Journal of Research in
Orthopedic Science
August 2023. Volume 10. Number 3

Case Series

Evaluation of Shoulder Imbalance in Lenke Type 2 Adolescent Idiopathic Scoliosis Undergoing Surgery: A Single Institution Case Series

Mohammadreza Chehrassan[1], Farshad Nikouei[1], Mohammadreza Shakeri[1], Ali Valiollahpour Amiri[1], Mahdi Yaqubnejad[1], Ebrahim Ameri[1], Hasan Ghandhari[1]

1. Department of Orthopedics, School of Medicine, Bone and Joint Reconstruction Research Center, Shafayahyaeian Hospital, Iran University of Medical Sciences, Tehran, Iran.

Use your device to scan and read the article online

Citation Chehrassan M, Nikouei F, Shakeri M, Valiollahpour Amiri A, Yaqubnejad M, Ameri E, et al. Evaluation of Shoulder Imbalance in Lenke Type 2 Adolescent Idiopathic Scoliosis Undergoing Surgery: A Single Institution Case Series. Journal of Research in Orthopedic Science. 2023; 10(3):173-182. http://dx.doi.org/10.32598/JROSJ.10.3.1355.2

http://dx.doi.org/10.32598/JROSJ.10.3.1355.2

Article info:
Received: 19 May 2023
Revised: 25 May 2023
Accepted: 29 Jun 2023
Available Online: 01 Aug 2023

Keywords:
Adolescent idiopathic scoliosis (AIS), Lenke classification, Spinal fusion, Upper instrumented vertebra (UIV), Shoulder balance, Radiographic analysis

ABSTRACT

Background: Surgical correction of Lenke type 2 adolescent idiopathic scoliosis (AIS) is challenging, particularly when selecting the upper instrumented vertebra (UIV) in the proximal thoracic (PT) curve. Although incorporating PT curve into fusion is standard practice, the effect of UIV selection on postoperative shoulder imbalance is uncertain.

Objectives: This study aims to evaluate shoulder imbalance in patients with lenke type 2 AIS undergoing corrective surgery.

Methods: This retrospective cohort study included 12 Lenke type 2 AIS patients who underwent corrective surgery. Data, including demographic details, radiological features, and shoulder balance, were collected preoperatively, postoperatively, and during follow-up. Statistical analyses were performed to evaluate changes in radiographic angles and shoulder balance.

Results: Significant postoperative reductions were observed in Cobb angles, sagittal alignment, shoulder balance, and lumbar lordosis. The median shoulder balance deviation decreased from the preoperative to the final follow-up. The type of UIV device used showed no significant relationship with changes in shoulder balance. However, the UIV inclination demonstrated a median change of 4.5°, with no significant relationship with the device used.

Conclusion: Preoperative lateral shoulder balance considerably influences postoperative balance, surpassing the impact of UIV selection. Our results underscore the importance of considering shoulder balance when selecting UIV for patients with Lenke type 2 AIS.

*** Corresponding Author:**
Ali Valiollahpour Amiri, MD.
Address: *Department of Orthopedics, Bone and Joint Reconstruction Research Center, School of Medicine, Shafayahyaeian Hospital, Iran University of Medical Sciences, Tehran, Iran.*
Phone: *+98 (911) 3903565*
E-mail: *hamidortho50@gmail.com*

Introduction

Lenke type 2 adolescent idiopathic scoliosis (AIS) is characterized by structural proximal thoracic (PT) and main thoracic (MT) curvature, as well as a non-structural compensatory lumbar curve [1]. Surgical intervention for Lenke type 2 poses challenges in selecting the upper instrumented vertebra (UIV) on the PT curve. Key considerations include avoiding PT curve progression, postoperative shoulder asymmetry, and proximal junctional kyphosis [2]. Postoperative shoulder balance significantly affected AIS patient satisfaction and self-perception. Thus, selecting an optimal level for UIV necessitates careful consideration of postoperative shoulder balance.

Neglecting to incorporate the PT curve into surgical fusion can lead to severe postoperative shoulder imbalance [3]. Consequently, it is customary to include the PT curve in surgical instrumentation for Lenke type 2. Nevertheless, UIV selection presents clinical dilemmas, particularly in achieving shoulder balance. Some authors advise against routine instrumentation of the first or second thoracic vertebra (T1 or T2) due to greater surgical complexity, muscle dissection, scar visibility, and blood loss [4]. Recommendations for fusion to T2 vary among authors, with some advocating for T2 fusion for all Lenke type 2 cases, while others suggest T2 fusion selectively under specific conditions [2, 5, 6].

Despite various UIV selection methods for Lenke type 2, spinal surgeons rely on their experience to make this decision [7]. However, existing UIV selection systems fail to accurately predict postoperative shoulder balance [8]. Our literature review revealed limited discussion on the correlation between UIV and shoulder balance in patients with Lenke type 2 AIS. Therefore, this study aimed to investigate the clinical features of these patients at our hospital.

