The Egyptian Journal of Hospital Medicine (October 2024) Vol. 97, Page 4449-4456

Coronal and Sagittal Balance in Surgically Treated Adolescent Idiopathic Scoliosis

Mahmoud M. Hadhoud[1], Tarek A. Elfiky[2], Mohammad A. Fayek[1], Emad B. Badawy[1], Gehad S. Bedda[1], Osama A. Sherif*[1]

[1]Orthopaedic Surgery Department, Faculty of Medicine, Menoufia University, Egypt

[2]Orthopaedic Surgery Department, Faculty of Medicine, Alexandria University, Egypt

***Corresponding author:** Osama A. Sherif, **Mobile:** (+20) 01501562818, **Email:** osamasherif3981@gmail.com

ABSTRACT

Background: Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional deformity in coronal, sagittal & axial vertebral planes.

Objectives: This study aimed to evaluate sagittal & coronal spine balance in adolescent idiopathic scoliosis patients treated surgically.

Patients and methods: Patients were assessed clinically & radiologically preoperatively & postoperatively by standard standing long anteroposterior and sagittal spine X-ray. Measurements were done using Surgimap® software.

Results: 25 AIS patients, 6 males & 19 females average 16 years. Preoperative & postoperative means respectively were as follows: 1ry Cobb was 72.88 & 26.76 ($p < 0.001$) and 2ry Cobb was 51.18 & 15.73 ($p < 0.001$). Coronal balance was 15.32 & 15.40. Cervical lordosis was 10.76 & 10.60. Thoracic kyphosis, lumbar lordosis & T1 slope were 46.24, 63.68 & 22.96 and 26.24, 50.72 & 18.04 respectively ($p < 0.001$, $p < 0.001$ & $p = 0.021$ respectively). PI, SS & PT were 50.88, 39.52 & 11.28 and 51.24, 39.12 & 12.16 respectively. SSA, SVA, SFD & GT were 132.9, -20.60, 36.68 & 7.04 and 130.9, -8.40, 37.96 & 9.56 respectively. The SVA/SFD ratio was -0.74 & 0.15 ($p < 0.021$). Implant density was 74.59 %. Intraoperative blood loss was 2618 cc. Operative time was 5.12 hours. There were many statistically significant correlations pre- & post-operatively.

Conclusion: TK & LL has highly significant changes & correlations. T1 slope correlates to TK and CL. SVA/SFD ratio may be more important for assessing global sagittal balance. Correlation chain existed (PI to SS to LL to TK to CL). PI = SS + PT.

Keywords: Balance, Coronal, Idiopathic, Sagittal, Scoliosis.

INTRODUCTION

Scoliosis is a spinal three-dimensional (3D) complex deformity, and the most common type is Adolescent idiopathic scoliosis (AIS). It is a spine lateral curvature with Cobb angle of 10^{o} or more in otherwise healthy pediatric patients [1]. AIS deformities include coronal and sagittal changes with axial rotation. Cobb angle is the standard item in measuring curve magnitude. It can be used in coronally and sagittally to measure parameters. Spinopelvic parameters were reported in literature to be correlated to health-related quality of life (HRQOL) [2].

Understanding & achieving spinopelvic sagittal balance in line with coronal balance is very important in decision making and treatment strategy. The aim of balanced posture is to align the spine and sacropelvis to minimize energy expenditure and preserve horizontal gaze [3]. The management modality is related to many factors. Age, growth remaining years and the curve magnitude at time of presentation [4].

Surgery in AIS in a skeletally immature patient is indicated at a curve magnitude > 40° and in a progressive curve of 30°. In skeletally mature patient, surgery is indicated in curves > 50°. Complete deformity correction is not possible in all cases to respect spinal & rib cage rigidity & flexibility conditions (including cardiopulmonary status) and, not to compromise neurological tissues either by distraction, compression or derotation. Surgery aims for a balanced spine with solid fusion and preservation of maximum mobile levels [4].

Our study aimed to evaluate coronal & sagittal spine balance of AIS patients treated surgically.

PATIENTS AND METHODS

A prospective study on 25 AIS patients was done.

Inclusion criteria: Patients diagnosed as AIS with age is more than 10 years old and coronal curvature (Cobb angle) ≥ 45°.

