Original Article

The Effect of Smith-Peterson Osteotomy on Blood Loss during Surgical Correction of Adolescent Idiopathic Scoliosis

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Abstract

Introduction: Surgical correction of adolescent idiopathic scoliosis is inevitably accompanied by blood loss. About 37–85% of patients undergo allogeneic transfusions associated with a risk of serious complications. Prediction of the expected blood loss volume remains a topical problem. In this regard, there is a need to clarify predictors of increased blood loss.

Aim: To assess the effect of vertebrectomy on the intraoperative blood loss volume during surgical correction of adolescent idiopathic scoliosis.

Materials and methods: A retrospective study included 511 adolescents who underwent posterior correction of spinal deformity. Two groups were allocated: Group I consisted of 303 patients who underwent multilevel transpedicular fixation; Group II included 208 patients who underwent multilevel transpedicular fixation combined with Smith-Peterson osteotomy.

Results: Intergroup comparisons revealed significant differences in the number of transpedicular fixation levels and the volume of blood loss, which were higher in Group II. After aligning the groups by the number of transpedicular fixation levels using the Propensity Score Matching method, no statistically significant difference was observed. We derived formulas for calculating the expected blood loss volume in Groups I and II. Comparison of the formulas revealed that the formula for Group II predicted a significantly lower volume of blood loss, by 2.51%, while the formula for Group I predicted a significantly higher volume of blood loss, by 3.27%. In our opinion, application of the formula that overestimates expected intraoperative blood loss is most reasonable due to a possibility of the worst case scenario during surgery; therefore, the formula for Group I approaches a universal model for use.

Conclusion: Smith-Peterson osteotomy did not affect the amount of blood loss during surgical correction of adolescent idiopathic scoliosis, considering the number of transpedicular fixation levels.

Keywords

PENSOFT.

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a complex orthopedic pathology that often requires surgical correction of existing spinal deformity. Surgery is often accompanied by intraoperative blood loss due to injury to the soft tissue and bone structures of the spine.[1-3] In such cases, patients with low body weight are at risk of significant blood loss due to a smaller circulating blood volume (CBV).[4,5] According to the literature[6,7], donor blood components have been used to compensate for blood loss in 37–85% of patients undergoing posterior instrumented correction of spinal deformity. However, real risks of serious complications associated with allogeneic blood transfusions have remained to date.[8,9] Almost all researchers agree that a number of factors can significantly affect the amount of bleeding in the surgical site tissue. In particular, these include: the intra-abdominal pressure, duration of surgery, severity of deformity, used instrumentation, hemodynamic features, and anesthesia technique. Some researchers have identified a close relationship between the factors and the amount of intraoperative blood loss[10-12], but others have found similar relationships only with the extension and duration of surgery.[13] Earlier, we demonstrated the main factors underlying the amount of blood loss during AIS correction were a change in the abdominal pressure in the patient being in the prone position, the number of transpedicular fixation (TPF) levels, and baseline deviations in the hemostatic system. In this case, the main statistically significant predictor of increased blood loss was found to be the number of TPF levels, which is consistent with opinions of other authors.[11,14] In some cases, to achieve more spine mobilization, surgeons perform vertebrectomy, which is a resection of posterior spinal elements at one or several levels. Information obtained from published papers indicates that application of vertebrectomy increases the intraoperative blood loss volume to a significant level. Some publications have reported the effect of the number of vertebrectomy levels on the blood loss volume.[15-17] However, the authors have also indicated difficulties in accounting for the volume of lost blood at this stage of surgery, which is associated with an insignificant duration of the stage (90–120 s per level).[3]

Given the fact that a particular problem in AIS surgery is prediction of the expected blood loss volume, it seems interesting to evaluate the effect of vertebrectomy on the intraoperative blood loss volume and the possibility of its prediction for clinical cases where multilevel TPF is combined with vertebrectomy.

AIM

The study purpose was to evaluate the effect of vertebrectomy on the intraoperative blood loss volume during surgical correction of adolescent idiopathic scoliosis.

MATERIALS AND METHODS

The study was based on a retrospective analysis of case records of 511 AIS patients for the period between 2012 and 2017. The inclusion criteria were as follows: AIS and first posterior correction of spinal deformity. The exclusion criteria included: posterior spinal fusion, multi-stage surgery, radical spinal osteotomy (PSO, pVCR), and blood diseases. The criterion for group formation was the amount of surgery. Two groups were allocated: Group I consisting of 303 patients operated on using a multilevel TPF technique; Group II including 208 patients operated on using the multilevel TPF technique in combination with Smith-Peterson osteotomy (SPO) involving resection of part of the posterior spinal elements: at two levels in 125 patients, at three levels in 72 patients, and at four levels in 11 patients.

