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Blood Loss Control in Patients with Idiopathic Scoliosis Undergoing Spinal Fusion: Prospective Evaluation of a Cohort*

Controle de sangramento em pacientes com escoliose idiopática submetidos a artrodese da coluna: Avaliação prospectiva de uma coorte de pacientes

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Abstract

Objective This study aimed to identify risk factors for increased perioperative bleeding in scoliosis surgery.

Methods This is a prospective cohort study including 30 patients with idiopathic scoliosis undergoing posterior instrumentation using the pedicle screw system at a university hospital.

Results Intraoperative blood losses totaled 798.6 ± 340 mL (24.8% of blood volume). Nine subjects presented massive blood loss. On average, hemoglobin dropped by 3.7 g/dL, and each patient received 1.4 blood bags. Postoperative blood loss was 693.4 ± 331.1 mL, and the total number of days using a drain was 2.7 ± 0.7. Intraoperatively, the following variables showed significant correlations ($p < 0.05$) with increased bleeding: age, time from diagnosis to treatment, preoperative Cobb angle, amount of curve correction, number of instrumented and fixated levels, total number of screws, and the number of transfused bags. Postoperatively, the following variables had significant correlations ($p < 0.05$): age, preoperative Cobb angle, length of hospital stay, number of blood bags transfused, and number of levels fixated with screws.

Conclusion The variables most contributing to blood loss were age, preoperative Cobb angle, number of blood bags transfused, and number of levels fixated with a screw. Therefore, patients may benefit from surgical treatment while younger and

Keywords
- ► scoliosis
- ► spinal fusion
- ► hemorrhage
- ► blood loss, surgical

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presenting a lower Cobb angle, consequently requiring a lower degree of curve correction and lower-density implants.

Resumo

Objetivo O objetivo deste estudo é identificar os fatores de risco para o aumento de sangramento perioperatório em cirurgias para tratamento de escoliose.

Métodos Estudo de coorte prospectivo incluindo 30 pacientes com escoliose idiopática submetidos à instrumentação posterior com o uso do sistema de parafusos pediculares em um hospital universitário.

Resultados As perdas sanguíneas intraoperatórias totalizaram 798,6 ml ± 340 ml (24,8% do volume sanguíneo). Houve perda maciça de sangue em 9 pacientes. Em média, a hemoglobina caiu 3,7 g/dl e foram transfundidas 1,4 bolsas de sangue por paciente. A perda sanguínea pós-operatória foi de 693,4 ml ± 331,1ml, e o total de dias utilizando dreno foi 2,7 ± 0,7. No intraoperatório, as seguintes variáveis apresentaram correlações significativas ($p < 0,05$) com o aumento do sangramento: idade, intervalo entre diagnóstico e tratamento, Cobb pré-operatório, quantidade de correção da curva, número de níveis instrumentados e fixados, número total de parafusos e o número de bolsas transfundidas. No pós-operatório, as seguintes variáveis apresentaram relação ($p < 0,05$): idade, Cobb pré-operatório, tempo de internação, quantidade de bolsas de sangue transfundidas e o número de níveis fixados com parafuso.

Conclusão As variáveis que mais contribuíram para a perda sanguínea foram idade, Cobb pré-operatório, quantidade de bolsas de sangue transfundidas e número de níveis fixados com parafuso. Portanto, os pacientes podem se beneficiar do tratamento cirúrgico enquanto mais jovens e com menor ângulo de Cobb, consequentemente, exigindo menor grau correção da curva e a utilização de implantes de menor densidade.

Palavras-chave
- escoliose
- fusão vertebral
- hemorragia
- perda sanguínea cirúrgica

Introduction

Posterior vertebral arthrodesis (PVA) is a common treatment for severe, progressive scoliosis. However, although effective, it can result in excessive bleeding.[1–3] It is estimated that subjects undergoing PVA present an average loss of 21% of their estimated blood volume (EBV). In addition, 18% require a blood transfusion.[3] Massive bleeding increases surgical time, transfusional requirements, hospital stays, postoperative pain, and infection rates. Therefore, excessive perioperative blood loss is a cause for concern.[1–4]

Blood transfusion, although safe, is not risk-free. Potential complications include viral infection (hepatitis B [HBV], hepatitis C (HCV), and human immunodeficiency virus [HIV]), surgical site infection, pneumonia, urinary tract infection, alloimmunization, acute lung injury, circulatory overload, renal failure, and coagulopathy.[1,3]

Knowledge about the factors predisposing to increased perioperative bleeding in patients undergoing PVA is fundamental to minimizing these unfavorable outcomes.