Methods

This retrospective cohort study utilized a census sampling approach, including all patients diagnosed with AIS who underwent corrective surgery at Shafayahaieyan Hospital between 2020-2022. The inclusion criteria involved patients diagnosed with AIS by a spine specialist and categorized as type II Lenke. The exclusion criteria encompassed patients with congenital, neuromuscular, or infantile scoliosis, prior spine surgeries, such as discectomy, and conditions, like rheumatoid arthritis and diabetes, that may impact surgical outcomes.

Data collection included reviewing patients' hospital and follow-up records and gathering demographic details, including age, sex, and radiological features during pre-operation, post-operation, and final follow-up after 12-18 months. The radiological features included upper thoracic Cobb's angle (T2–T5), mid thoracic Cobb's angle (T5–T12), sagittal balance (distance of C7 plumb line to the posterior superior corner of S1 endplate), coronal balance (distance of central sacral vertical line [CSVL] from C7 plumb line), shoulder height (based on the superior shadow of acromioclavicular [AC] joint soft tissue), cervical lordosis (C2–C7), thoracic kyphosis (T1–T12), and lumbar lordosis (L1–S1). Figure 1 shows the measurements applied in this study.

The dependent variable in our study was shoulder balance, defined as the disparity (in millimeters) between the heights of the left and right shoulders. Additionally, shoulder balance was categorized into different grades as follows: Grade 3, severe imbalance (>3 cm); grade 2, moderate imbalance (2–3 cm); grade 1, mild imbalance (1–2 cm); and grade 0, balanced state (0–1 cm) [9].

Statistical analysis

Data were analyzed using SPSS software, version 26, and results were presented as frequencies and percentages for qualitative variables and Mean±SD for quantitative variables. Paired sample t-test and repeated measures analysis of variance (ANOVA) test were used to evaluate the changes in radiologic angles throughout the study. The significance level was set at $P<0.05$.

Results

In this study, 135 patients underwent AIS correction surgery, of whom 12(8.9%) had Lenke type two and were thus eligible for our study. The patients' mean age was 15.2±3.0 years (range: 11-20 years), and 9(75%) were female. Regarding medical history, only one patient had a history of ADHD. All patients underwent PSF corrective surgery, in which the UIV device included 10(83.3%) using the hybrid method (hook-screw instrumentation) and two (16.7%) using the screw-screw method (Table 1).

The patients' radiographic features were evaluated and compared, and the results are presented in Table 2. As demonstrated, a considerable reduction was observed in the UT and MT Cobb's angles, shoulder imbalance, and lumbar lordosis during the study period, and a significant increase in the sagittal balance angle, which was mainly due to the difference in the preoperative and post-

Table 1. Demographic and clinical features of Lenke type 2 AIS patients undergoing surgery (n=12)

Variables		No. (%)/Mean±SD
Gender	Male	3(25)
	Female	9(75)
Age (y)		15.2±3
BMI (kg/m^2)		17.9±4.1
UIV device	Hybrid	10(83.3)
	Screw-screw	2(16.7)
UIV	T2	10(83.3)
	T3	2(16.7)
LIV	L1	4(33.3)
	L2	3(25)
	L3	4(33.3)
	L4	1(8.3)

Abbreviations: AIS: Adolescent idiopathic scoliosis; UIV: Upper instrumented vertebra; LIV: Lower instrumented vertebra; BMI: Body mass index.

operative angles. Sagittal and shoulder imbalances also significantly changed from the post-operative period to the last follow-up.

We further evaluated patients' shoulder balance based on surgical features in our study. All patients had significantly impaired shoulder balance before surgery. During the final follow-up of the cases in our study, eight patients (66.7%) had significant imbalance, one (8.3%) had moderate imbalance, two (16.7%) had minimal imbalance, and one (8.3%) had no imbalance. In addition, one case (case 7) converted from significant imbalance to minimal imbalance, while another (case 1) converted to moderate imbalance after surgery, which later converted to minimal imbalance following surgery. One patient in our study (case 6) had a significant imbalance after surgery, which converted to no imbalance during the final follow-up.

The median deviation from normal shoulder balance pre-operatively was 9 (5.3-13.8), while during the post-operative follow-up, it was 15.0 (5.3-24), and during the last follow-up, it was 6 (2-12) degrees. The median change in shoulder balance after surgery was 20.5 (10.3-

