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A Comparison Between the Perioperative Outcomes of Female Adolescent Idiopathic Scoliosis (AIS) Versus Adult Idiopathic Scoliosis (AdIS) Following Posterior Spinal Fusion: A Propensity Score Matching Analysis Involving 425 Patients

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Abstract

Study Design: Retrospective propensity score matching (PSM) study.

Objective: To investigate the perioperative outcomes comparing adolescent idiopathic scoliosis (AIS) and adult idiopathic scoliosis (AdIS) patients following posterior spinal fusion (PSF).

Methods: 425 female AIS and AdIS patients who were operated (between January 2015 to March 2020) using a dual attending surgeon strategy were stratified into G1 (AIS aged 10-16 years old) and G2 (AdIS > 20 years old). PSM analysis with one-to-one, nearest neighbor matching technique with match tolerance of 0.001 was used to matched 357 AIS patients to 68 AdIS patients. Operation duration, intraoperative blood loss (IBL), blood loss percentage, hemoglobin drift, blood salvaged, postoperative wound length, allogenic blood transfusion requirement, postoperative hospital stay, postoperative Cobb, correction rate and postoperative complications were documented and reported.

Results: Following PSM, G1 and G2 each had 50 patients with comparable and balanced covariates. As anticipated, G2 patients were heavier, taller and had higher body mass index compared to G1 patients ($P < 0.05$). We could not find any significant differences in the perioperative outcome comparing this 2 groups. AIS and AdIS patients had similar operation duration (125.9 $\pm$ 27.2 min vs 127.3 $\pm$ 37.8 min), IBL (749.8 $\pm$ 315.7 ml vs 723.8 $\pm$ 342.1 ml) and length of hospital stay (3.3 $\pm$ 0.4 days vs 3.5 $\pm$ 0.8 days) ($P > 0.05$). Hemoglobin drift and amount of blood salvaged were comparable ($P > 0.05$). G2 had stiffer curves. There was a trend toward a lower correction rate in G2 in the immediate postoperative period, however it did not reach statistical significance (61.8 $\pm$ 11.2% vs. 66.3 $\pm$ 11.6%, $P = 0.051$). No patients required blood transfusion and none had any postoperative complications.

Conclusion: Adolescent and adult female scoliosis patients had comparable perioperative outcome following PSF surgery that was carried out using a dual attending surgeon strategy.

Keywords

female, adolescent, adult, scoliosis, posterior spinal fusion, perioperative outcome, operation duration, blood loss, complication rate

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Introduction

Based on natural history studies carried out in adolescent idiopathic scoliosis (AIS) patients, curves exceeding 45 degrees would progress even after patients had attained maturity.[1,2] The Iowa natural history study revealed that 68% of the major curve in untreated scoliosis patients progressed after skeletal maturity. In untreated patients whose scoliosis progressed to adulthood, these patients experienced decreased pulmonary function and increased back pain.[2-6]

Based on large multicenter databases, there were many published reports on the perioperative outcomes of AIS patients.[7-10] Important perioperative outcome parameters that were relevant for patients included the operative time, estimated blood loss, rate of allogeneic blood transfusion, length of hospital stay and perioperative complications. Previously published papers reported average operation duration that ranged between 180 minutes to 337 minutes.[7-9,11-13] Intraoperative blood loss ranged from 345 ml to 1211 ml[11,13] and the complication rate ranged between 1.4% to 27.3%.[14,15] This information could be useful during preoperative counseling and in managing patients' expectations before the surgery. However, this information was not readily available for adult idiopathic scoliosis (AdIS) patients who were contemplating surgery.

Lonner et al,[16] recently assessed differences in operative data and outcomes comparing AIS and AdIS. They matched 28 AdIS to 56 AIS patients (1:2) based on gender and curve type. They found that AdIS had longer operative time (414.3 vs 281.3 mins), higher blood loss (1403.6 vs 722.9 ml), longer fusion levels (12.9 vs 9.4 levels) and longer hospital stay (6.3 vs 5.3 days) compared to AIS patients. However, the baseline differences between this cohort of patients were not well matched. This makes it difficult to have a valid comparison of the perioperative outcomes between the 2 groups. Therefore, the objective of the study was to conduct a propensity score matching analysis comparing AIS and AdIS patients in terms of their perioperative outcome following posterior spinal fusion (PSF) surgery.

