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Original Article

Is It Possible to Predict Postoperative Blood Loss in Surgery for Idiopathic Scoliosis?

Maya N. Lebedeva[1], Anastasia A. Ivanova[1], Mikhail V. Mikhaylovskiy[1], Vyacheslav V. Novikov[1], Vitaliy L. Lukinov[1], Aleksandr S. Vasyura[1]

[1] *Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, Novosibirsk, Russia*

Corresponding author: Anastasia Ivanova, Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics, 17 Frunze St., Novosibirsk 630091, Russia; Email: aivanova.nsk@yandex.ru; Tel.: 89139 468 840

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Abstract

Introduction: Postoperative drain loss can exceed intraoperative blood loss and affect the severity of the patient's condition.

Aim: The objective of the study was to find significant predictors of postoperative blood loss in surgery for idiopathic scoliosis.

Materials and methods: We analyzed the data of 140 patients with idiopathic scoliosis. One hundred three patients (group 1) underwent Smith-Petersen osteotomy as part of the multilevel pedicle screw fixation; 37 patients (group 2) required no spinal osteotomy. Correlation and regression analysis of the data was performed.

Results: There were significant differences between the groups in the number of fixed segments ($p<0.001$), the volume of intraoperative blood loss ($p<0.001$), drain loss ($p=0.010$), and perioperative blood loss ($p<0.001$). The study showed that spinal osteotomy had no effect on the volume of postoperative blood loss. A univariate regression analysis revealed the following predictors: patient's body weight −0.3 [−0.4; −0.2] ($p<0.001$) and intraoperative blood loss expressed as a percentage of circulating blood volume 0.3 [0.2; 0.5] ($p<0.001$). The predictors established in univariate regression analysis were significant also in the multivariate analysis.

Conclusions: The study established the most significant predictors determining the volume of postoperative blood loss in surgery for idiopathic scoliosis: body weight and intraoperative blood loss expressed in percentages of circulating blood volume. A model for predicting the volume of postoperative blood loss was created based on the identified parameters. This model will optimize support for the treatment associated with transfusion during the perioperative period.

Keywords

blood loss predictors, pedicle screw fixation, spinal deformity, spinal osteotomy, wound drain

INTRODUCTION

The end of spinal surgery does not mean cessation of the patient's blood loss due to the impossibility of achieving complete hemostasis in the area of tissue damage. Various types of postoperative wound drains are used to remove the wound output. Although the drains are commonly used after spinal surgery, their effectiveness remains controversial.[1,2] The decision of whether to apply drainage and what type of placement and management of postoperative drains to use is often based on the surgeon's preference rather than evidence-based medicine.[3-6] The volume of postoperative blood loss can be equal to or even exceed that of the intraoperative blood loss.[7-10] However, the question of what factors determine the volume of blood loss in the postoperative period remains open.

The predictors of massive postoperative blood loss during surgical correction of scoliosis in adolescents are believed to be the following: the body mass index, preoperative platelet count, the severity of spinal deformity, the number of fusion levels and screws placed, osteotomy surgeries, volume of intraoperative infusion of crystalloids and colloids, and transfusions of donor blood components.[8,11,12]

Maintaining an adequate oxygen capacity of the blood is known to be the key to successful postoperative rehabilitation of a patient. In this regard, underestimation of the significance of drain loss can significantly affect the postoperative state of patients who underwent the surgery for idiopathic scoliosis (IS). Therefore, increasing the patient's safety level is tightly associated with prediction, adequate assessment, and correction of both intraoperative and postoperative blood loss.[13-15] Analyzing the available scientific sources on the topic, we did not come across a single publication proposing options for predicting the postoperative blood loss .

Taking into account different opinions about the effect of spinal osteotomies on drain loss, we proposed the following null hypothesis: spinal osteotomies have no significant effect on the postoperative blood loss.

AIM

The objective of the study was to find the significant predictors of postoperative blood loss in surgery for idiopathic scoliosis.