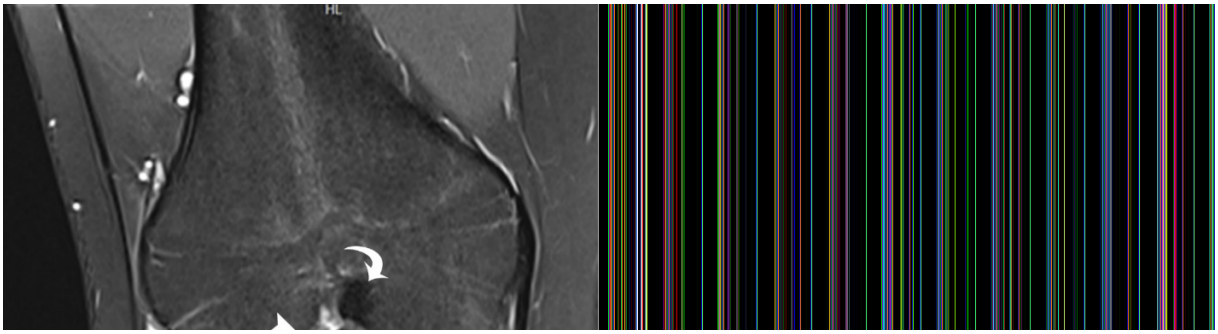


Figure 1. Method of measurements applied for the desired angle

I) Shoulder height, II) Upper and lower instrumented vertebra inclination, III) Coronal balance, IV) Sagittal balance, V) Cobbs angle, VI) Thoracic kyphosis and lumbar lordosis

Table 2. Angle and measurements of patients with Lenke type 2 adolescent idiopathic sclerosis undergoing correction surgery

Angle	Measurement (mm)			Change		
	Mean±SD			Mean±SD, P		
	Pre-op	Post-op	Last Follow-up	Pre–Post	Post–follow-up	Overall
Cobb upper thoracic	41.4±7	15±9	16.4±10.3	26.4±5.7, <0.001*	-0.60±3.6, 0.61	<0.001*
Cobb mid thoracic	63.9±13.5	12.2±9.4	15.2±12.0	51.8±10.5, <0.001*	-2.5±5.1, 0.07	<0.001*
Cobb TL	32.0±??	23±??	27±??	-	-	-
Sagittal balance	12.7±10.2	24.1±37.1	29.7±28.3	-25.9±42.8, 0.06	41.7±56.1, 0.03*	0.04*
Coronal balance	14.7±16.6	11±15.4	9.7±8.1	3.7±12.1, 0.32	2.0±18.8, 0.73	0.51
Shoulder height	9.7±4.9	15.8±10.5	7.1±5.6	20.1±14.2, <0.001*	-10.3±14.3, 0.04*	<0.001*
Cervical lordosis	7.1±5.6	11.1±9.5	13.9±15.9	-2.8±20.1, 0.64	9.5±16.3, 0.08	0.21
Thoracic kyphosis	39.5±15.9	27.4±10.7	29.6 ±8.8	12.1±15.0, 0.02*	-2.6±7.7, 0.28	0.70
Lumbar lordosis	60.5±10.5	48.3±12.3	54.6±17.2	12.3±10.4, 0.002*	-6.7±14.5, 0.16	0.03*
Inclination UIV	7.3±2.2	6.7±4.9	-	5.6±5.4, 0.137	-	-
Inclination LIV	10.9±6.9	3.3±1.8	-	8.7±6.6, 0.004*	-	-

UIV: Upper instrumented vertebra; LIV: Lower instrumented vertebra.
*Significant relationship.