Methodology

This was a retrospective analysis of female scoliosis patients who were operated between January 2015 to March 2020. This study was approved by our institutional ethical board. The inclusion criteria were all female Adolescent /Adult Idiopathic Scoliosis patients who underwent PSF surgeries that were carried out by using a dual attending surgeon strategy. We intentionally excluded patients who were aged 17 to 20 years as we believe they were in a transition stage to adulthood. Patients who underwent halo gravity traction prior to definitive surgery was also an exclusion. Adult patients who were diagnosed as degenerative kyphoscoliosis were also excluded. Ethical approval was obtained from University Malaya Medical Centre Medical Ethic Committee (2 020 424-8556) and patients' consent was acquired for publication purpose.

Data Collection

Preoperative data that was collected included age, height, weight, body mass index (BMI), Lenke curve classification, preoperative proximal thoracic (PT), PT side bending (PT SB), main thoracic (MT), MT SB, Lumbar, and Lumbar SB Cobb angles, and preoperative hemoglobin. The main perioperative outcomes were: operation duration, intraoperative blood loss (IBL), rate of allogeneic blood transfusion, length of hospital stay and perioperative complications.

We also documented the amount of salvaged blood, number of screws inserted and the number of fusion levels. Postoperative hemoglobin, surgical wound length, postoperative Cobb angle and postoperative correction rate were also traced.

Estimated blood volume,[17] correction rate, estimated blood loss, blood loss percentage and preoperative flexibility were calculated using the formula shown below.

1. Intraoperative blood loss (IBL): (Final volume accumulated in the reservoir) – (Total volume of anticoagulant citrate dextrose [ACD] – (Total fluid used for irrigation intraoperatively) + (total unfiltered blood)
2. Correction rate (%): (Preoperative major Cobb angle − postoperative major Cobb angle)/ preoperative major Cobb angle X 100
3. Estimated blood volume (EBV): (0.3561 × height^3) + (0.03 308 × Weight) +0.1833.
4. Blood loss percentage (%): (IBL / EBV) x 100
5. Flexibility (%): (Preoperative major Cobb angle – Preoperative major SB Cobb angle)/ Preoperative major angle x 100

Propensity score matching (PSM) process. All analysis and test were carried out using SPSS v 25.0 (IBM statistics, New York, USA). There were 762 scoliosis patients who underwent PSF in our database from January 2015 to March 2020. Based on the inclusion/ exclusion criteria, 425 female patients were eligible for PSM analysis (Figure 1). Data of 425 female patients was extracted from the database and categorized into Group 1 and Group 2 according to their age.

Patients were divided into 2 groups

Group 1: Female adolescent scoliosis patients aged from 10 to 16 years.

Group 2: Female adult scoliosis patients aged more than 20 years.

357 patients were aged from 10 to 16 years old (Group 1). Meanwhile, 68 patients were aged more than 20 years old (Group 2). PSM analysis was used to match 357 patients from Group 1 to 68 patients in Group 2 to eliminate possible confounding factors that would affect the perioperative outcome. Covariates used to run PSM were Lenke types, preoperative major Cobb angle, number of screw, fusion level and screw density (Table 1).

Match tolerance of 0.001 with nearest neighbor matching technique (greedy matching) without replacement was used. This was done sequentially until the list of patients (Group 2)