MATERIALS AND METHODS

In this retrospective study, we analyzed the data for 140 adolescent IS patients who received surgical treatment for spinal deformities at Novosibirsk Research Institute of Traumatology and Orthopedics n.a. Y.L. Tsivyan in 2016–2017. The inclusion criteria were IS, age of 11–18 years, and first dorsal fusion with pedicle screw fixation (PSF). The exclusion criteria were blood disorders, multistage surgery, and Risser stage <3 skeletal maturity. During surgery, 103 patients (group 1) underwent dorsal fusion with PSF and Smith-Petersen osteotomy, 37 patients (group 2) were given only dorsal fusion with PSF. These operations were performed by experienced surgeons using the technology accepted in the clinic under general anesthesia (sevoflurane, fentanyl, clonidine or ketamine) with mechanical ventilation and complete decompression of the anterior abdominal wall (on the Jackson table). Intraoperative blood loss was determined by measuring the volume of blood aspirated from the wound and weighing the total surgical output. The infusion-transfusion assistance to the performed surgeries was determined based on the blood loss volume and blood hemoglobin level. Hemodilution was not used during surgery. Before wound suturing, all patients underwent wound drainage in the fusion area. After wound sealing, the drainage tube was checked for patency. The drainage was then blocked for four hours to achieve spontaneous hemostasis in the wound. Drain placement and postoperative management were carried out in all operated patients according to the only technology adopted in the clinic. After completion of surgery, the patients were transferred to the intensive care unit where the drainage was opened after a specified period of time, and the volume of drain blood poured out at once and further wound outputs were assessed. All information was documented in the patients' medical records. If vital signs were satisfactory and the rate of drain loss did not exceed 20 ml per hour, patients were transferred to the specialized unit. The drain was removed in all patients three days postoperatively provided that drain losses for the previous day were insignificant (≤100 ml). The following parameters were analyzed in the groups and the general sample: sex, age, anthropometric data, surgery duration, number of PSF levels, number of osteotomy levels in group 1 patients, intraoperative blood loss and drainage blood loss volumes expressed in both ml and % of circulating blood volume (CBV).

The research was conducted in full compliance with the ethical laws (extract from the minutes of the Biomedical Ethics Committee No. 006/11 dated 25.03.2011 and No. 005/17 dated 03.03.2017).

Statistical analysis

All statistical analyses were performed using the RStudio software (version 1.3.959 – © 2009–2020 RStudio, Inc., USA, https://www.rstudio.com/) in R language (versions 4.0.2 (2020-06-22), https://www.R-project.org/). Empirical data distributions were tested for compliance with the normal distribution law according to the Shapiro-Wilk test. Due to the abnormal data distribution, the nonparametric Mann-Whitney U test was used to compare continuous scores between the groups.

Descriptive characteristics are presented as median [first quartile; third quartile] (MED [Q1; Q3]) for numerical data and as percentage for categorical data. To statistically test the hypotheses about the equality of numerical characteristics of sample distributions in the compared groups, the unpaired Mann-Whitney U test was used: the distribution bias was calculated by obtaining a 95% confidence interval for the bias. Two-tailed Fisher's exact test was used to compare categorical data.

Pairwise relationships between parameters were identified by calculating the Spearman's correlation coefficient. The relationship between the parameters and postoperative blood loss was analyzed using univariate and multivariate linear regression models.

Statistical hypotheses were tested at a critical level of significance of $p=0.05$, i.e. the difference was considered statistically significant at $p<0.05$.

RESULTS

The main parameters in the groups are presented in **Table 1.**

As can be seen in **Table 1**, the groups differed statistically significantly in the number of PSF levels and the volume of intraoperative blood loss.

Sixty-two percent of group 1 patients underwent two-level osteotomy, 32% and 6% of patients had three- and four-level osteotomy, respectively. The vast majority of patients were females: women were 86.4% and 78.4% in groups 1 and 2, respectively (p=0.294).

Analysis of postoperative drainage loss demonstrated that blood loss volume was the highest on the first day of the postoperative period and amounted to 300 [200; 350] ml in group 1 and 250 [200; 350] ml in group 2 (p=0.294). On the second day, the drainage blood loss volume decreased to 200 [100; 250] ml in group 1 and 150 [100; 200] ml in group 2 (p=0.067). Data on the total postoperative blood loss are presented in **Table 2**.