Journal of Research in Orthopedic Science

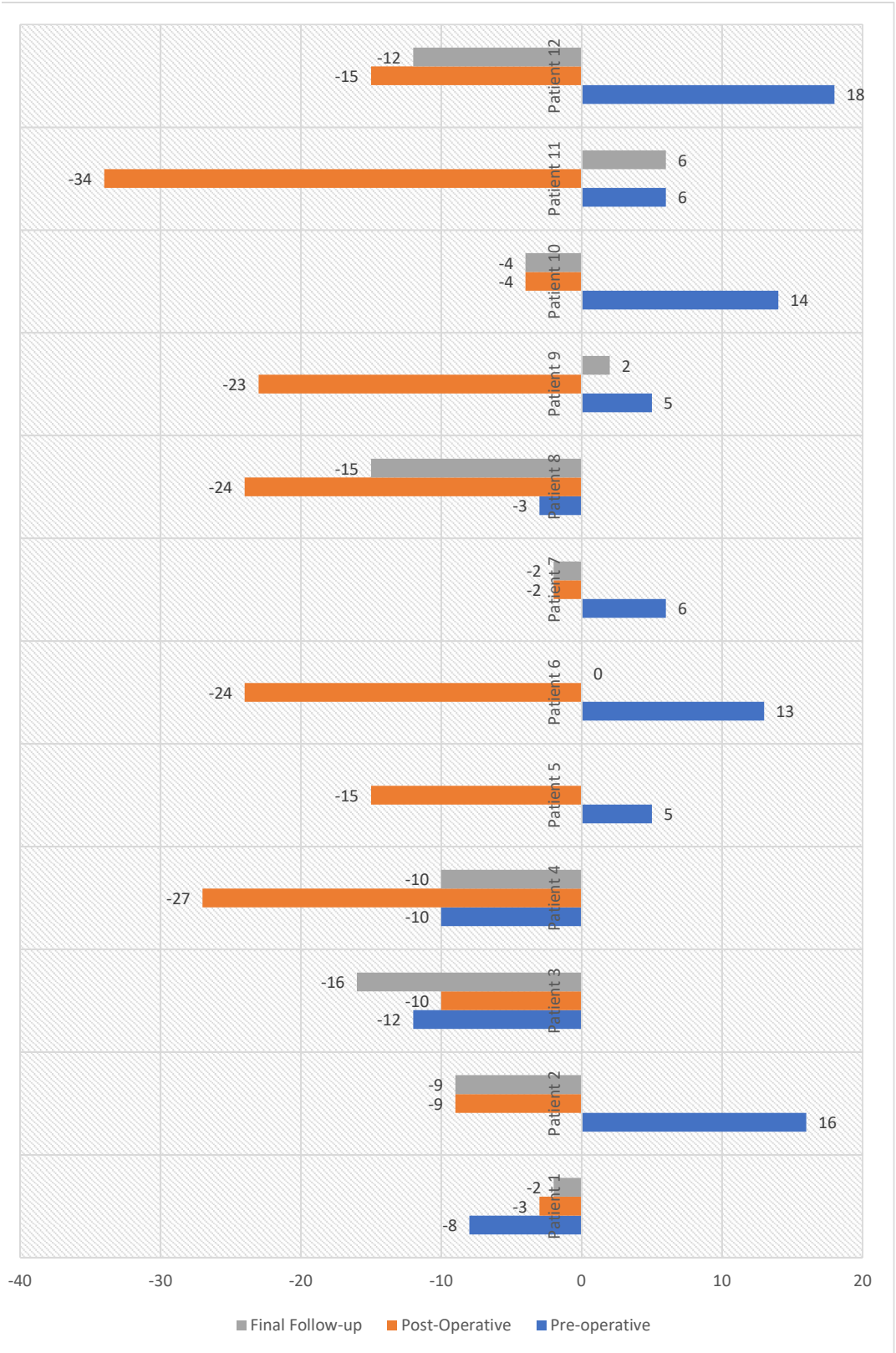
31.8) degrees, compared to the last follow-up of 8 (3-18.0) degrees. During follow-up, from post-operative measurements until the final follow-up, the median change was 6.0 (0-24.0) degrees. No significant relationship was observed between the type of UIV device and the amount of shoulder balance change from pre-operative to post-operative, post -operative until the last follow-up, and pre-operative to the last follow-up (P=0.83, 0.81, and 0.64, respectively). Regarding UIV, T3 had significantly higher changes than T2 from the pre-operative to post-operative measurements (P=0.03). However, this change was insignificant between the post-operative and final follow-up (P=0.057) and pre-operative until final follow-up period (P=0.55). The LIV (L2, L3, L4) had no significant relationship with the mentioned period measurement changes. Figure 2 shows the shoulder balance measurements during the study period.

Regarding the inclination measurements, the median pre-operative and post-operative UIV inclination were 6.5 (6.0-8.5) and 6.0 (3-8.5), respectively, while the median change was 4.5 (0.8-9.8) degrees. Regarding LIV inclination, the median preoperative and post-operative LIV inclination were 10.0 (5.8-12.8) and 3.5 (2.0-4.0), respectively, while the median change was 7.5 (3.5-13.3) degrees. These changes were not significantly associated with using UIV in the device (P=0.79). Figures 3 and 4 show the changes in UIV and LIV, respectively, in our study.

Figure 5 demonstrates the bending and correction of one of the cases in our study according to the pre-operative, post-operative, and last follow-up radiographs.