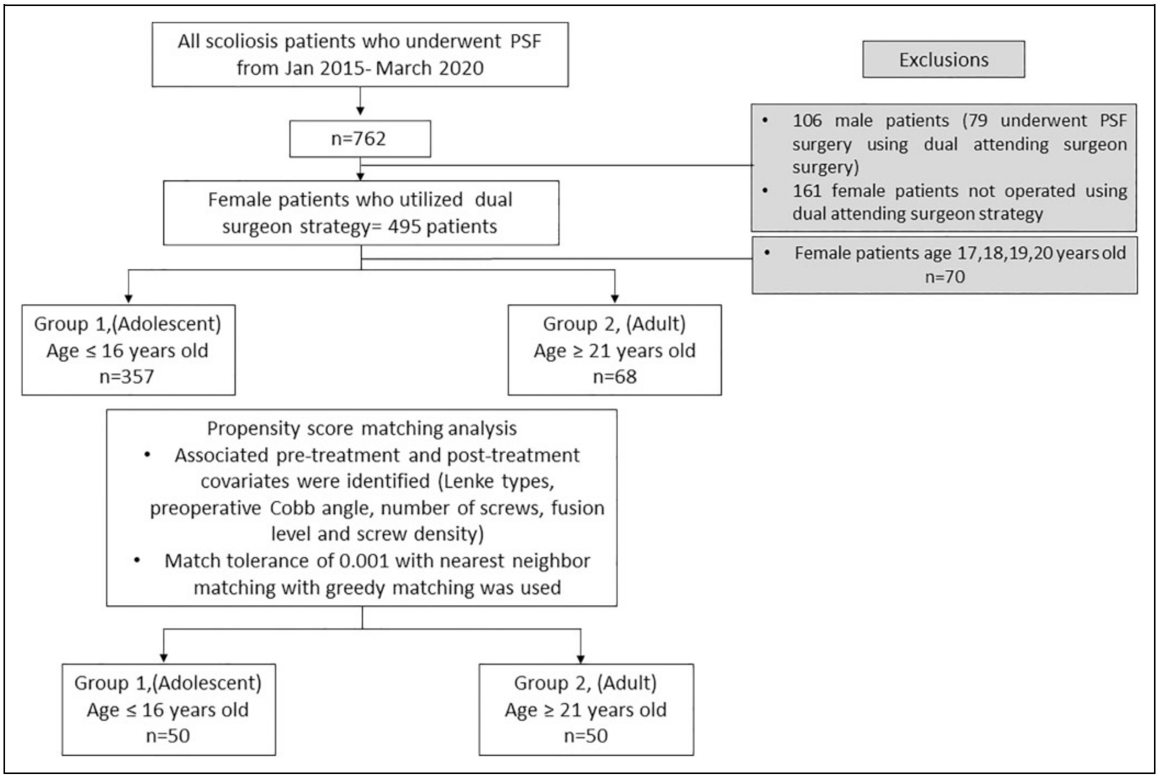

Figure 1. Flow chart of sampling method to recruit patients using the propensity score matching (PSM) method. Female patients aged 17 years old to 20 years old was excluded. Patients with degenerative kyphoscoliosis and those who underwent halo gravity traction prior to PSF surgery was excluded as well.

Table 1. Demographic, Intraoperative and Postoperative Data Comparing Group 1 and Group 2 Before Propensity Score Matching.

Variables	Whole group (n = 425)	Group 1, adolescent (n = 357)	Group 2, adult (n = 68)	*P* value
Variables used to match the 2 groups with match tolerance of 0.001				
Lenke classification				
1	186	158	28	
2	94	78	16	
3	18	14	4	0.059
4	8	8	0	
5	80	72	8	
6	35	24	11	
Preoperative major Cobb (°)	67.4 ± 17.5	67.2 ± 17.5	68.5 ± 17.9	0.583
Number of screws (n)	13.7 ± 2.4	13.6 ± 2.4	14.2 ± 2.4	0.054
Fusion level (n)	10.3 ± 2.3	10.2 ± 2.4	10.6 ± 2.0	0.176
Screw density	1.4 ± 0.3	1.4 ± 0.3	1.3 ± 0.2	0.618

was exhausted and pairs were found. At the end of the PSM analysis, 50 patients from Group 1 were matched to 50 patients in Group 2 (Figure 1, Table 2).

Anesthesia Protocol

One single anesthetist was involved in all the surgeries. Patients were induced with intravenous (IV) propofol, IV target-controlled infusion (TCI) of remifentanil and IV rocuronium to facilitate endotracheal intubation. Anesthesia was maintained with desflurane and TCI remifentanil. Tranexamic acid was routinely used in all cases. Patients were kept normothermic and normovolemic throughout the operation.

Surgical and Postoperative Protocol

All surgeries were carried out using a dual attending surgeon strategy involving MMK and CYWC. They would operate simultaneously and independently during the surgery at the various stages (exposure, screw insertion, posterior release, and closure). The reduction and balancing process of the spine was performed together. Three to 4 pedicle screws were inserted as

Table 2. Demographic, Intraoperative and Postoperative Data Comparing Group 1 and Group 2 After Propensity Score Matching.