AIS patients were assessed preoperatively & postoperatively clinically and radiologically by standard standing long spine anteroposterior (AP) and Lateral X-rays. Measuring had been done by Surgimap® application (Nemaris Inc., New York) (Figure 1).

Received: 17/07/2024
Accepted: 17/09/2024

Figure (1): Preoperative & postoperative standing coronal (AP) & sagittal (lateral) X-ray measurements using Surgimap® (Nemaris Inc., New York).

Coronal (AP) radiographs included measurements of the curves **Cobb angle** "the most tilted upper/lower end vertebrae above and below the apex of the curve, respectively", **Risser staging** "ossification of the iliac epiphysis. Grade 1 is 25% ossification, grade 2 is 50% ossification, grade 3 is 75% ossification, grade 4 is 100% ossification, and grade 5 is fusion of ossified epiphysis to the iliac wing" & Coronal balance **(CB)** "measured in millimeters by the C7 coronal plumb line (C7PL) lateral displacement from the central sacral vertical line (CSVL). CB values was rated as coronal decompensation (CB > 20 mm), satisfactory (CB = 11:20 mm), and excellent (CB ≤ 10 mm)".

Sagittal (lateral) radiographs included measurements of regional spinal, pelvic, and global parameters. Regional spinal measures were **cervical lordosis (CL)** "angle between the inferior end plate of C2 to the inferior end plate of C7", **thoracic kyphosis (TK)** " angle between the superior endplate of T4 to the inferior endplate of T12", **lumbar lordosis (LL)** " angle between superior endplate of L1 to the superior endplate of S1" and **The T1 lateral slope** "angle between a horizontal line and the superior end plate of T1". Regional pelvic parameters were **pelvic incidence (PI)** "angle between the perpendicular to the sacral plate at its midpoint and the line connecting this point to center of bicoxofemoral axis", **Sacral slope (SS)** " angle between the horizontal line and the sacral plate" and **pelvic tilt (PT)** "angle between the vertical line perpendicular to the center of bicoxofemoral axis and the line through the midpoint of the sacral plate". Global measures were **sagittal vertical axis (SVA)** "distance between the posterosuperior point of the sacral plate and plumb line from C7 (C7PL). Anterior is "+" & Posterior is "-"", **spinosacral angle (SSA)** "angle between sacral plate and the line connecting the centroid of C7 vertebral body and the midpoint of sacral plate", **sacro-femoral distance (SFD)** " the horizontal distance between the vertical line perpendicular to the center of bicoxofemoral axis and the vertical line passing through the posterior corner of the sacrum", **SVA/SFD ratio** (Barrey's ratio) & **Global tilt (GT)** "angle formed by intersection of two lines, the first line is drawn from the center of C7 to the center of the sacral endplate and the second line is drawn from the center of the bicoxofemoral axis to the center of the sacral endplate".

Patients have undergone surgical correction through posterior approach using pedicular screws & rods with various correction techniques (Figures 2 & 3).