Most patients were females. The gender ratio was 5:1 in Group I and 4:1 in Group II. In all cases, general anesthesia was used based on combination of sevoflurane, fentanyl, clonidine, and subanesthetic doses of ketamine with mechanical ventilation. All patients underwent surgery under complete decompression of the anterior abdominal wall on a Jackson table. Intraoperative blood loss was evaluated using the gravimetric technique and measuring the volume of blood aspirated from the wound. During the study, we analyzed the age, gender, body weight, duration of surgery, number of TPF levels, number of osteotomy levels, and volume of intraoperative blood loss in mL and % of CBV. To calculate the CBV, we used the formula: $CBVd = P*q$, where P is the patient's body weight (kg); q is the amount of blood per 1 kg of body weight (80 mL/kg in children aged 6 to 12 years and 70 mL/kg in children over 12 years and adults).

All statistical calculations were performed using the language R[18] in the RStudio software version 1.1.463.[19] Verification of the data distribution normality using the Shapiro-Wilk criterion revealed that the distribution of most indicators was not normal; therefore, to compare continuous parameters in the groups, we used a nonparametric unpaired Mann-Whitney U-test and calculation of a distribution shift with construction of a 95% confidence interval (CI) for the shift. Descriptive indicators are presented as the median (M), interquartile range between the first and third quartiles (IQR) for continuous indicators, quantity, and percentage (95% confidence interval) calculated by the Wilson formula. Predictors of intraoperative blood loss were identified by constructing univariate and multivariate linear regression models.

RESULTS

Intergroup comparison of the studied indicators revealed statistically significant differences. The patient's body weight, duration of surgery, number of TPF levels, and volume of blood loss (% of CBV) were higher in Group II. The differences approached the level of statistical significance only for one indicator – the volume of blood loss expressed in mL (Table 1).

Table 1. Distribution of the main studied indicators in the groups

Indicator	Group I N = 303 M [IQR]	Group II N = 208 M [IQR]	Mann-Whitney U-test	
			Difference [95% CI]	p value
Duration of surgery, min	150 [130; 185]	180 [155; 205]	20 [15; 30]	<0.001*
Body weight, kg	51 [46; 56]	49.5 [44; 56]	−2 [−4; −1]	0.007*
Number of TPF levels	4 [3; 5]	7 [5; 12]	3 [3; 4]	<0.001*
Blood loss, mL	500 [400; 650]	535 [400; 665]	50 [0; 50]	0.059
Blood loss, % of CBV	14 [11; 18]	16 [12; 21]	2 [1; 3]	<0.001*

* – statistically significant difference

Table 2. Distribution of the main studied indicators in the groups after PSM

Indicator	Group I N = 99 M [IQR]	Group II N = 99 M [IQR]	Mann-Whitney U-test	
			Difference [95% CI]	p value
Duration of surgery, min	160 [140; 190]	160 [145; 185]	0 [−10; 10]	0.911
Body weight, kg	51 [45.5; 55]	50 [42.5; 56]	−2 [−4; 1]	0.157
Number of TPF levels	5 [4; 6]	5 [4; 6]	0 [0; 0]	0.836
Blood loss, mL	450 [350; 550]	500 [400; 600]	20 [−20; 50]	0.317
Blood loss, % of CBV	13 [11; 16]	14 [10.5; 18.5]	1 [0; 3]	0.116

Given the fact that the number of TPF levels was significantly higher in Group II and the known information about the influence of the number of TPF levels on the amount of intraoperative blood loss, the groups were aligned for the number of TPF levels using the PSM method (Propensity Score Matching)[20] to achieve the reliability of the results and the validity of the conclusions (**Table 2**).