Variables	Whole group (n = 100)	Group 1, adolescent (n = 50)	Group 2, adult (n = 50)	P value
Variables used to match the 2 groups with match tolerance of 0.001				
Lenke classification				
1	50	24	26	
2	26	13	13	
3	3	2	1	0.423
4	1	1	0	
5	17	10	7	
6	3	0	3	
Preoperative major Cobb (°)	66.2 ± 17.2	68.2 ± 18.4	64.1 ± 15.8	0.240
Number of screws (n)	13.7 ± 2.1	13.8 ± 2.2	13.5 ± 2.0	0.451
Fusion level (n)	10.2 ± 2.2	10.2 ± 2.3	10.2 ± 2.0	0.928
Screw density	1.4 ± 0.2	1.4 ± 0.2	1.3 ± 0.2	0.378

proximal and distal anchors. Skip level screw placement strategy was used in between the proximal and distal anchors. Spinal flexibility was increased intraoperatively through radical facet joint release. Reduction was performed using translation method as well as direct vertebral rotation. Fusion was augmented using autogenous local bone graft. Cell salvage autologous blood recovery system was used in all cases (Haemonetics Cell Saver 5+). A deep subfascial drain was inserted prior to closure. Postoperative protocol followed our accelerated regime that had been published previously.[18]

Statistical Analysis and Sample Size Calculation

Sample size calculation was performed using the study published by Lonner et al.[16] Sample size was calculated based on estimated blood loss as the outcome parameter (Adult scoliosis = 1403.6 ± 1101.5 ml vs AIS = 722.9 ± 470.1 ml). This was performed using G power software (version 3.1.9.7).[19] The marginal error (α) was set at 0.05. A statistical power analysis indicated that a minimum sample size of 26 patients in each group would be needed to obtain 80% power of test to detect the difference in operation duration between 2 groups, with an effect size of 0.80. Student t-test was used to investigate differences in continuous variables between Group 1 and Group 2 patients. Chi-square test was used to investigate differences between categorical variables. The cut-off point of statistical significance was defined at 0.05.

Results

At the end of the PSM analysis, 50 patients from Group 1 and Group 2 were matched with a comparable covariate. Table 2 shows a comparable cohort of patients after PSM analysis. When we compared the 2 groups, they were better distributed in terms of the type of Lenke curves and the mean number of screws was also more comparable. The mean major Cobb angle was 68.2 ± 18.4° in G1 and 64.1 ± 15.8° in G2.

Table 3 shows the preoperative demographic and the curve characteristics of both groups. The mean age of G1 was 13.5 ± 1.4 years and 26.2 ± 5.1 years in G2. As to be expected, G2 was heavier (44.9 ± 10.1 vs 51.8 ± 9.5, $P = 0.001$). Patients in G2 were also taller. When we calculated their BMI, G2 had significantly higher BMI with a mean of 20.5 ± 3.7 kg/m.[2] The difference in the anthropometric parameters had a significant effect on the estimated body blood volume when calculated using the Nadler's formula. G2 had higher mean EBV compared to G1 patients; 3351.4 ± 412.6 ml vs. 2998.8 ± 440.9 ml. Nevertheless, the preoperative Hb level was higher in G1 patients.

Table 4 shows the comparison between both groups in terms of their perioperative outcome measures. We could not find any significant differences between the 2 groups for all the perioperative outcome measures. The average operation duration for G1 was 125.9 ± 27.2 minutes with IBL of 749.8 ± 315.7 ml. This is similar to patients in G2 whereby their operation duration was 127.3 ± 37.8 minutes with IBL of 723.8 ± 342.1 ml ($P > 0.05$). Due to the difference in EBV, G2 actually had lower percentage blood loss. This led to a lower hemoglobin drift in G2 ($P = 0.075$) (Figure 2). It is important to highlight that there was a trend toward longer wounds and hospital stay in G2 although the difference did not reach statistical significance. The mean length of hospital stay was 3.3 ± 0.4 days (G1) vs. 3.5 ± 0.8 days (G2). Other outcomes that includes postoperative serum hemoglobin and the amount of blood salvaged were comparable. None of the patients required allogeneic blood transfusion. No perioperative complications were encountered in both groups.