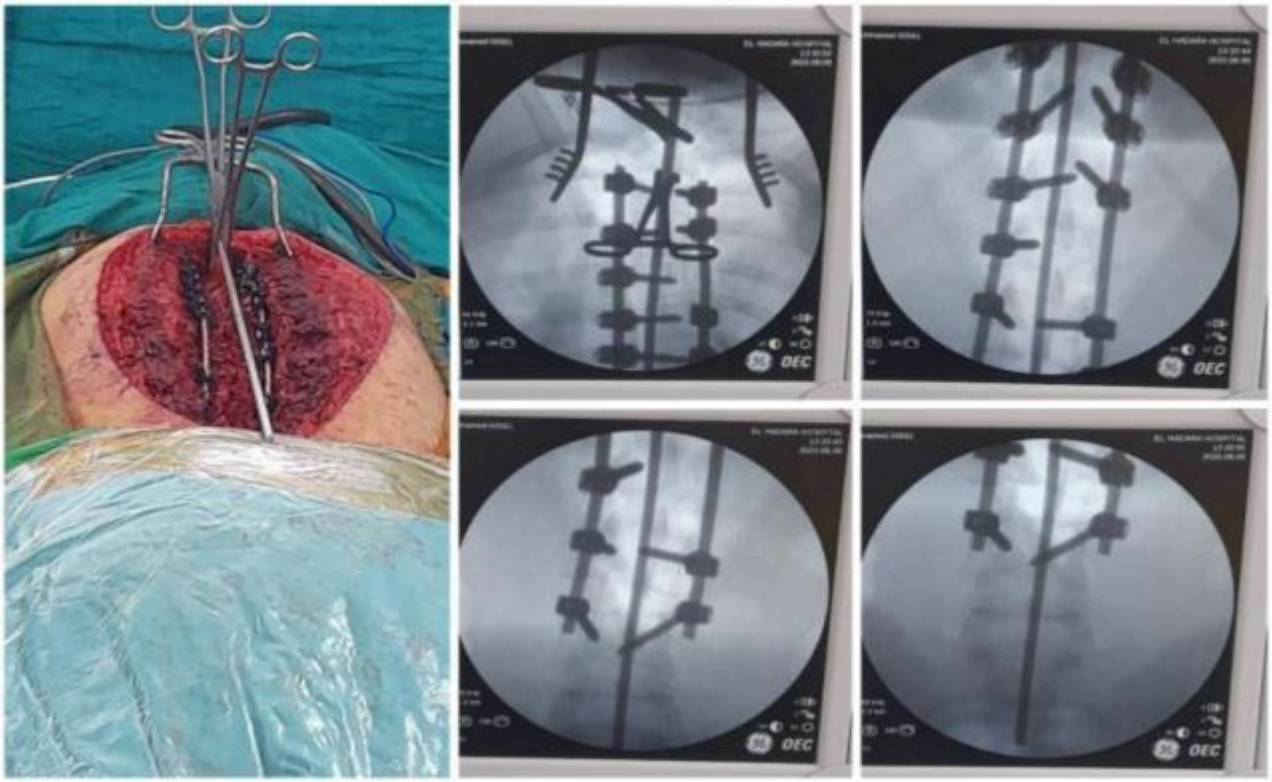

Figure (2): Intra-operative checking of coronal balance after final reduced Bone-Screws-Rod construct using posterior approach.

Figure (3): Intra-operative application of bone marrow aspirate, bone grafts & bone substitutes to enhance fusion.

Implant density was recorded as (ID) = screws numbers / overall pedicles number in fixed levels. We also recorded operative time, intraoperative blood loss amount & postoperative complications.

Ethical approval: This study has been approved by Menoufia Faculty of Medicine's Ethics Committee. Following receipt of all information, signed consent was provided by each participant. The study adhered to the Helsinki Declaration throughout its execution.

Statistics analysis

The computer performed data analysis using the IBM SPSS program version 20.0. The paired t-test was used to compare regularly distributed quantitative data across two periods, whereas the Wilcoxon signed ranks test was used to examine abnormally distributed quantitative variables. The Pearson coefficient was used to connect two normally distributed quantitative variables. P-values ≤ 0.05 were regarded statistically significant, while ≤ 0.001 were considered extremely significant.

RESULTS

There were 6 males & 19 females with average age of 16 years old. Table (1) showed different means of the study parameters pre- & postoperative with the significance of their change. Lenke 1 type was most of cases (15 cases). Other Lenke types were of 3, 5 and 6 with number of cases 6, 1 and 3 respectively. Risser stages found were 0, 3, 4 and 5 with number of cases for each stage 1, 8, 13 and 3 respectively.

- In **AP (coronal) X– Ray** measurements, significant change of 1ry and 2ry Cobb angles showed highly significant impact of the surgery to correct high coronal curves whether, primary or secondary curves. In **sagittal (lateral) radiographs**, (CL) showed no statistically significant change, maybe due to cervical region not being included in fixation area.
- **Regional pelvic measures** PI, SS & PT showed no statistically significant change in-between the same parameter, but there was obvious mathematical correlation between them (PI = SS + PT).
- **Global measures** SSA, SVA, SFD & GT showed no statistically significant change in-between the same parameter, but the SVA/SFD ratio (Barrey's ratio) showed statistically significant change (p = 0.021). This means that this ratio might be more clinically applicable in assessing global sagittal balance, which isn't affected by the magnification & zooming in x-rays, as it is a ratio, not distance.