This study prospectively analyzes a cohort of patients undergoing surgical treatment for idiopathic scoliosis and identifies the factors correlated with increased intraoperative and postoperative bleeding.

Material and Methods

This is a prospective cohort study, with data collection in a specific form, including patients with idiopathic scoliosis who underwent surgical treatment between 2021 and 2022 in a university hospital. Four surgical teams participated in the procedures; all were certified and experienced in scoliosis surgery. All cases underwent a spinal arthrodesis with posterior instrumentation using the same synthesis method, that is, fixation with pedicle screws and nails. Autologous graft from spinous processes and iliac crest provided intervertebral fusion. The Ethics Committee approved this study under the number CAAE 45721721.0.0000.5086.

We gathered information on gender, age, time from diagnosis to treatment, body mass index (BMI), hemoglobin level, Cobb angle, sagittal modifier, number of transfused blood bags, number of instrumented and fixated levels, number of screws, surgical time, length of hospital stay and drain use, and blood loss.

Intraoperative bleeding was quantified as the sum of the suction container in the operating room and the volume calculated by weighing the compresses, considering human blood density as 1,053 g/mL. In addition, we discounted the amount of saline solution applied to irrigate the surgical site. Postoperative bleeding was measured using the sum of losses in vacuum drains positioned subcutaneously. Massive blood loss was defined as $\geq$ 30% EBV (preset at 70 mL blood/kg).

All study participants received preoperative and intraoperative tranexamic acid in a standardized manner. Tranexamic acid dosing followed our institutional protocol: a loading dose of 100 mg/kg 30 minutes before the procedure and a continuous infusion of 30 mg/kg/h during surgery.

For sagittal modifier assessment, we calculated the kyphosis angle between the T5 and T12 vertebrae. Normal values ranged from 10° to 40°. Therefore, we defined hypokyphosis and hyperkyphosis as values lower than 10° and greater than 40°, respectively.

A Shapiro-Wilk's normality test for numerical variables was used to analyze the result. Central tendency and dispersion measurements were expressed as means and standard deviation (SD) for continuous variables with symmetric distribution and as medians and minimum and maximum values for variables with asymmetric distribution. Quantitative and continuous variables were evaluated with analysis of variance (ANOVA) and Pearson correlation. Non-normal values assessment was made by employing the Mann-Whitney and Spearman correlation tests. Variables with statistical significance ($p < 0.05$) were included in the multivariate models. A linearity test was performed, and multiple regression identified predictors.

Results

►**Table 1** describes the characteristics of the population. Thirty patients were included, 26 female and 4 male, with a mean age of 15.2 ± 3.2 years. The mean body mass index (BMI) was 18.7 ± 2.7 kg/m^2. Per the scoliosis categorization according to age groups, 7 cases (24%) were in children, 18 (60%) in adolescents, and 5 (16%) in young adults. The time from diagnosis to treatment was 6.5 years ± 5.3 years.

The Cobb angle was 64.7° ± 18.2° in the preoperative period and 30.6° ± 15.0° after surgery, resulting in a correction of 34.1° ± 12.0°. The mean sagittal modifier was 29.4° ± 26.6° in the preoperative period and 24.2° ± 12.2° after surgery, totaling 5.2° ± 19.4° of correction. Regarding the sagittal modifier type, 7 patients (23.3%) had hypokyphosis, 16 (53.4%) presented normokyphosis, and 7 (23.3%) had hyperkyphosis.

On average, 10.3 ± 2.8 levels underwent instrumentation, and 8.7 ± 2.2 received fixation with pedicle screws. The number of screws used was 13.8 ± 3.6. The mean surgical time was 3 hours and 22 minutes ± 1 hour and 3 minutes. Intraoperative blood loss totaled 798.6 ± 340 mL, equivalent to 24.8% of the EBV. Nine patients (30%) suffered massive blood loss. Each patient received an average of 1.4 ± 2 bags of packed red blood cells. Hemoglobin levels ranged from 13.1 ± 1.2 g/dL to 9.4 ± 1.4 g/dL, with an average drop of