For preoperative radiological parameters, the Cobb angle for the major curve, proximal thoracic (PT), main thoracic (MT) and lumbar segment was similar in both groups. In G2, the curves were stiffer. The PT flexibility, MT flexibility and lumbar flexibility were 42.1 ± 19.0% vs. 40.4 ± 19.4%; 54.0 ± 26.0% vs. 51.5 ± 15.9%; and 90.4 ± 41.9% vs. 83.8 ± 40.7% in G1 and G2, respectively. However, the differences in stiffness did not reach statistical significance ($P > 0.05$). Among all 3 segments, the lumbar curves were the most flexible (Table 3). There was also a trend toward a lower correction rate in G2 in the immediate postoperative radiographs. The correction rate was 66.3 ± 11.6% and 61.8 ± 11.2% in G1 and G2, respectively ($P = 0.051$) (Table 4).

Table 3. Preoperative Demographic, Anthropometric and Preoperative Radiological Parameters Comparing Adolescent and Adult Groups After PSM Analysis.

Variables	Whole group (n = 100)	Group 1, adolescent (n = 50)	Group 2, adult (n = 50)	*P* value
Preoperative demographic data				
Age (years)	19.9 ± 7.4	13.5 ± 1.4	26.2 ± 5.1	<0.001*
Height (m)	1.6 ± 0.1	1.5 ± 0.1	1.6 ± 0.1	0.001*
Weight (kg)	48.4 ± 10.4	44.9 ± 10.1	51.8 ± 9.5	0.001*
BMI (kg/m^2)	19.6 ± 3.7	18.7 ± 3.6	20.5 ± 3.7	0.018*
Preoperative Hb (g/L)	13.4 ± 1.2	13.7 ± 1.2	13.1 ± 1.1	0.029*
Estimated blood volume, EBV (ml)	3175.1 ± 460.3	2998.8 ± 440.9	3351.4 ± 412.6	<0.001*
Preoperative radiological parameters				
Proximal thoracic Cobb (°)	35.9 ± 12.9	37.6 ± 14.7	34.1 ± 10.6	0.221
Proximal thoracic SB (°)	22.2 ± 12.1	23.2 ± 13.9	21.1 ± 9.8	0.452
Proximal thoracic flexibility (%)	41.3 ± 19.1	42.1 ± 19.0	40.4 ± 19.4	0.703
Main thoracic Cobb (°)	63.2 ± 19.8	65.4 ± 21.6	61.1 ± 17.9	0.286
Main thoracic SB (°)	31.4 ± 19.5	31.8 ± 21.7	30.9 ± 17.3	0.827
Main thoracic flexibility (%)	52.7 ± 21.4	54.0 ± 26.0	51.5 ± 15.9	0.559
Lumbar Cobb (°)	47.1 ± 16.3	48.9 ± 15.5	45.3 ± 17.1	0.338
Lumbar SB (°)	9.7 ± 16.5	9.5 ± 13.2	9.9 ± 19.3	0.924
Lumbar flexibility (%)	87.0 ± 41.2	90.4 ± 41.9	83.8 ± 40.7	0.495
Major Cobb SB (°)	31.8 ± 20.1	32.0 ± 22.0	31.7 ± 18.1	0.953
Flexibility (%)	54.4 ± 22.5	55.8 ± 26.7	53.0 ± 17.3	0.532

*significantly different at 0.05, BMI = Body mass index, SB = Side bending, Hb = Hemoglobin.

Table 4. Comparison of Intraoperative and Postoperative Outcome of Group 1 and Group 2.