Table (1): Preoperative & postoperative means of different parameters

Item	Preoperative mean	Postoperative mean	p - value
Age (Years)	16.12		
BMI (kg/m^2)	22.77		
AP cobb angle 1ry curve (°)	72.88	26.76	**< 0.001***
AP cobb angle 2ry curve (°)	51.18	15.73	**< 0.001***
coronal balance (CB) (mm)	15.32	15.4	0.726
cervical lordosis (CL)°	10.76	10.6	0.977
Thoracic Kyphosis (TK)°	46.24	26.24	**< 0.001***
Lumbar Lordosis (LL)°	63.68	50.72	**< 0.001***
T1 sagittal slope°	22.96	18.04	**0.021***
Pelvic incidence (PI)°	50.88	51.24	0.345
Sacral slope (SS)°	39.52	39.12	0.777
Pelvic tilt (PT)°	11.28	12.16	0.467
Sacro-femoral distance (SFD) (mm)	36.68	37.96	0.476
Sagittal vertical axis (SVA) (mm)	-20.6	-8.4	0.259
SVA/SFD ratio (barrey's ratio)	-0.74	0.15	**0.021***
Spinosacral angle (SSA)°	132.9	130.9	0.264
Global tilt (GT) angle°	7.04	9.56	**0.055**
Screws Inserted		20	
Implant density (ID) %		74.59	
Intraoperative blood loss (cc)		2618	
Operative time (hours)		5.12	

*: Statistically significant change at p ≤ 0.05

Postoperative complications were superficial wound infection & cellulitis, fascial oedema & prominent proximal implants at 1 year (3 cases out of 25; 12 %, two of them had just supportive treatment and recovered). For the 3rd case, the prominent proximal part of the construct was removed. Numerous statistically significant correlations were found between study parameters whether direct (r is positive) or inverse relation (r is negative). Correlations (r) were considered as: High (≥ 0.80), marked (0.60 to 0.79), moderate (0.40 to 0.59) and low (< 0.40). Some were preoperative only, some were postoperative only and some were statistically significant in both pre- & post-operative. We considered the latter to be the most important as it occurred in both pre- & post-operative. Table (2) and figure (4) showed these latter correlations. Also, there was significant inverse correlation between ID & postoperative 1ry curve Cobb angle ($r = -0.467$, $p = 0.019$) i.e. as ID increases, more correction of Cobb angle occurred & vice versa. Also, PI had inverse correlation to ID ($r = -0.41$, $p = 0.042$) i.e. that may mean in high PI, less ID needed to correct the deformity & vice versa may be due to there is residual for compensation (as PI was correlated to SFD as shown in "figure 4"). Meaning that in high PI there is high SFD, this permits good residual for SVA to fall in the balance or compensation zone & away from decompensation zone.

N.B. parameters correlations which are statistically significant **preoperative only** or **postoperative only** are **not shown here**.

Table (2): Parameters correlations which were statistically significant in both preoperative & postoperative

	Preoperative		**Postoperative**		
	r	p	r	p	
PI	0.586	0.002	0.476	0.016	SS
	0.616	0.001	0.656	<0.001	PT
	0.597	0.002	0.695	<0.001	GT
	0.558	0.004	0.602	0.001	SFD
PT	0.918	<0.001	0.933	<0.001	GT
	0.965	<0.001	0.974	<0.001	SFD
GT	0.848	<0.001	0.890	<0.001	SFD
SS	0.826	<0.001	0.816	<0.001	LL
	0.895	<0.001	0.868	<0.001	SSA
LL	0.786	<0.001	0.895	<0.001	SSA
	0.451	0.024	0.519	0.008	TK
TK	0.696	<0.001	0.536	0.006	CL
	0.774	<0.001	0.769	<0.001	T1 slope
CL	0.795	<0.001	0.655	<0.001	T1 slope