Table 1 Descriptive statistics and numerical variables characterization

Variable	Mean value	Standard deviation
Body mass index (kg/m^2)	18.7	2.7
Age (years)	15.2	3.2
Time from diagnosis to treatment (years)	6.5	5.3
Preoperative Cobb angle (degrees)	64.7	18.2
Postoperative Cobb angle (degrees)	30.6	15.0
Curve correction amount in the coronal plane (degrees)	34.1	12.0
Preoperative sagittal modifier (T5–T12) (degrees)	29.4	26.6
Postoperative sagittal modifier (T5–T12) (degrees)	24.2	12.2
Sagittal modifier variation (degrees)	-5.2	19.4
Preoperative hemoglobin level (g/dL)	13.1	1.2
Intraoperative blood loss (mL)	798.6	340.0
Intraoperatively transfused blood bags (unit)	0.4	0.8
Number of instrumented levels	10.3	2.8
Number of levels fixated with pedicle screw	8.7	2.2
Total number of screws used	13.8	3.6
Surgical time (minutes)	202.4	63.0
Admission time (days)	6.3	3.7
Postoperatively transfused blood bags (unit)	1.0	1.2
Postoperative hemoglobin level (g/dL)	9.4	1.4
Postoperative total drain loss (mL)	693.4	331.1
Total number of days using drain	2.7	0.7

Table 2 Pearson correlation between variables and intraoperative blood loss

Variable	Intraoperative blood loss	
	Correlation	*p*
Intraoperatively transfused blood bags (unit)	0.742	**0.000**
Preoperative Cobb angle(degrees)	0.687	**0.000**
Age (years)	0.571	**0.003**
Time from diagnosis to treatment (years)	0.561	**0.004**
Total number of screws used	0.500	**0.011**
Number of levels fixated with pedicle screw	0.490	**0.012**
Curve correction amount in the coronal plane (degrees)	0.479	**0.015**
Number of instrumented levels	0.462	**0.019**
Postoperatively transfused blood bags (unit)	0.459	**0.020**
Surgical time (minutes)	0.372	0.067
Admission time (days)	0.313	0.126
Sagittal modifier variation (degrees)	-0.276	0.180
Preoperative sagittal modifier (T5–T12) (degrees)	-0.253	0.221
Body mass index (kg/m^2)	0.110	0.598
Weight (kilograms)	0.094	0.652
Postoperative hemoglobin level (g/dL)	-0.029	0.888
Preoperative hemoglobin level (g/dL)	-0.027	0.898
Age at diagnosis (years)	-0.009	0.964

3.7 g/dL. Postoperative blood loss was 693.4 ± 331.1 mL, and the total number of days using the drain was 2.7 ± 0.7.

As for intraoperative blood loss (►**Table 2**), the following variables showed significant correlations ($p < 0.05$): age ($p = 0.003$), time from diagnosis to treatment ($p = 0.004$), preoperative Cobb angle ($p < 0.001$), amount of curve correction in the coronal plane ($p = 0.015$), number of instrumented levels ($p = 0.019$), number of levels fixated with screws ($p = 0.012$), total number of screws ($p = 0.011$), and the number of blood bags transfused intraoperatively ($p < 0.001$) and postoperatively ($p < 0.02$). The other variables had no significant association, maybe due to the small sample size.

During the postoperative period (►**Table 3**), the following variables had significant correlations: age ($p = 0.027$), preoperative Cobb angle ($p = 0.017$), length of hospital stay (p = 0.004), number of blood bags transfused intraoperatively ($p = 0.002$) and postoperatively (p = 0.021), and number of levels fixated with a pedicle screw ($p = 0.027$). The other variables presented no significant association, once again maybe due to the small sample size.

Our study revealed that patients with massive blood loss were older (17.3 versus 14.1 years old), had a longer time from diagnosis to treatment (10.8 versus 4.5 years), a higher preoperative Cobb angle (84.8° versus 55.2°), and required a higher curve correction in the coronal plane (42.0° versus 30.4°). They also had more instrumented levels (11.75 versus 9.6), levels fixated with screws (9.5 versus 8.3), and a higher total number of screws (15.25 versus 13.1). In addition, they remained hospitalized for more days (7.2 versus 5.8 days). ►**Figs. 1** and **2** depict the graphical distribution for comparison.

Fixating ≥10 levels with a pedicle screw ($p = 0.03$), having ≥13 instrumented levels ($p = 0.013$), a preoperative Cobb angle ≥65° ($p = 0.011$), and using ≥14 screws ($p = 0.015$) significantly increased the risk of bleeding.

Age, preoperative Cobb, number of screw-fixated levels, and number of blood bags transfused were the only variables showing significantly positive correlations ($p < 0.05$) with intraoperative and postoperative bleeding.

