following posterior spinal fusion for thoracic adolescent idiopathic scoliosis. Scoliosis, 10: S18.
15. **Liu Z, Hu Z, Qiu Y *et al.* (2017)**: Role of Clavicle Chest Cage Angle Difference in Predicting Postoperative Shoulder Balance in Lenke 5C Adolescent Idiopathic Scoliosis Patients after Selective Posterior Fusion. Orthop Surg., 9: 86-90.
16. **Han X, Liu Z, Qiu Y *et al.* (2016)**: Clavicle Chest Cage Angle Difference: Is It a Radiographic and Clinical Predictor of Postoperative Shoulder Imbalance in Lenke I Adolescent Idiopathic Scoliosis? Spine (Phila Pa 1976), 41: 1346-54.
17. **Suk S, Kim W, Lee C *et al.* (2000)**: Indications of proximal thoracic curve fusion in thoracic adolescent idiopathic scoliosis: recognition and treatment of double thoracic curve pattern in adolescent idiopathic scoliosis treated with segmental instrumentation. Spine (Phila Pa 1976), 25: 2342-9.
18. **Ilharreborde B, Even J, Lefevre Y *et al.* (2008)**: How to determine the upper level of instrumentation in Lenke types 1 and 2 adolescent idiopathic scoliosis: a prospective study of 132 patients. J Pediatr Orthop., 28: 733-9.
19. **Trobisch P, Ducoffe A, Lonner B *et al.* (2013)**: Choosing fusion levels in adolescent idiopathic scoliosis. J Am Acad Orthop Surg., 21: 519-28.
20. **Chang D, Kim J, Kim S *et al.* (2014)**: How to improve shoulder balance in the surgical correction of double thoracic adolescent idiopathic scoliosis. Spine (Phila Pa 1976), 39: E1359-67.
21. **Sielatycki J, Cerpa M, Beauchamp E *et al.* (2019)**: The Amount of Relative Curve Correction Is More Important Than Upper Instrumented Vertebra Selection for Ensuring Postoperative Shoulder Balance in Lenke Type 1 and Type 2 Adolescent Idiopathic Scoliosis. Spine (Phila Pa 1976), 44: E1031-e7.
22. **Kuklo T, Lenke L, Graham E *et al.* (2002)**: Correlation of radiographic, clinical, and patient assessment of shoulder balance following fusion versus nonfusion of the proximal thoracic curve in adolescent idiopathic scoliosis. Spine (Phila Pa 1976), 27: 2013-20.
23. **Ono T, Bastrom T, Newton P (2012)**: Defining 2 components of shoulder imbalance: clavicle tilt and trapezial prominence. Spine (Phila Pa 1976), 37: E1511-6.