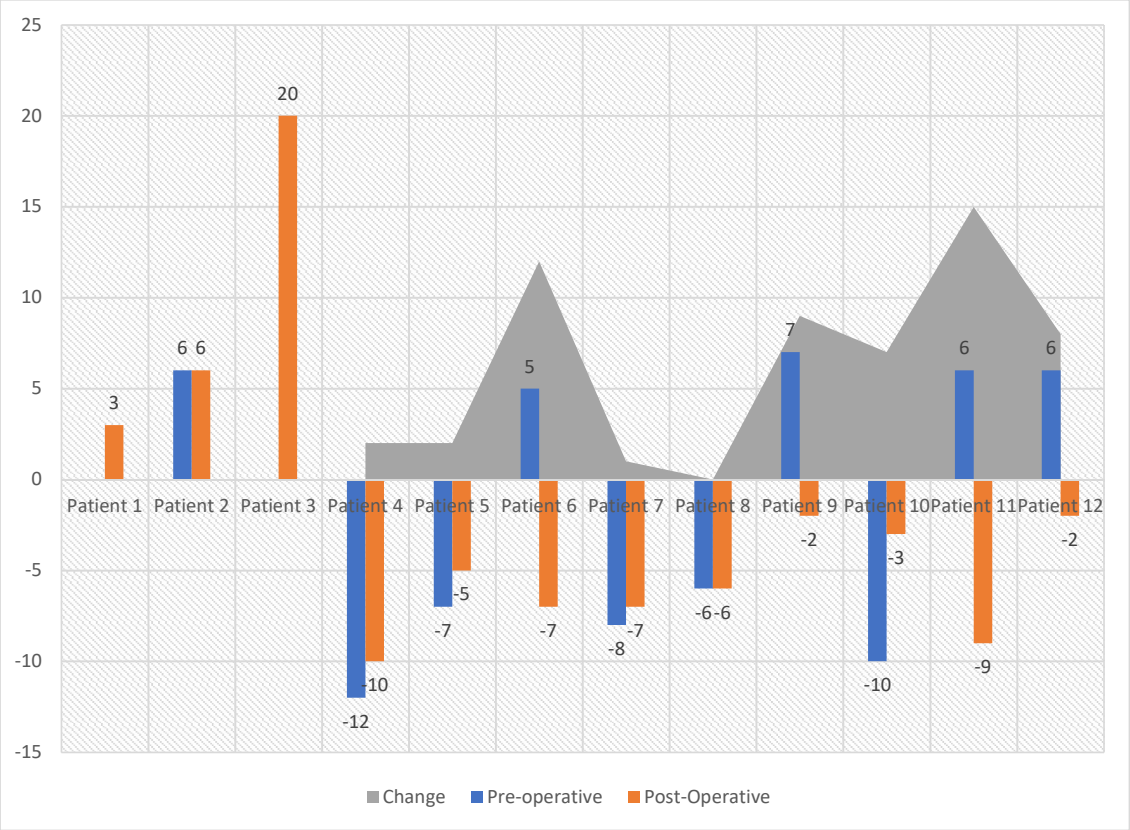
Discussion

Patients and their families often express significant concerns regarding shoulder imbalance, which can lead to dissatisfaction [10-13]. Our study included 12 Lenke type 2 AIS patients who underwent corrective surgery. The average age was 15.2±3.0 years (range: 11-20 years), of whom 975%) were females. All patients underwent corrective PSF surgery, with the majority (83.3%) using the hybrid method for the UIV device. Significant reductions were observed in Cobb angle, sagittal alignment, shoulder balance, and lumbar lordosis between the preoperative and postoperative periods. Shoulder balance significantly changed from postoperative to the last follow-up, with a median deviation 6°. The type of UIV device used showed no significant relationship with the changes in shoulder balance. UIV inclination showed a median change of 4.5°, while LIV inclination had a



Journal of Research in
Orthopedic Science

Figure 2. Shoulder balance measurements during pre-operative, post-operative, and final follow-up period
Notes: Minus values represent left-side deviations, while positive values represent right-side deviations.



Journal of Research in Orthopedic Science

Figure 3. UIV based on pre-operative and post-operative measurements

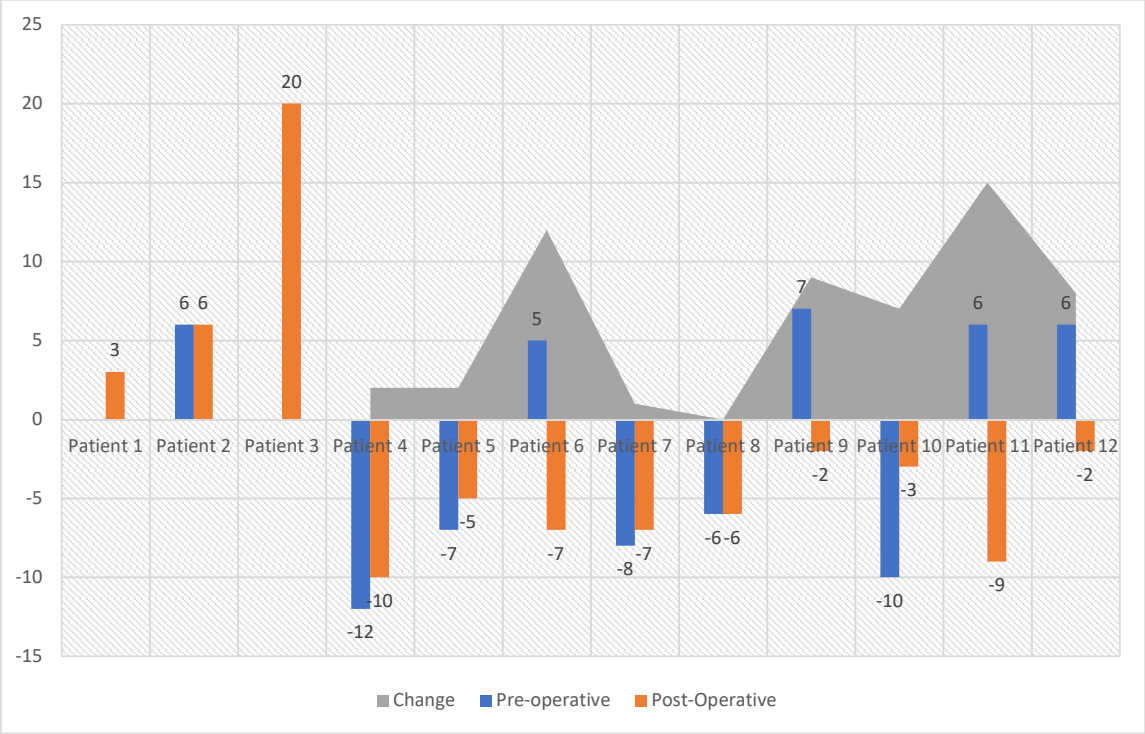
UIV: Upper instrumented vertebra.