Intraoperative and postoperative outcome variables				
Variables	Whole group (n = 100)	Group 1, adolescent (n = 50)	Group 2, adult (n = 50)	*P* value
Operation duration (min)	126.6 ± 33.0	125.9 ± 27.2	127.3 ± 37.8	0.826
Intraoperative blood loss, IBL (ml)	736.8 ± 327.8	749.8 ± 315.7	723.8 ± 342.1	0.693
Blood loss percentage (%)	23.7 ± 10.9	25.4 ± 11.2	22.0 ± 10.5	0.114
Postoperative Hb (g/L)	10.6 ± 1.4	10.6 ± 1.4	10.5 ± 1.4	0.831
Hb drift (g/L)	2.9 ± 1.4	3.1 ± 1.5	2.5 ± 1.1	0.075
Amount of salvaged blood (ml)	368.4 ± 179.4	381.6 ± 161.8	355.1 ± 196.3	0.464
Blood transfusion (n, %)	0	0	0	-
Wound length (cm)	29.5 ± 5.5	28.4 ± 5.4	30.5 ± 5.4	0.080
Postoperative hospital stays (days)	3.4 ± 0.6	3.3 ± 0.4	3.5 ± 0.8	0.081
Postoperative Cobb (°)	24.4 ± 12.7	23.4 ± 12.2	25.4 ± 13.1	0.444
Correction rate (%)	64.1 ± 11.6	66.3 ± 11.6	61.8 ± 11.2	0.051
Postoperative complication (n, %)	0	0	0	-

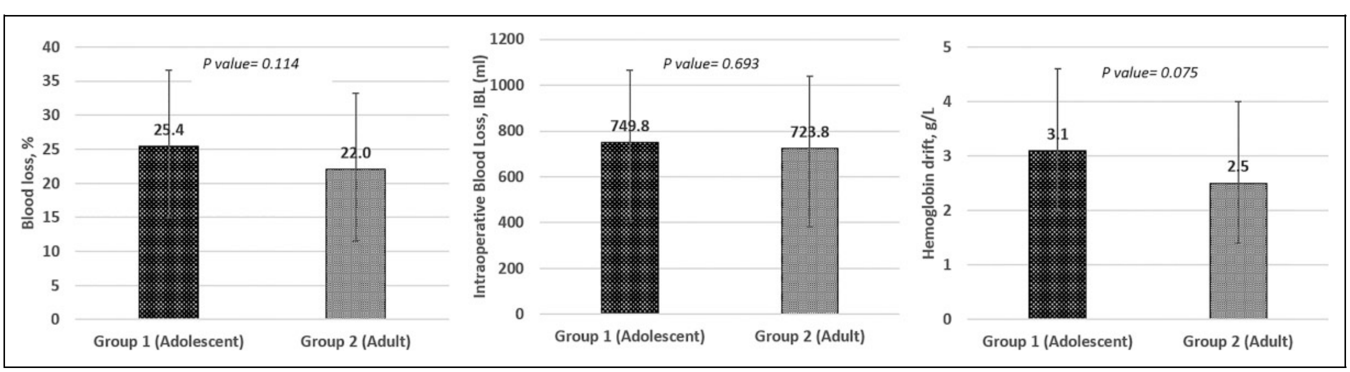

Figure 2. The intraoperative blood loss (IBL), blood loss percentage and hemoglobin drift comparing adolescent idiopathic scoliosis (AIS) and adult idiopathic scoliosis (AdIS) patients.

Discussion

Children and adults are known to have different physiological capability of tissue repair.[20,21] However, there is a scarcity of published literature that report on direct comparison between children and adults who were affected by similar afflictions. In digital replantation, a review of 3010 patients reported that age less than 18 years old was associated with a lower likelihood of suffering a complication, requiring amputation or experiencing length of stay > 5 days.[22] A retrospective review which was performed in patients with open tibia fractures reported significantly lower rates of surgical site infection among children (13.5%) as compared to adults (21.3%). Similarly the mean waiting time for soft tissue recovery was lower in children leading the authors to conclude that children had the superior ability of soft tissue recovery compared to adults.[23] In hematopoietic cell transplantation, although children had 2.9-fold higher incidence of infections their outcome was 2.5-fold better compared to adults.[24]

In idiopathic scoliosis, due to the natural progression of the curve severity once the Cobb angle surpasses 45 degrees, we encounter 2 distinct age groups of patients who would undergo corrective surgery. The perioperative outcomes of AIS had been well published based on numerous multicenter databases. Basques et al,[8] conducted a retrospective analysis of 733 patients and they reported an average operation duration of 275 minutes. However, in 108 patients the operation duration was longer than 365 minutes. In another prospective multicenter study, Tarrant et al., reported operation duration of 5.5 hours (330 minutes) and intraoperative blood loss of 1012 ml (791-1400 ml).[9] Chiu et al,[12] in their prospective study analyzing 100 AIS patients, found that the average operative time was 188.5 min with a mean blood loss of 951.0 ml.