The combination of subtraction and instrumentation osteotomies occurred in 5 patients (~16%). These subjects presented a higher mean rate of perioperative bleeding (~500 mL). However, there was no significant association ($p < 0.6$), probably due to the small sample size.

Few patients (~13%) had any clinical (decreased evoked potentials and/or reduced blood pressure/shock) or surgical (repositioning/change of synthesis material) complications.

Discussion

Managing blood loss is essential for optimal surgical outcomes.[1–5] The use of fresh plasma, crystalloids, platelet concentrate, and/or packed red blood cells to minimize morbidity linked to excessive bleeding is not free of complications. As such, reducing perioperative blood loss may decrease the need for these measures.[5]

Surgeries for scoliosis treatment often result in significant perioperative blood loss and may require transfusions of two

Table 3 Pearson correlation between variables and postoperative blood loss

Variable	Post-operative blood loss	
	Correlation	*p*
Intraoperatively transfused blood bags (unit)	0.583	**0.002**
Admission time (days)	0.552	**0.004**
Preoperative Cobb angle(degrees)	0.470	**0.017**
Postoperatively transfused blood bags (unit)	0.458	**0.021**
Age (years)	0.440	**0.027**
Number of levels fixated with pedicle screw	0.441	**0.027**
Surgical time (minutes)	0.391	0.053
Total number of screws used	0.387	0.055
Curve correction amount in the coronal plane (degrees)	0.354	0.082
Number of instrumented levels	0.326	0.111
Time from diagnosis to treatment (years)	0.293	0.154
Postoperative Cobb angle (degrees)	0.288	0.162
Postoperative hemoglobin level (g/dL)	-0.285	0.167
Preoperative sagittal modifier (T5–T12) (degrees)	0.184	0.376
Sagittal modifier variation (degrees)	-0.158	0.447
Weight (kilograms)	0.126	0.547
Body mass index (kg/m^2)	-0.048	0.819
Age at diagnosis (years)	-0.029	0.888
Preoperative hemoglobin level (g/dL)	0.015	0.941

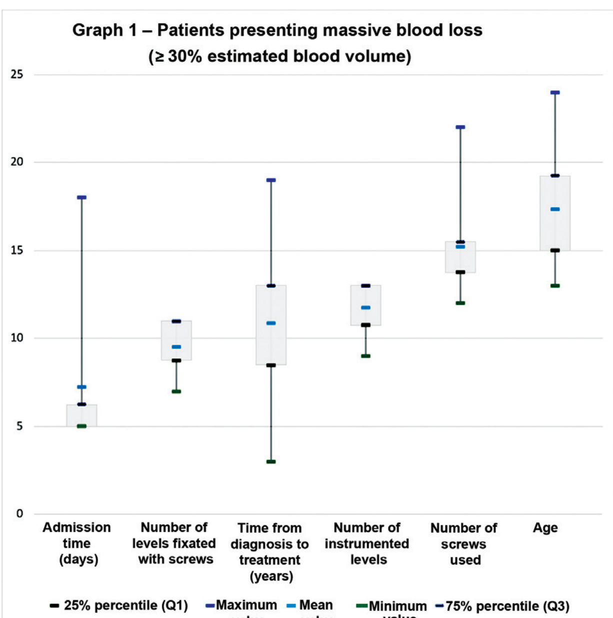

Fig. 1 Quartile distribution of variables in patients with massive bleeding.

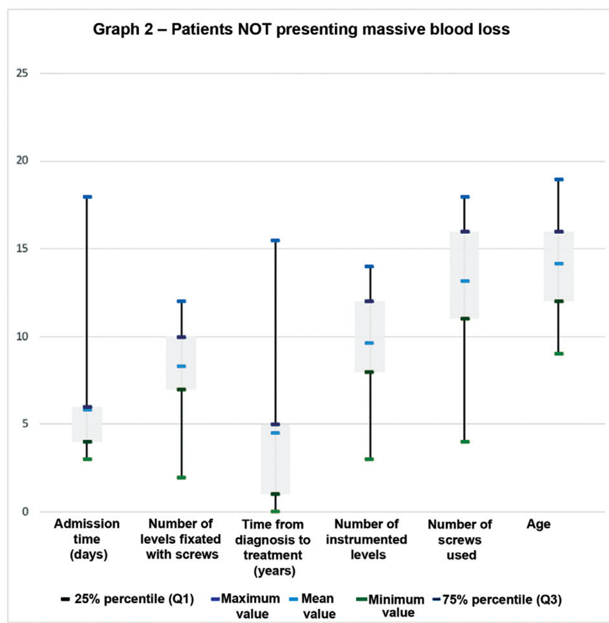

Fig. 2 Quartile distribution of variables in patients with NO massive bleeding.