As can be seen in **Table 2**, significant differences were found in the total drainage blood loss volume expressed in % of CBV between the groups.

Calculation of Spearman's correlation coefficient (r) in group 1 revealed a high positive correlation between drainage blood loss volume in % of CBV and intraoperative blood loss volume (r=0.87; p<0.001); a weak correlation with surgery duration (r=0.41; p<0.001) and the number of PSF levels (r=0.41; p<0.001); and a very weak negative correlation with the patient's body weight (r=−0.27; p<0.006) and height (r=−0.25; p<0.010).

The univariate linear regression models made it possible to establish the most significant predictors determining the drainage blood loss volume expressed in % of CBV in group 1: patient's weight (coefficient: −0.361, 95% CI [−0.48; −0.24], p<0.001), height (coefficient: −0.148, 95% CI [−0.28; −0.01], p=0.034), and intraoperative blood loss in % of CBV (coefficient: 0.274, 95% CI [0.11; 0.44], p=0.002). Construction of multivariate models did not reveal any relation between the factors.

An average negative correlation of drainage blood loss volume as % of CBV with patient's body weight (r=−0.54; p<0.001), a weak negative correlation with patient's height (r=−0.37; p=0.026), and an average positive correlation with intraoperative blood loss volume (r=0.54; p<0.001) were found in group 2. Construction of linear regression models of drainage blood loss volume as % of CBV in group 2 did not reveal any significant predictors.

Assessment of perioperative blood loss (intraoperative + postoperative) did not show any significant differences between the groups in blood loss expressed both in ml and % of CBV: 1250 [1050; 1450] ml in group 1; 1100 [950; 1250] ml in group 2 (p=0.005); 36.4% [30.4; 43.2]% of CBV in group 1; 30.6 [25.9; 35.1]% of CBV in group 2 (p<0.001).

Construction of univariate linear regression models allowed us to identify significant predictors of perioperative blood loss in ml in group 1: patient's body weight (coefficient: 6.98, 95% CI [0.26; 13.7], p=0.042), intraoperative blood loss in % of CBV (coefficient: 30.34, 95% CI [23.92; 36.76], p<0.001), surgery duration (coefficient: 2.681, 95% CI [0.95; 4.41], p=0.003), and the number of PSF levels (coefficient: 21.208, 95% CI [1.54; 40.88], p=0.035). Significant univariate predictors of perioperative blood loss in ml in group 2 were patient's weight (coefficient: 12.191, 95% CI [6.33; 18.05], p<0.001) and intraoperative blood loss in ml (coefficient: 1.486, 95% CI [0.99; 1.98], p<0.001).

Since we found statistically significant differences between the groups in the drainage blood loss volume as % of

Table 1. Distribution of main parameters between the groups

Parameter	Group 1 (n=103) MED [Q1; Q3]	Group 2 (n=37) MED [Q1; Q3]	Difference [95% CI]	Mann-Whitney U test *p* value
Age, years	15 [13; 16]	14 [13; 17]	0 [-1; 1]	0.933
Height, cm	161 [154.5; 167.5]	160 [155; 165]	0 [-3; 4]	0.857
Body weight, kg	50 [44; 56]	48 [44; 59]	2 [-6; 2]	0.358
Surgery duration, min	175 [152.5; 200]	155 [150; 185]	10 [0; 25]	0.058
Number of PSF levels	7 [5; 12]	5 [4; 7]	2 [1; 3]	<0.001*
Intraoperative blood loss, ml	550 [400; 670]	450 [350; 500]	100 [0; 150]	0.009*
Intraoperative blood loss, % of CBV	15 [11; 21]	12 [10; 15]	3 [1; 5]	<0.001*

* statistically significant difference.

Table 2. Total postoperative blood loss in groups

Parameter	Group 1 (n=103) MED [Q1; Q3]	Group 2 (n=37) MED [Q1; Q3]	Difference [95 % CI]	Mann-Whitney U test, *p* level
Total drainage blood loss volume, ml	700 [600; 850]	650 [550; 800]	50 [0; 130]	0.104
Total drainage blood loss volume, % of CBV	20.4 [17.1; 23,8]	17.9 [14.6; 21.5]	2.7 [0.6; 4.7]	0.010*

* statistically significant difference.