r: Pearson coefficient *: Statistically significant at $p \leq 0.05$

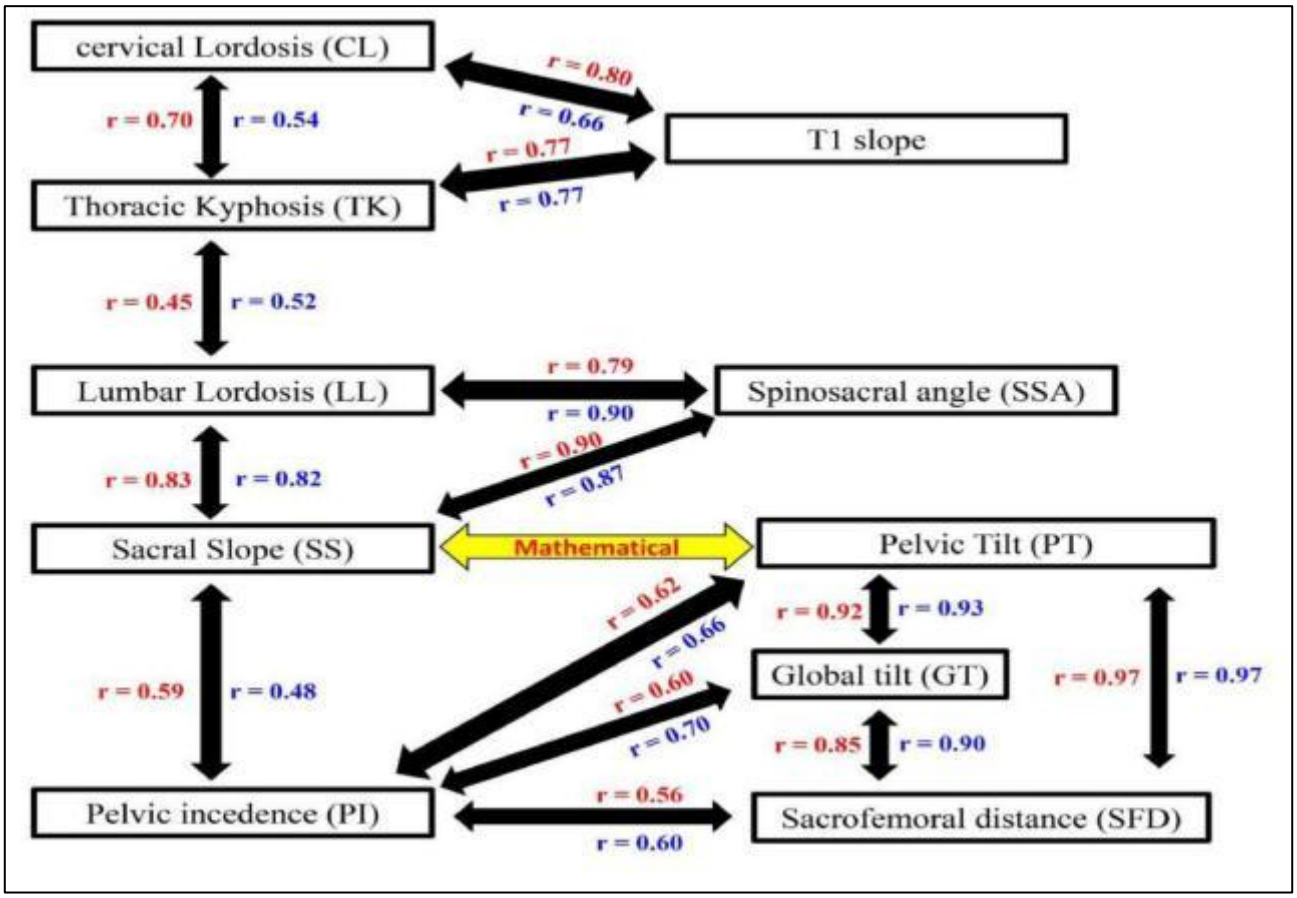

Figure (4): Overview of parameters correlations which are only statistically significant in both preoperative (Red) and postoperative (blue) statistical analysis.

DISCUSSION

Our study revealed the great efficacy of surgery to correct coronal plane deformities using pedicle screws techniques. Yet, respecting the stiffness of the curves & the flexibility of spine, to avoid coronal & sagittal decompensation after surgery and neurological compromise. Although, secondary curves Cobb angles showed high preoperative mean, this did not indicate to be structural. By application of Lenke' classification parameters for structural curves, most of them are not structural curves. This is also explained by the obvious correction of these 2ry curves by X-rays side bending views.