Notes: Minus values represent left-side deviations, while positive values represent right-side deviations.

median change of 7.5°, with no significant relationship with the UIV device used. These results provide valuable insights into surgical outcomes and shoulder balance changes following AIS correction surgery.

During the final follow-up of the cases in our study, eight patients (66.7%) had significant imbalance, one (8.3%) had moderate imbalance, two (16.7%) had minimal imbalance, and one (8.3%) had no imbalance. A study by Li et al. [14] indicated that achieving fusion of both the primary and PT curves using posterior spinal fusion leads to favorable outcomes regarding shoulder balance. Among their cohort of 25 patients, 21(84%) achieved normal shoulder balance, while the remaining four (16%) experienced mild imbalance [14]. Their results were significantly superior to ours, which could be due to the technique of surgery, patient features and age, and amount of imbalance before operation. The Lenke type 2 classification criteria include the presence of a double thoracic curve, which corresponds to King type V [15]. King et al. observed that fusion of the lower curve alone worsened shoulder balance in young patients. He hypothesized that in these instances, excessive correction of the distal curve outweighed the compensatory capacity of the proximal curve, suggesting that fusion of both curves is advisable for King type V [16]. Suk et al. conducted a study to determine the necessity of double thoracic curve fusion versus single-curve fusion. They analyzed pre- and postoperative shoulder imbalance in 12 of 40 patients with Lenke type 2 who underwent PSF surgery for double curves. Their results demonstrated a 60% scoliosis correction rate for the primary thoracic curve and 75% balanced shoulders post-surgery [17]. In our study, 75% of our patients had moderate-to-severe imbalances during the final follow-up while 25% had a minimal-to-no imbalance. This difference could be attributed to a greater incidence of preoperative moderate or severe imbalance in the studies by Suk et al. (33%) [17] and Li et al. (16%) [14] than in ours (100% severe).

Kuklo et al. [18] examined shoulder imbalance in patients with Lenke type 2 scoliosis undergoing anterior and posterior fusion of the primary thoracic curve. Among the 85 participants, 10 had Lenke type 2, with



Journal of Research in
Orthopedic Science

Figure 4. LIV based on pre-operative and post-operative measurements
LIV: Lower instrumented vertebra.
Notes: Minus values represent left-side deviations, while positive values represent right-side deviations.

six having moderate and three mild shoulder imbalances preoperatively. Surgery decreased shoulder imbalance to moderate in one patient and mild imbalance in three. Although the type of instrumentation was not specified, the primary thoracic curve correction achieved (52%) was similar to older instrumentation methods. Cil et al. investigated whether proximal curves met the King rules for double fusion, but not the Lenke rules, indeed required double-curves fusion [19]. Their data showed a primary curve correction of approximately 56%, regardless of including the proximal curve during surgery. Although shoulder height was not measured, clavicle angle data suggested improvement in shoulder imbalance, particularly when the proximal curve was included in the fusion. This indicates that patients not meeting the Lenke criteria for double-curve fusion may not require