As can be seen from the data presented in **Table 2**, there were no statistically significant differences between the groups after their alignment for the number of TPF levels.
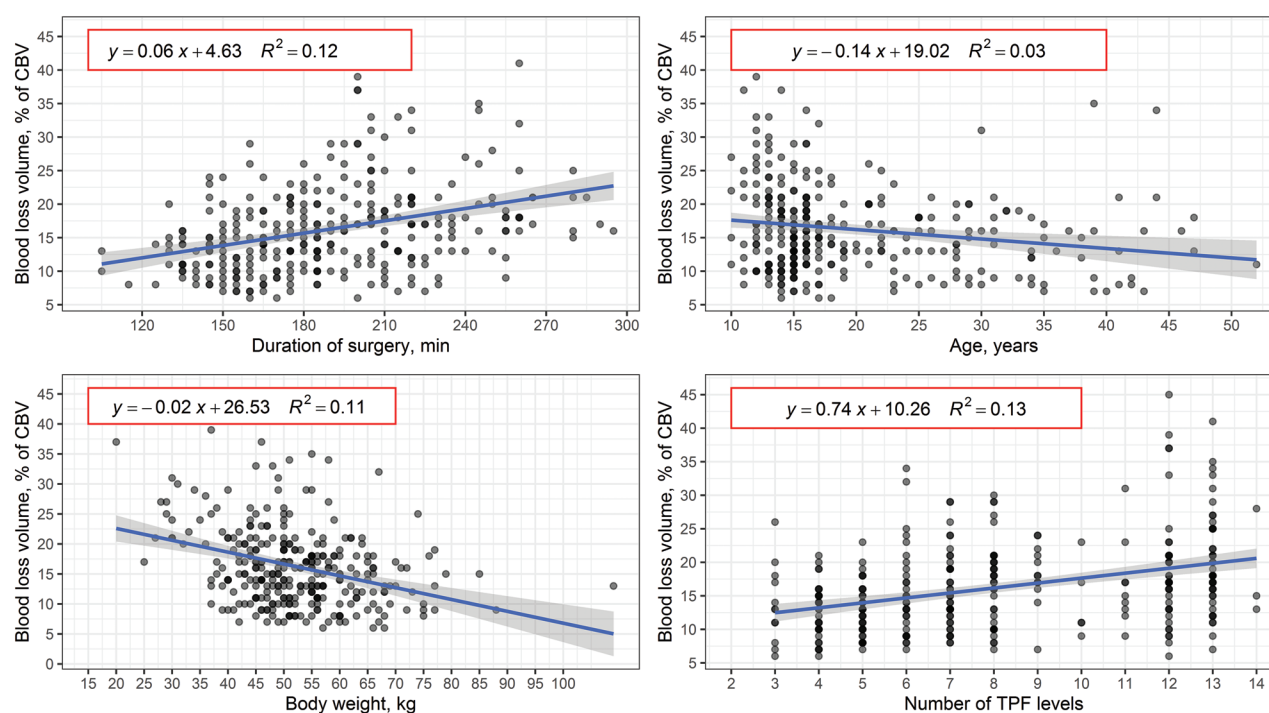
Figure 1. Univariate linear regression models of the blood loss volume for patients operated on using vertebrectomy.

Based on the data obtained after PSM, calculations were performed for univariate and multivariate models in order to generate a mathematical model for predicting the expected blood loss volume in patients who were planned to undergo multilevel TPF in combination with vertebrectomy **(Fig. 1)**.

The statistical calculations were used to derive a formula for determining the volume of expected intraoperative blood loss in AIS patients who were planned to undergo multilevel TPF in combination with vertebrectomy (**formula 1**):

% of CBV = 0.66 × number of TPF levels – 0.17 × body weight + 19.84 ± 4.15,

where 0.66 and 0.17 are linear regression coefficients; 19.84 is the base; 4.15 is an estimate of random residuals of the model.

In our earlier study, we proposed a formula for predicting the intraoperative blood loss volume for cases of multilevel TPF alone (**formula 2**):

% of CBV = 0.34 × number of TPF levels – 0.19 × body weight + 25.88 ± 6.67,

where 0.34 and 0.19 are linear regression coefficients; 25.88 is the base; 6.67 is a random residual of the model.

We compared the formulas. Upon comparison of the residuals, the Mann-Whitney U-test was –3.27 [–6.71; 0.33] and –0.46 [–4.15; 2.95], respectively; the shift was 2.51 [1.63; 3.38], which indicated a statistically significant difference ($p<0.001$).

Therefore, we have found that **formula 1** predicts a statistically significantly lower volume of intraoperative blood loss, by 2.51% [1.63; 3.38], compared to **formula 2** that overestimates, by 3.27% [–6.71; 0.33], a predicted volume of blood loss expressed as % of CBV. Therefore, we have concluded that some overestimation of expected intraoperative blood loss is most reasonable for increasing the level of patient safety due to readiness for the worst case scenario during surgery.

DISCUSSION

SPO osteotomy at one or several levels is a surgical stage, the inevitable consequence of which is additional injury to the intervertebral ligaments and muscles as well as to the bone elements at each spinal motion segment level. Given the available literature data and the technique for performing this stage, it was logical to assume that vertebrectomy might affect intraoperative blood loss. Comparison of the obtained data revealed that the blood loss volume was significantly higher in Group II where patients underwent vertebrectomy. However, it was noteworthy that the number of operated TPF levels in Group II was also statistically significantly higher. Because our previous studies demonstrated that the number of TPF levels was a significant predictor of intraoperative blood loss, we decided to align the

groups for the number of TPF levels using the PSM method, which revealed no statistically significant differences between the groups.