CBV, we decided to conduct a statistical analysis of the data for the entire sample of patients to confirm or exclude the effect of spinal osteotomies on the value of postoperative blood loss.

Analysis of the entire sample of patients revealed a weak positive correlation of drainage blood loss volume with surgery duration (r=0.35; p<0.001) and the number of PSF levels (r=0.39; p<0.001) as well as a weak negative correlation with the patient's body weight (r=−0.32; p=0.033) and height (r=−0.26; p=0.002). **Table 3** shows the results from the regression analysis in the general sample of patients.

As can be seen from the data presented in **Table 3**, significant predictors of drainage blood loss volume expressed in % of CBV identified by univariate regression analysis were also significant in multivariate analysis and included in the formula for predicting the volume of postoperative blood loss.

Regression model formula

Drainage blood loss in % of CBV =
−0.235*×body weight + 0.198*×IBL% of CBV + 28.53* + random discharges,

where * are coefficients for a multivariate linear regression model and IBL is intraoperative blood loss in % of CBV.

Having estimated the boundaries of the interval for random discharges, we obtained the following formulas for:

The upper limit of the estimated drainage blood loss volume in % of CBV:

Drainage loss in % of CBV=
−0.235 * × body weight + 0.198 * × IBL % of CBV + 39.14

The lower limit of the estimated drainage blood loss volume in % of CBV:

Drainage loss in % of CBV=
−0.235 * × body weight + 0.198 * × IBL % of CBV + 19.44

The total p level of model significance is < 0.001.

Since intergroup comparison showed significant difference in the number of PSF levels between the groups and because we had previously shown that the main factor determining the volume of intraoperative blood loss is this variable, as well as to finally confirm the significance of the effect of spinal osteotomy on drain loss, we decided to fit such heterogeneous parameters as PSF levels and intraoperative blood loss volume in the groups using the Propensity Score Matching (PSM) method, namely, the Caliper Nearest Neighbor Matching method. The propensity score was calculated using a logistic regression model with an objective function belonging to the group without (II) and with spinal osteotomy (I); the intraoperative blood loss (ml) was considered as a covariant. IBL was chosen as a covariant due to its correlation with number of PSF levels (r=0.42; p<0.001) and its greater significance as a predictor in assessing drain loss compared to the number of PSF levels. The caliper was assumed 0.3; the group ratio was 1: 1. After fitting, there were 36 patients left in the groups. **Table 4** provides a comparison of parameters between the groups after PSM.

DISCUSSION

Awareness of predictors determining the volume of postoperative blood loss during surgical correction of IS is an important aspect of personalized patient management which increases safety after completion of the surgical stage of treatment. The data we obtained on the value of postoperative and perioperative blood loss during surgical correction of IS, as well as relationships revealed both in the groups and in the general sample of patients, are quite consistent with the data presented by other authors.[8,11,16,17] However, there are some differences in the literature data on this issue, which is most likely due to the fact that the authors consider heterogeneous preoperative and intraoperative parameters as factors influencing the volume of postoperative blood loss.

Table 3. Linear regression models for the general sample of patients

Covariant	Univariate model		Multivariate model	
	Coefficient [95% CI]	p	Coefficient [95% CI]	p
Sex	−0.96 [−3.9; 21.9]	0.521		
Age	−0.3 [−0.7; 0.2]	0.293		
Body weight	−0.3 [−0.4; −0.2]	<0.001*	−0.235 [−0.33; −0.14]	<0.001*
Height	−0.1 [−0.2; 0]	0.056		
Intraoperative blood loss, ml	0.0 [0; 0.01]	0.196		
Intraoperative blood loss, % of CBV	0.3 [0.2; 0.5]	<0.001*	0.198 [0.06; 0.34]	0.006*
Surgery duration	−0.0 [−0.1; 0.0]	0.110		
Number of PSF levels	0.00 [−0.3; 0.3]	0.849		
Spinal osteotomies	3.4 [−1.1; 5.8]	0.005*		

* – statistically significant difference.