In AdIS, there were several published reports on their surgical outcome but few were matched comparisons with AIS. Kurra et al.[25] analyzed the trends in complications in operative adolescent and AdIS derived from the SRS database. The authors noted an increasing rate of neurological deficit, blindness and overall complications in adult patients despite evolution in surgical techniques. This was in comparison to adolescents whereby the complication rates remained constant. Adult patients were reported to have higher amount of blood loss. In a review of 8432 patients from a nationwide database, increasing age was a significant predictor of hemorrhagic complications, pulmonary embolism, infection and revision surgery.[26] Zhu et al.[27] performed a match-pair analysis of 160 AIS and AdIS patients. They only included Lenke 1A/B patients with cobb angle 45°-80°. The matching was done manually. They concluded that AIS patients would obtain better radiographic correction due to the increased curve stiffness in AdIS patients. In a recent article that matched 28 adult scoliosis patients with 56 AIS patients, the operative time and estimated blood loss was significantly higher in adults (Operative time 376.6 vs. 279.0 minutes, Blood loss 1121 vs. 746.9mls). However, there was no significant difference in the length of stay when comparing the 2 groups (7.5 days in AdIS vs. 5.4 days in AIS).[16]

In our study cohort, we attempted to match both groups in terms of variables that could significantly affect the perioperative outcome. We intentionally omit matching anthropometric parameters such as weight, height and body mass index as the physical differences between adults and adolescents were apparent and impossible to match. These differences could affect the difficulty of the corrective surgery. The anthropometric differences also affected the estimated blood volume of the patients when calculated using Nadler's formula. We found that the adult patients had a significantly higher mean blood volume of 3351mls compared to 2999mls in adolescent.

The estimated body blood volume would affect the risk of allogeneic blood transfusion. Nevertheless, our results demonstrated no significant differences in terms of the key perioperative parameters such as estimated blood loss and operative time. Our sample size calculation, which was carried out prior to commencement of the study, was based on estimated blood loss. Both groups were comparable with mean blood loss of 750 ml in adolescents and 724 ml in adults. The operative times were also similar averaging almost 125 minutes in both groups. When we accounted for the difference in mean blood volume, the percentage of blood loss was lower in adults with a mean of 22%. This could also explain the lower hemoglobin drift in the adults which was 2.5g/L compared to 3.1g/L in adolescents ($P = 0.075$).

The findings of our study contradict the report by Lonner et al. whereby adult patients had poorer perioperative outcomes.[16] The physical differences between adults and adolescents would be expected to increase surgical difficulty for AIS surgery. Therefore, it seemed counter intuitive that our results showed similar findings in both groups. We believe our results were contributed by the use of dual attending surgeon strategy and the accelerated recovery protocol in our unit.[18,28] Dual attending surgeon strategy had been proven to reduce the operative time, blood loss and the risk of allogeneic blood transfusion.[28,29] As a result, this could mitigate the difference in surgical difficulty that was apparent between both groups and this led to similar perioperative outcome. Using the accelerated recovery regime, both groups also had short length of stay with a mean of approximately 3.3 days (adolescents) and 3.5 days (adults) respectively.

The limitations in our study include the retrospective nature of our study. Some patients were excluded due to incomplete data. Although this could have led to bias in case selection, propensity matching of the cases was effective in creating 2 comparable groups. We did not analyze some important parameters such as postoperative pain level and amount of PCA morphine usage. We believe these are important aspects that could be studied in future studies. Our study was not powered to analyze parameters such as length of hospitalization and correction rate. With bigger sample size, there could be significant difference in this outcome parameter.

In summary, this study demonstrated comparable perioperative outcomes between adolescent idiopathic scoliosis (AIS) and adult idiopathic scoliosis (AdIS) patients in terms of the operation duration, intraoperative blood loss and the rate of allogeneic blood transfusion. The perioperative complications rate was also comparable in both groups.

Declaration of Conflicting Interests

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