In surgery for AIS, the problem of preoperative prediction of the blood loss severity remains topical for personifying preoperative preparation, optimizing infusion-transfusion support, and, thereby, increasing the safety level of operated patients. The authors of some studies have proposed formulas for predicting the volume of expected blood loss for posterior correction of AIS. For example, Ialenti MN et al. reported a formula accounting for the duration of surgery, magnitude of kyphotic spinal deformity in degrees, and gender of patients.[21] Chao Li et al. studied predictors of increased blood loss and proposed a formula for determining its expected value, which included the data on deformity stiffness/mobility, determined based on functional X-rays of the spine; values of the Risser test that positively correlated with age, body weight, circulating blood volume, and skeletal maturation; fibrinogen indicators; APTT and the number of levels involved in the posterior fusion area. The authors reported that 1 unit of the fusion level caused an increase in intraoperative blood loss by 53.470 units.[12]

Previously, using statistical regression analysis, we developed mathematical models for predicting intraoperative blood loss in posterior spinal fusion surgery involving the multilevel TPF technique, which accounted for different technological capabilities of clinics, i.e. the availability of a Jackson table and the possibility of preoperative examination of the hemostasis system using low-frequency piezoelectric thromboelastography.[14]

The present study did not reveal a significant effect of vertebrectomy on the volume of intraoperative blood loss. This fact once again indicates that it is the number of TPF levels that is an indicator that may be used as a prognostic one. The previously proposed mathematical model for predicting intraoperative blood loss in posterior correction of AIS using the multilevel TPF technique, which includes the main significant a priori predictor of blood loss – the number of TPF levels (% of CBV = 0.34×number of TPF levels – 0.19×body weight + 25.88±6.67), approaches, in our opinion, a universal model and may be successfully used in daily practice.[14]

CONCLUSION

Smith-Peterson osteotomy did not affect the amount of blood loss during surgical correction of adolescent idiopathic scoliosis, considering the number of transpedicular fixation levels.

Author's Contribution

AI: setting and processing of material, development of design of research, writing of article;
MM: scientific consulting;
VN: setting of clinical material, participation in the review

of publications on the topic of the article;
AV: setting of clinical material, participation in the review of publications on the topic of the article;
VL: statistical analysis of the material;
ML: scientific guidance, editing of the article

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Влияние остеотомии Смита-Петерсона на кровопотерю при хирургической коррекции подросткового идиопатического сколиоза

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Резюме

Введение: Хирургическая коррекция подросткового идиопатического сколиоза неизбежно сопровождается кровопотерей. Около 37-85% пациентов подвергаются аллогенным переливаниям, связанным с риском серьёзных осложнений. Прогнозирование объёма ожидаемой кровопотери остается актуальной проблемой. В связи с этим возникает необходимость уточнить предикторы повышенной кровопотери.

Цель: Оценить влияние вертебрэктомии на объём интраоперационной кровопотери при хирургической коррекции подросткового идиопатического сколиоза.

Материалы и методы: В этом ретроспективном исследовании приняло участие 511 подростков, которым была проведена коррекция задней деформации позвоночника. Были выделены две группы: 1-я группа состояла из 303 пациентов, перенёсших многоступенчатую транспедикулярную фиксацию; В группу 2 вошло 208 пациентов, перенёсших многоступенчатую транспедикулярную фиксацию в сочетании с остеотомией Смита-Петерсона.

Результаты: Межгрупповые сравнения выявили существенные различия в количестве уровней транспедикулярной фиксации и объёме кровопотери, которые были выше в группе 2. После выравнивания групп по количеству уровней транспедикулярной фиксации с использованием метода оценки воздействия (Метод сопоставления баллов склонности), статистически значимой разницы обнаружено не было. Мы вывели формулы для расчёта объёма ожидаемой кровопотери в группах 1 и 2. Сравнение формул показало, что формула в группе 2 предсказывала значительно меньшую кровопотерю – на 2.51%, в то время как формула для группы 1 предсказывала значительно более высокий объём кровопотери – на 3.27%. По нашему мнению, применение формулы, которая переоценивает ожидаемую интраоперационную кровопотерю, является разумным из-за возможности сценария наихудшего варианта во время операции. Следовательно, формула для группы 1 напоминает универсальную модель приложения.

Заключение: Остеотомия Смита-Петерсона не влияла на количество кровопотери при хирургической коррекции подросткового идиопатического сколиоза, учитывая количество уровней транспедикулярной фиксации.

Ключевые слова

подростковый идиопатический сколиоз, кровопотеря, транспедикулярная фиксация, вертебрэктомия