Table 4. Comparison of parameters between the groups after PSM

Parameter	Group 1 (n=103) MED [Q1; Q3]	Group 2 (n=37) MED [Q1; Q3]	Comparison	
			Difference [95 % CI]	Mann-Whitney U test, *p* value
Age, years	15 [13; 17]	14.5 [13.75; 17]	0 [-1; 1]	0.641
Height, cm	161 [155; 168.25]	160.5 [155; 165.75]	2 [-2; -6]	0.457
Body weight, kg	50 [45; 56]	49 [44; 59]	0 [−6; 3]	0.875
Surgery duration, min	160 [140; 180]	157.5 [150; 185]	−5 [−15; 10]	0.664
Number of PSF levels	5 [4; 7]	5 [4; 7]	0 [−1; 1]	0.544
Intraoperative blood loss, ml	450 [387.5; 562.5]	450 [387.5; 512.5]	0 [−50; 70]	0.540
Intraoperative blood loss, % of CBV	11.709 [10.48; 7.46]	12.005 [10.39; 15.1]	0.45 [−1.16; 2.3]	0.582
Total drain blood loss volume	205 [200; 285]	245 [187.5; 277.5]	0 [−50; 50]	0.868
Perioperative blood loss, ml	1160 [1000; 1262.5]	1125 [972.5; 1262.5]	50 [−50; 150]	0.323
Perioperative blood loss, % of CBV	32.86 [29.08; 37.85]	30.81 [26.21; 35.11]	2.34 [−0.95; 5.62]	0.131
Sex	f – 31 (86.1 %) m – 5 (13.9 %)	f – 28 (77.8 %) m – 8 (22.2 %)		0.541
Number of Smith-Petersen osteotomies	2 – 23 (63.9 %) 3 – 13 (36.1 %)			

In particular, a strong correlation between drainage blood loss volume and intraoperative blood loss was reported by Gubin et al.[11], while patient's body weight was not considered a significant factor. Guay et al.[18] studied IS patients and concluded that the number of fused segments is a key factor in predicting intraoperative and total (intraoperative + postoperative) blood loss. The authors also noted that no factor considered alone could adequately predict postoperative bleeding.

The data presented by Choi et al.[19] are the closest to our study. This is because the authors analyzed the effect of Ponte osteotomies in addition to other preoperative and intraoperative parameters on postoperative blood loss in 50 patients with IS who underwent dorsal correction of spinal deformity with PSF. The data presented by the authors indicate a positive correlation of drain loss with intraoperative blood loss (r=0.28, p=0.049), number of red blood cells transfused during surgery (r=0.31, p=0.03), and the number of Ponte osteotomies (r=0.43, p=0.002). The strongest correlation among osteotomy parameters was found with the volume of postoperative blood loss. A multivariate regression analysis performed by the authors established the number of spinal osteotomies to be the only significant variable associated with the volume of postoperative blood loss. Having conducted a statistical analysis, the authors concluded that multiple spinal osteotomies and significant intraoperative blood loss are more likely to result in significant drain loss.

The univariate regression analysis revealed the following predictors of drainage loss: patient's body weight −0.3 [−0.4; −0.2] (p<0.001), the volume of intraoperative blood loss in % of CBV 0.3 [0.2; 0.5] (p<0.001), and spinal osteotomies 3.4 [−1.1; 5.8] (p=0.005). However, multivariate regression analysis showed that osteotomy is an insignificant factor. This conclusion was further confirmed by the results of group fitting using heterogeneous parameters. Thus, the results of our study demonstrated the absence of any effect of spinal osteotomy on the volume of postoperative blood loss and, hence, confirmed the validity of the formulated null hypothesis.

It is interesting to note that the correlation analysis showed that body weight and the drainage blood loss volume expressed in % of CBV negatively correlate with each other. We assume that the greater the patient's body weight is, the more severe the tissue damage in the fusion area is, which is associated with a high level of tissue factor released to the bloodstream. This circumstance causes a pronounced activation of the hemostasis system and, thus, affects the drainage blood loss volume. Further research aimed at studying the perioperative functional state of the hemostatic system in a specific category of patients will make it possible to confirm this assumption.