to six units of packed red blood cells per patient.[4] Although blood transfusion is safe, the remote risk of HIV or HCV infection remains. Moreover, they carry a risk of hemolytic transfusion reaction, graft-versus-host disease, coagulopathy, and hypothermia.[4,6,7]

In this context, it is critical to minimize perioperative blood loss and to identify risk factors for its occurrence to improve postoperative outcomes[4] and reduce complications.[4,5,7] Therefore, our study focused on determining variables correlated with higher levels of intraoperative and postoperative bleeding in a cohort of patients undergoing surgical idiopathic scoliosis treatment.

In a series of 212 patients undergoing PVA for scoliosis, Tang et al.[4] reported that the intraoperative blood loss per instrumented level was 79.3 mL. They also concluded that the higher number of implants ($p < 0.001$), male gender ($p < 0.007$), and longer surgical time ($p < 0.001$) correlated with increased blood loss. Fixation of $\geq$ 10 levels increased the blood loss to 500 mL. Furthermore, for each minute of surgery, there was an increase of 1.5% in the chance of excessive blood loss; the placement of each implant increased the bleeding chance by 36.4%.[4]

Song et al.[6] evaluated 1,896 patients operated on for scoliosis. The variables associated with bleeding included a surgical time $\geq$ 4 hours ($p < 0.001$), number of instrumented levels $\geq$ 10 ($p < 0.001$), BMI < 18.1 kg/m^2 ($p < 0.001$), preoperative platelet count < 186.5×10^9/L ($p = 0.009$); preoperative international normalized ratio (INR) > 1 ($p = 0.003$), and a preoperative Cobb angle > 53° ($p = 0.036$). Among these patients, 633 (33%) had massive blood loss. In this group, length of stay ($p < 0.001$), incision drain volume ($p < 0.001$), blood transfusion rate ($p < 0.001$), and use of opioids ($p = 0.006$) were significantly higher.[6]

In their review, Li et al.[8] studied 1,461 patients with scoliosis who underwent PVA. The risk factors independently associated with postoperative massive blood drainage were the following: BMI < 17.63 kg/m^2 (odds ratio [OR] = 2.90), platelet count < 190×10^9/L (OR = 1.67), preoperative Cobb angle $\geq$ 55° (OR = 1.66), arthrodesis levels $\geq$ 11 (OR = 2.33), number of screws $\geq$ 15 (OR = 1.73); use of osteotomy(s) (OR = 1.54); and transfusion volume $\geq$ 19.55 mL/kg (OR = 1.72).[8]

Abousamra et al.[9] investigated the relationship between some common features and intraoperative blood loss in 837 patients with scoliosis. Each instrumented level cumulately increased the estimated blood loss (EBL) by 2%. Each 10 mg/kg^2 reduction in BMI ensured an average increase of 7% in EBL. A 10° decrease in the sagittal modifier caused a 1% increase in EBL.[9]

In a cohort of 311 patients operated on for idiopathic scoliosis, Thompson et al.[10] calculated that an EBL > 1,700 mL had a significant association with the number of instrumented levels ($p < 0.001$), Cobb angle ($p = 0.04$), and number of screws ($p < 0.001$). Patients with EBL < 1,700 mL had, on average, 10.1 ± 2.12 instrumented levels, whereas those with EBL $\geq$ 1,700 mL presented 12.5 ± 1.29 instrumented levels. Furthermore, the probability of achieving an EBL of 1,700 mL was 7% with 12 instrumented levels versus 12.7% with 13 levels. Patients with a higher bleeding rate had a mean blood loss of 124 mL per fixated screw, in addition to 184.3 mL per arthrodesis level.[10]

Five patients ($\sim$ 16%) underwent subtraction osteotomies. These subjects had higher perioperative bleeding ($\sim$ 500 mL) consistent with previous studies.[6,8] However, the multivariate analysis showed no statistically significant association ($p < 0.6$), as in the study from Abousamra et al.[9] Another study, from Tang et al.,[4] preferred not to include patients undergoing any osteotomy in their sample, using it as an exclusion criterion. Thompson et al.[10] did not consider osteotomies in their analysis.