Imrie *et al.* [5] did a retrospective review of a multi-center database of a total of 385 cases. Showing that over the past 50 years, AIS Cobb correction changed from 43% by Moe with no instrumentation in 1958 to more than 60% to 70% with pedicular screws. Recent fixation and surgical techniques do not permit regaining "ideal" spine completely straight and still flexible. Trying to have safe maximum correction, surgeon has to assess "straightness" versus "balance" coronally, having head & trunk over pelvis with level shoulders, sagittally to have C7 plumb line just behind the bicoxofemoral axis center with extended knees and hips and axially, decreasing thoracic or lumbar prominence.

Regarding coronal balance (CB), **Ameri *et al.*** [6] in their study on 85 AIS patients, found that mean of pre- and post-operative CB was 20 mm & 12 mm respectively. Also, after comparison of 3 methods of CB, they found that C7PL (head over pelvis) is the most reliable parameter of CB than others & showed the most correlation with coronal imbalance. In our study, we also used C7PL/CSVL method for CB. Its mean was 15.32 preoperative & 15.4 postoperative. This is considered in the satisfactory category (CB = 11:20 mm) as described above.

Regarding sagittal parameters of the spine, our study revealed high significant change in-between the same parameter pre- & post-operative in TK, LL & T1 slope. This indicates the importance of paying great attention to these parameters in surgical techniques of correction.

But, regarding pelvic parameters, our study revealed insignificant changes in-between the same parameter pre- & post-operatively. However, there were statistically significant relations between PI & SS and PI & PT, but not between SS & PT. However, still there was mathematical correlation between SS, PT & PI. **Ozkunt *et al.*** [7] did two studies for pre- & post-operative spinopelvic parameters analysis in different Lenke types in AIS. Their studies declared that pelvic parameters did not change significantly postoperatively. This indicates that the spinopelvic compensatory mechanisms worked only in the spine and did not extend to the pelvic region. Additionally, in their studies, unlike the other studies about AIS, the

mean thoracic kyphosis values were 35.3° & 38.3° and changed to 28.6° & 26.4° postoperatively respectively. However, the pre-surgical measures do not show hypokyphosis, surgery appears to decrease kyphosis. This may be because of compensation for lumbar lordosis correction or simply surgeon over correction. Also, **Shimizu *et al.*** [8] in their study on 51 AIS patients found that pelvic and lower extremity parameters showed no significant change after AIS corrective surgery, possibly due to young AIS patients ability to accommodate instrumented thoracic changes by the residual unfused spinal levels (cervical and lumbar).

Assessing global sagittal alignment parameters of the spine (SVA, SFD, Barrey's ratio, SSA & GT), our study didn't find significant change in these parameters individually pre- & post-operative except for (SVA/SFD) ratio. May be explained as this ratio correlate the whole thoracolumbar spine as one unit with the pelvis. The correlations between different parameters included in our study were shown in table (2) and figure (4) to overview the only statistically significant correlations in both preoperative and postoperative at the same time. Our study also found no correlation between individual coronal & sagittal parameters in general, showing that coronal deformities don't affect sagittal deformities & vice versa. This coincides with some studies, however other studies confirm this correlation. This leads to a need for more research on this item specifically. **Hu *et al.*** [9] studied 184 AIS subjects retrospectively. They found that coronal asymmetry effect on sagittal measures was limited. Most coronal & sagittal measures were not correlated, and coronal deformity did not affect global sagittal patterns. **Ma *et al.*** [2] studied 103 AIS patients & the results were assessed with the age-matched normal group. TK, LL, SS, & PI in the normal group were not different. However, PT increased in patient groups significantly. Coronal and sagittal measurements were strongly correlated. Although, there was no SVA correlation to any coronal measure. **Pasha *et al.*** [10] evaluated 80 right main thoracic (MT) curves, 80 left thoracolumbar/lumbar (TL/L) curves & 35 asymptomatic controls. They found that PI was correlated to LL in AIS. In MT and TL/L subjects, coronal pelvic obliquity was significantly correlated to leg length discrepancy LLD. Also, in AIS, Pelvic orientation was correlated to thoracic and lumbar changes.