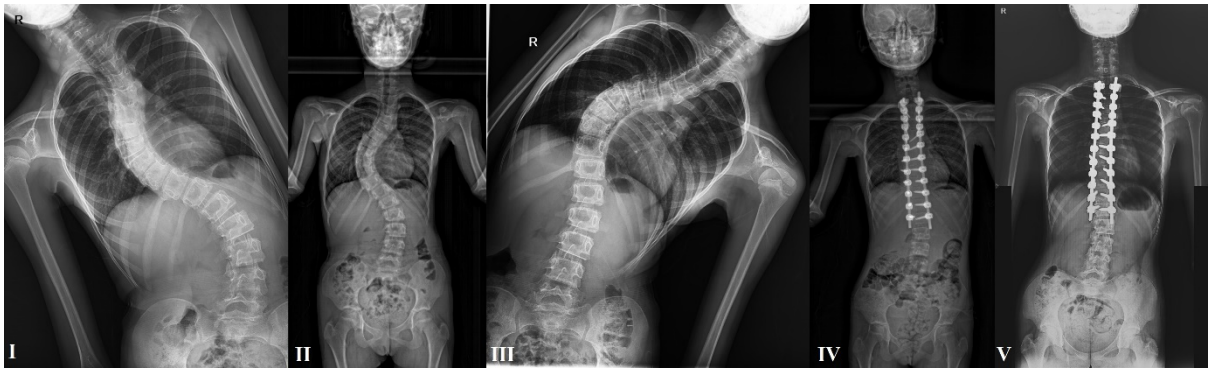


Figure 5. Radiography of a 12-year-old female, case of AIS Lenke type 2 undergoing corrective surgery
I, II, III) Pre-operative standing and bending radiography, IV) Post-operative (after 3 days), V) Last follow-up (after 18 months)
AIS: Adolescent idiopathic scoliosis.

upper-curve fusion. Lee et al. [20] examined the effects of double thoracic curve fusion on shoulder balance in 138 patients. Despite achieving only 38% correction of the primary thoracic curve using older techniques, 63% achieved shoulder balance postoperatively. Their study predated the common practice of PSF surgery. These investigations found that the degree of correction of the primary thoracic curvature may influence the success of restoring shoulder balance in patients with Lenke type 2 scoliosis after double fusion. Furthermore, according to the results of Cil et al., individuals with curvatures that are not severe enough to meet the Lenke 2 categorization criteria appear to perform similarly, regardless of whether the proximal curve is fused or left unfused [19].

Pedicle screws, renowned for their ability to apply substantial corrective force to the lower curve, have gained widespread popularity globally. This robust correction underscores the importance of determining whether fusion of the upper curve is necessary. According to Lenke et al., if the preoperative bending Cobb angle exceeds 25° and or T2-5 kyphosis is greater than 20°, surgical fusion of the upper curve should be addressed [21]. Subsequently, Cil et al. [19], in a study utilizing the Lenke criteria to guide decisions regarding upper curve fusion, observed similar postoperative outcomes in terms of T-1 tilt, clavicular angle, and coracoid process height between patients with and without upper curves fusion. This result indicated that the Lenke criteria may serve as an appropriate standard for determining the necessity of proximal curve fusion. However, the most recent categorization system established by the Scoliosis Research Society is not informative regarding this issue, as it is specifically tailored for adult spinal deformities [22, 23].

Conclusion

This study was conducted to understand better the relationship between UIV selection and shoulder imbalance in patients with Lenke type 2 AIS. Our results indicate that preoperative lateral shoulder balance significantly influences postoperative lateral shoulder balance than UIV level selection. However, more extensive population-based and randomized controlled trials must provide more specific evidence for the optimal approach in Lenke type 2 patients.

Our study limitations include the small sample size among our patients various techniques, and preoperative features, which limit the conclusion on the most optimal management and approach. Larger multicenter and randomized controlled trials are warranted to obtain more precise evidence and results for the optimal management of Lenke type II patients.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interception of the results and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

Conflict of interest

The authors declared no conflict of interest.

References

[1] Lenke LG. The Lenke classification system of operative adolescent idiopathic scoliosis. Neurosurg Clin N Am. 2007; 18(2):199-206. [DOI:10.1016/j.nec.2007.02.006] [PMID]

[2] Trobisch PD, Ducoffe AR, Lonner BS, Errico TJ. Choosing fusion levels in adolescent idiopathic scoliosis. J Am Acad Orthop Surg. 2013; 21(9):519-28. [DOI: 10.5435/JAAOS-21-09-519] [PMID]

[3] Puno RM, An KC, Puno RL, Jacob A, Chung SS. Treatment recommendations for idiopathic scoliosis: An assessment of the Lenke classification. Spine. 2003; 28(18):2102-14. [DOI:10.1097/01.BRS.0000088480.08179.35] [PMID]

[4] Kuklo TR, Lenke LG, Won DS, Graham EJ, Sweet FA, Betz RR, et al. Spontaneous proximal thoracic curve correction after isolated fusion of the main thoracic curve in adolescent idiopathic scoliosis. Spine. 2001; 26(18):1966-75. [DOI:10.1097/00007632-200109150-00006] [PMID]

[5] Ilharreborde B, Even J, Lefevre Y, Fitoussi F, Presedo A, Souchet P, et al. 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. 2008; 28(7):733-9. [DOI:10.1097/BPO.0b013e318185a36b] [PMID]

[6] Rose PS, Lenke LG. Classification of operative adolescent idiopathic scoliosis: Treatment guidelines. Orthop Clin North

Am. 2007; 38(4):521-9, vi. [DOI:10.1016/j.ocl.2007.06.001] [PMID]

[7] Erken HY, Burc H, Saka G, Aydogan M. Disagreements in surgical planning still exist between spinal surgeons in adolescent idiopathic scoliosis: A multisurgeon assessment. Eur Spine J. 2014; 23(6):1258-62. [DOI:10.1007/s00586-014-3278-y] [PMID]