Thirteen percent of our patients had some perioperative complication, such as a drop in evoked potential and/or decreased blood pressure/shock or a change in the preplanned synthesis material. These complications could increase the surgical time and, consequently, the perioperative bleeding rate, as described by some authors.[4,6,9] Still, in our study, surgical time was not statistically related to blood loss ($p = 0.067$).

Our study indicated the risk of higher perioperative blood loss in older patients, probably related to the higher muscle mass and scoliosis progression, among other factors.[8] Moreover, the association between excessive bleeding and other analyzed variables, such as a longer time from diagnosis to treatment, maximum preoperative Cobb angle,[6–10] higher amount of curve correction, more instrumented and/or fixated levels,[4] and higher number of screws,[8,10] potentially results from the coexistence of severe conditions, requiring greater soft-tissue dissection and osteotomies.[10]

The number of blood bags transfused in the perioperative period had a paradoxically significant positive correlation with the increased intraoperative ($p < 0.001$) and postoperative ($p < 0.021$) bleeding. Some authors suggest that blood transfusion stimulates the consumption of clotting factors and dilutes them, increasing blood loss.[1,3,4]

We believe our study is clinically significant because of the role played by these variables in blood loss during idiopathic scoliosis surgeries, helping to define the patient profile with higher bleeding potential. Our findings may help other colleagues to optimize their patients' perioperative conditions, minimizing surgical morbidity. Double-blind, randomized trials with larger cohorts are required for a better understanding of perioperative blood loss prevention in scoliotic patients based on identifying predisposing factors, especially in major surgeries, such as PVA.

Conclusion

Blood loss in scoliosis surgery is worrisome and significantly affects the patient's prognosis. Thus, further research is needed to determine risk factors related to increased perioperative bleeding.

In our study, the variables contributing to higher blood loss were age, number of blood bags transfused, preoperative Cobb angle, amount of curve correction in the coronal plane, and the number of fixated levels. Therefore, other patients may benefit from surgical treatment while younger and with a smaller Cobb angle, consequently requiring less curve correction in the coronal plane and using lower-density implants, which, ultimately, could reduce surgical bleeding.

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Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Shrestha IK, Ruan TY, Lin L, et al. The efficacy and safety of high-dose tranexamic acid in adolescent idiopathic scoliosis: a meta-analysis. J Orthop Surg Res 2021;16(01):53

2 Yang H, Jia X, Hai Y. Posterior minimally invasive scoliosis surgery versus the standard posterior approach for the management of adolescent idiopathic scoliosis: an updated meta-analysis. J Orthop Surg Res 2022;17(01):58

3 Eisler L, Hassan F, Lenke LG, Chihuri S, Hod EA, Li G. Allogeneic Red Blood Cell Transfusion and Infectious Complications Following Pediatric Spinal Fusion: NSQIP-P Analysis. JBJS Open Access 2022; 7(04):e22.00038

4 Tang CYK, Kamath VHD, Cheung PWH, Cheung JPY. Predictive factors for intraoperative blood loss in surgery for adolescent idiopathic scoliosis. BMC Musculoskelet Disord 2021;22(01):225

5 Karimi S, Lu VM, Nambiar M, Phan K, Ambikaipalan A, Mobbs RJ. Antifibrinolytic agents for paediatric scoliosis surgery: a systematic review and meta-analysis. Eur Spine J 2019;28(05):1023–1034

6 Song JS, Sun JJ, Sun YE, Liu Y, Gu XP, Ma ZL. [Risk factors of massive introperative blood loss in posterior spinal fusion for adolescent idiopathic scoliosis]. Zhonghua Yi Xue Za Zhi 2021;101(14): 1002–1008

7 Li C, Yang M, Wang C, et al. Preoperative factors predicting intraoperative blood loss in female patients with adolescent idiopathic scoliosis. Medicine (Baltimore) 2015;94(01):e359

8 Li N, Jia R, Gu XP, Ma ZL. [Risk factors associated with massive drainage after posterior spinal orthopaedic surgery for adolescent scoliosis]. Zhonghua Yi Xue Za Zhi 2017;97(44):3460–3465

9 Abousamra O, Sponseller PD, Lonner BS, et al; Harms Study Group. Thoracic Lordosis, Especially in Males, Increases Blood Loss in Adolescent Idiopathic Scoliosis. J Pediatr Orthop 2019;39(03): e201–e204

10 Thompson ME, Kohring JM, McFann K, McNair B, Hansen JK, Miller NH. Predicting excessive hemorrhage in adolescent idiopathic scoliosis patients undergoing posterior spinal instrumentation and fusion. Spine J 2014;14(08):1392–1398