Our study didn't find a direct correlation between PI & LL, but correlation was found between PI & SS and SS & LL independently. **Blondel *et al.*** [11] did a study on 30 AIS patients. There was a significant correlation between TK correction & LL improvement for hypokyphotic patients, as a positive interactive change. Interestingly, the results showed that this improvement happened after 3rd postsurgical month. They found no correlation between sagittal changes and coronal correction. These findings raise the question of the need of achievement of maximal correction coronally in AIS. **Yang *et al.*** [12] studied 76 Lenke 1 & 2 AIS patients. TK & LL were reduced significantly postoperative. TK & LL were significantly correlated pre- & post-operative. Pre-operative and post-operative LL minus TK showed no significant difference. This showed that LL minus TK might help in preserving sagittal balance as an important compensatory mechanism. **Newton *et al.*** [13] also found these relations between TK & LL in a study of 251 AIS patient pre- & post-operatively.

Our study also showed these highly significant changes in-between TK & LL individually pre- & post-operative and between each other. **Pesenti *et al.*** [14] studied 29 AIS patients in a retrospective study. This study showed that T1 lateral slope is a good marker in assessing CL, TK & global sagittal parameters. It was not statistically correlated to coronal Cobb correction. Lack of normative values was a limitation for this study.

Our study showed that the change of T1 slope was statistically significant pre- & post-operative. Also, there is a highly significant & powerful correlation between T1 sagittal slope, CL & TK.

Regarding implant density (ID), its mean in our study was 74.59 %, with a mean screws number of 20. A significant inverse correlation was found between ID & postsurgical primary Cobb i.e. as ID increases, more correction of Cobb angle occurred, but how much ID is needed for good correction and its effect on clinical outcomes, this needs more research. **Larson *et al.*** [15] did systematic review on correction & implant density in AIS. Mean implant density ranged from 1.06 to 2.0 implants per segment fused. Mean coronal correction ranged from 64% to 70%. In AIS, there is wide heterogeneity in implant density. Reports assessing increased implant density effects are mostly retrospective & unable to detect a relation between correction and patient outcomes. Till now, the evidence supporting efficacy of implant density on outcomes in AIS is insufficient.

In our work, Operative time had a mean of 5.12 hours and average intraoperative blood loss was 2618 cc. No correlations were found between them & the study parameters, except for age & risser stage had a direct relation with intraoperative blood loss. **Miyanji *et al.*** [16] in a multicenter analysis of 325 AIS patients to assess perioperative health care, found that average blood loss was 700 ml & mean operative time was 250 minutes (nearly 4 hours). They demonstrated that greater curves correction was related to increased consumption of resources, specifically longer surgeries, the extent of segments instrumented, and higher odds of blood transfusion.

All postoperative complications (3 cases out of 25; 12 %) were managed as mentioned. **Kwan *et al.*** [17] reviewed 84,320 AIS patients from morbidity and mortality database of Scoliosis Research Society (SRS) from 2004 to 2016. There were 1,268 complicated

patients (1.5%), twelve patients (0.014%) died and three had cardiac arrest intraoperative. Other causes of mortality were desfluorane-induced hepatic necrosis, thromboembolic stroke, abdominal compartment syndrome due to coagulopathy, sepsis due to pneumonia, cardiac failure, aortic laceration, narcotic overdose post discharge, and unspecified in two patients. Regarding other morbidities, the three most reported were surgical site infection (SSI) (441; 0.52%), new neurological deficit (293; 0.35%), and implant-related (172; 0.20%). Post-surgical visual compromise happened in 7 cases (0.008%). There were two cases of unilateral partial and one patient who experienced unilateral total visual field loss without recovery, and the remaining patients recovered. There was a weak statistically significant correlation between SSI and primary curve magnitude & blood loss in surgery, while the occurrence of a new neurological deficit was weakly correlated with age and primary curve magnitude [17].

LIMITATIONS

For our study was the axial plane assessment as this requires higher radiology equipments such as CT scan pre- & post-operative, this overloads more costs & radiation exposure to the patients. Also, EOS machine, which gives more clear images & more radiological assessment, but till now it is not available.

CONCLUSION

There was mathematical correlation between SS, PT & PI. There were highly significant changes in TK & LL pre- & post-operative individually, with statistically significant correlations in-between them. T1 played an important role in spine sagittal alignment for AIS patients. The T1 slope may be of great importance in assessment of CL & TK intraoperatively. SVA/SFD Barrey's ratio might be more clinically applicable in assessing global sagittal balance than SVA alone. There was correlation chain between some sagittal parameters: (from down upwards) PI > SS > LL > TK > CL. T1 slope correlate to both TK, CL. Surgery had great efficacy to correct coronal plane deformities. Correlation between coronal & sagittal parameters in general needs more research.