[8] Bjerke BT, Cheung ZB, Shifflett GD, Iyer S, Derman PB, Cunningham ME. Do current recommendations for upper instrumented vertebra predict shoulder imbalance? An attempted validation of level selection for adolescent idiopathic scoliosis. HSS J. 2015; 11(3):216-22. [DOI:10.1007/s11420-015-9451-y] [PMID]

[9] Lenke LG, Betz RR, Harms J, Bridwell KH, Clements DH, Lowe TG, et al. Adolescent idiopathic scoliosis: A new classification to determine extent of spinal arthrodesis. J Bone Joint Surg Am. 2001; 83(8):1169-81. [DOI:10.2106/00004623-200108000-00006] [PMID]

[10] Asher MA, Lai SM, Glattes RC, Burton DC, Alanay A, Bago J. Refinement of the SRS-22 Health-Related Quality of Life Questionnaire Function Domain. Spine. 2006; 31(5):593-7. [DOI:10.1097/01.brs.0000201331.50597.ea] [PMID]

[11] Haher TR, Gorup JM, Shin TM, Homel P, Merola AA, Grogan DP, et al. Results of the scoliosis research society instrument for evaluation of surgical outcome in adolescent idiopathic scoliosis. Spine. 1999; 24(14):1435-40. [DOI:10.1097/00007632-199907150-00008] [PMID]

[12] Raso VJ, Lou E, Hill DL, Mahood JK, Moreau MJ, Durdle NG. Trunk distortion in adolescent idiopathic scoliosis. J Pediatr Orthop. 1998; 18(2):222-6. [PMID]

[13] Smyrnis PN, Sekouris N, Papadopoulos G. Surgical assessment of the proximal thoracic curve in adolescent idiopathic scoliosis. Eur Spine J. 2009; 18(4):522-30. [DOI:10.1007/s00586-009-0902-3] [PMID]

[14] Li M, Gu S, Ni J, Fang X, Zhu X, Zhang Z. Shoulder balance after surgery in patients with Lenke Type 2 scoliosis corrected with the segmental pedicle screw technique. J Neurosurg Spine. 2009; 10(3):214-9. [DOI:10.3171/2008.11.SPINE08524] [PMID]

[15] Winter RB, Denis F. The King V curve pattern. Its analysis and surgical treatment. Orthop Clin North Am. 1994; 25(2):353-62. [DOI:10.1016/S0030-5898(20)31915-5] [PMID]

[16] King HA, Moe JH, Bradford DS, Winter RB. The selection of fusion levels in thoracic idiopathic scoliosis. J Bone Joint Surg Am. 1983; 65(9):1302-13. [DOI:10.2106/00004623-198365090-00012] [PMID]

[17] Suk SI, Kim WJ, Lee CS, Lee SM, Kim JH, Chung ER, Lee JH. 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). 2000; 25(18):2342-9. [DOI: 10.1097/00007632-200009150-00012] [PMID]

[18] Kuklo TR, Lenke LG, Graham EJ, Won DS, Sweet FA, Blanke KM, et al. 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). 2002; 27(18):2013-20. [DOI:10.1097/00007632-200209150-00009] [PMID]

[19] Cil A, Pekmezci M, Yazici M, Alanay A, Acaroglu RE, Deviren V, et al. The validity of Lenke criteria for defining structural proximal thoracic curves in patients with adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2005; 30(22):2550-5. [DOI:10.1097/01.brs.0000186579.74398.15] [PMID]

[20] Lee CK, Denis F, Winter RB, Lonstein JE. Analysis of the upper thoracic curve in surgically treated idiopathic scoliosis. A new concept of the double thoracic curve pattern. Spine (Phila Pa 1976). 1993; 18(12):1599-608. [DOI:10.1097/00007632-199309000-00006] [PMID]

[21] Lenke LG, Betz RR, Haher TR, Lapp MA, Merola AA, Harms J, et al. Multisurgeon assessment of surgical decision-making in adolescent idiopathic scoliosis: Curve classification, operative approach, and fusion levels. Spine (Phila Pa 1976). 2001; 26(21):2347-53. [DOI:10.1097/00007632-200111010-00011] [PMID]

[22] Berven SH, Lowe T. The Scoliosis Research Society classification for adult spinal deformity. Neurosurg Clin N Am. 2007; 18(2):207-13. [DOI:10.1016/j.nec.2007.03.002] [PMID]

[23] Lowe T, Berven SH, Schwab FJ, Bridwell KH. The SRS classification for adult spinal deformity: Building on the King/Moe and Lenke classification systems. Spine (Phila Pa 1976). 2006; 31(19 Suppl):S119-25. [DOI:10.1097/01.brs.0000232709.48446.be] [PMID]

This Page Intentionally Left Blank