The positive side of the presented research is that the defined inclusion and exclusion criteria determined the homogeneity of the study sample. However, the work has limitations: the study sample was not sufficiently large, which could affect the power of the statistical relationship. Moreover, we measured only visible postoperative blood loss, which is evaluated directly, and did not take into account possible occult bleeding. However, the decision to use this approach to assess the postoperative blood loss was a conscious choice, since drain output is known to have a low hematocrit[9], and the proposed formula for calculating the predicted drainage blood loss volume considers the loss of blood with hematocrit level similar to the one of circulating blood, thus minimizing possible design errors. We recommend performing calculations using the formula for the upper limit of the estimated drainage blood loss volume in practice. The proposed model for assessing the volume of postoperative blood loss is certainly not universal. The value of determination coefficient R^2 in our multivariate model, which equals 0.25, suggests that there are other factors besides the identified ones that affect postoperative blood loss. The search for these factors in future studies can make certain adjustments to the created mathematical model for predicting drainage blood loss volume.

CONCLUSIONS

The study established the most significant predictors determining the volume of postoperative blood loss in surgery for idiopathic scoliosis: body weight and intraoperative blood loss expressed in % of CBV. A model for predicting the volume of postoperative blood loss was created based on the identified parameters. This model will optimize the material and technical support for the treatment associated with transfusion during the perioperative period.

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Можно ли прогнозировать послеоперационную кровопотерю в хирургии идиопатического сколиоза?

Майя Н. Лебедева[1], Анастасия А. Иванова[1], Михаил В. Михайловский[1], Вячеслав В. Новиков[1], Виталий Л. Лукинов[1], Александр С. Васюра[1]

[1] *Новосибирский научно-исследовательский институт травматологии и ортопедии им. Я. Л. Цивьяна, Новосибирск, Россия*

Адрес для корреспонденции: Анастасия Иванова, Новосибирский научно-исследовательский институт травматологии и ортопедии им. Я. Л. Цивьяна, ул. Фрунзе № 17, Новос ибирск, Россия; Email: aivanova.nsk@yandex.ru; тел.: 89139 468 840

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Резюме

Введение: Послеоперационная дренажная потеря может превышать интраоперационную кровопотерю и влиять на тяжесть состояния пациента.

Цель: Цель исследования состояла в том, чтобы найти значимые предикторы послеоперационной кровопотери в хирургии идиопатического сколиоза.

Материалы и методы: Проанализированы данные 140 пациентов с идиопатическим сколиозом. Ста трём пациентам (1-я группа) выполнена остеотомия Смита-Петерсена в составе многоуровневой фиксации транспедикулярными винтами; У 37 пациентов (2-я группа) остеотомия позвоночника не потребовалась. Проведён корреляционный и регрессионный анализ данных.

Результаты: Выявлены достоверные различия между группами по количеству фиксированных сегментов ($p<0.001$), объёму интраоперационной кровопотери ($p<0.001$), дренажной кровопотере ($p=0.010$) и периоперационной кровопотере ($p<0.001$). Исследование показало, что остеотомия позвоночника не влияла на объём послеоперационной кровопотери. Однофакторный регрессионный анализ выявил следующие предикторы: масса тела пациента -0.3 [-0.4; -0.2] ($p<0.001$) и интраоперационная кровопотеря, выраженная в процентах от объёма циркулирующей крови 0.3 [0.2; 0.5] ($p<0.001$). Предикторы, установленные в одномерном регрессионном анализе, оказались значимыми и в многомерном анализе.

Заключение: Установлены наиболее значимые предикторы, определяющие объём послеоперационной кровопотери в хирургии идиопатического сколиоза: масса тела и интраоперационная кровопотеря, выраженные в процентах от объёма циркулирующей крови. На основании выявленных параметров создана модель прогнозирования объёма послеоперационной кровопотери. Эта модель оптимизирует поддержку лечения, связанного с переливанием крови, в периоперационный период.

Ключевые слова

предикторы кровопотери, транспедикулярная фиксация, деформация позвоночника, остеотомия позвоночника, дренирование раны