No Funds.
No Conflict of Interests.

REFERENCES

1. **Abdelaziz M, Sherif A, AlQazaz M *et al.* (2020):** Evaluation of Quality of Life (QoL) of Patients with Adolescent Idiopathic Scoliosis (AIS) after Surgical Correction. Egypt Spine J., 33 (1): 2–13.
2. **Ma Q, Wang L, Zhao L *et al.* (2020):** Coronal Balance vs. Sagittal Profile in Adolescent Idiopathic Scoliosis, Are They Correlated? Front Pediatr J., 7: 523. doi: 10.3389/fped.2019.00523.
3. **Mac-Thiong J, Labelle H, Roussouly P (2011):** Pediatric sagittal alignment. Eur Spine J., 20 (5): 586–90.
4. **Balaji Z (2023):** Adolescent idiopathic scoliosis. In: Balaji Z, Dilip Chand Raja S, Nikhil K (eds). Paediatric Scoliosis. Springer, Pp: 3-12.
5. **Imrie M, Yaszay B, Bastrom T *et al.* (2011):** Adolescent Idiopathic Scoliosis: Should 100% Correction Be the Goal? Pediatr Orthop J., 31: 9–13.
6. **Ameri E, Ghandhari H, Nabizadeh N *et al.* (2013):** Natural history of coronal balance after spinal fusion in adolescent idiopathic scoliosis. Shafa Orthopedic Journal, 1 (2): 12-16.
7. **Ozkunt O, Sariyilmaz K, Akgül T *et al.* (2017):** Analyzing the preoperative & postoperative spinopelvic parameters in Lenke type1 in AIS patients. The Journal of Turkish Spinal Surgery, 28 (4): 233-236.
8. **Shimizu T, Cerpa M, Lehman R *et al.* (2019):** Reciprocal Change in Sagittal Profiles After Adolescent Idiopathic Scoliosis Surgery with Segmental Pedicle Screw Construct. Spine J., 44 (24): 1705–1714.
9. **Hu P, Yu M, Liu X *et al.* (2016):** Analysis of the relationship between coronal and sagittal deformities in adolescent idiopathic scoliosis. Eur Spine J., 25 (2): 409–16.
10. **Pasha S, Aubin C, Sangole A *et al.* (2014):** Three-Dimensional Spinopelvic Relative Alignment in Adolescent Idiopathic Scoliosis. Spine J., 39 (7): 564-570.
11. **Blondel B, Lafage V, Schwab F *et al.* (2012):** Reciprocal sagittal alignment changes after posterior fusion in the setting of adolescent idiopathic scoliosis. Eur Spine J., 21: 1964-1971.
12. **Yang M, Yang C, Chen Z *et al.* (2016):** Lumbar Lordosis Minus Thoracic Kyphosis Remain Constant in Adolescent Idiopathic Scoliosis Patients Before and After Correction Surgery. Spine J., 41 (6): 359-363.
13. **Newton P, Yaszay B, Upasani V *et al.* (2010):** Preservation of Thoracic Kyphosis Is Critical to Maintain Lumbar Lordosis in the Surgical Treatment of Adolescent Idiopathic Scoliosis. Spine J., 35 (14): 1365-1370.
14. **Pesenti S, Blondel B, Peltier E *et al.* (2016):** Interest of T1 parameters for sagittal alignment evaluation of adolescent idiopathic scoliosis patients. Eur Spine J., 25: 424–429.
15. **Larson A, Aubin C, Polly D *et al.* (2013):** Are More Screws Better? A Systematic Review of Anchor Density and Curve Correction in Adolescent Idiopathic Scoliosis. Spine Deformity J., 1: 237-247.
16. **Miyanji F, Slobogean G, Samdani A *et al.* (2012):** Is Larger Scoliosis Curve Magnitude Associated with Increased Perioperative Health-Care Resource Utilization? J Bone Joint Surg Am., 94: 809-13.
17. **Kwan K, Koh H, Blanke K *et al.* (2020):** Complications following surgery for adolescent idiopathic scoliosis over a 13-year period. Bone & Joint J., 10 (4): 519-523.