Hidden Blood Loss in Adolescent Idiopathic Scoliosis Patients Undergoing Posterior Spinal Fusion Surgery: A Retrospective Study of 765 Cases in a Single Center

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Research Article

Keywords: Hidden blood loss (HBL), adolescent idiopathic scoliosis, risk factors, multivariate linear regression analysis, posterior spinal fusion surgery, postoperative blood transfusion

Posted Date: June 4th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-523705/v1

Abstract

Purpose: To investigate Hidden blood loss (HBL) and its potential risk factors in adolescent idiopathic scoliosis patients undergoing posterior spinal fusion surgery and elucidate the influence of HBL on postoperative blood transfusion.

Methods: We retrospectively studied 765 patients undergoing posterior spine fusion for adolescent idiopathic scoliosis from January 2014 to December 2018. The patient's demographics, blood loss related parameters, operation and blood loss information were extracted. The association between patient's characteristics and HBL was analyzed by Pearson or Spearman correlation analysis. Multivariate linear regression analysis was used to determine independent risk factors associated with HBL. Binary logistic regression analysis was used to analyze the influence of HBL on postoperative blood transfusion.

Results: A total of 765 patients including 128 males and 637 females (age range 10-18 years) were included in this study. The mean amount of HBL was 693.5±473.4 ml, accounting for 53.9% of the total blood loss. In multivariate linear regression analysis, we found that preoperative Hct (p=0.003) and allogeneic blood transfusion (p<0.0001) were independent risk factors for HBL, while tranexamic acid (p=0.003) was negatively related to HBL. Binary logistic regression analysis showed that HBL > 850 ml (P < 0.001, OR: 8.845, 95%CI: 5.806-13.290) was the independent risk factor for postoperative blood transfusion.

Conclusion: a large amount of HBL was incurred in adolescent idiopathic scoliosis patients undergoing posterior spinal fusion surgeries. Allogeneic blood transfusion and preoperative Hct were independent risk factors for HBL, while tranexamic acid was negatively related to HBL. HBL and its influential factors should be taken into account when considering the perioperative transfusion management. These patients with HBL greater than 850 ml should be paid more attention in case of postoperative anemia.

Level of evidence: Level III

Background

Blood loss remain a major focus in orthopedic surgery for adolescent idiopathic scoliosis due to extensive and complex operating procedure. Anesthesiologists and surgeons might mainly consider the visible blood loss including postoperative drainage, and ignore component penetration into the tissues, residual blood into vertebral canal and loss due to hemolysis, which was known to hidden blood loss [1]. The concept of HBL was firstly put forward by sehat in 2000 [2] and has received more and more attention by clinicians in recent years. Xu et al. [3] showed that the HBL in posterior lumbar interbody fusion surgery approximately accounted for 61% of total blood loss in rheumatoid arthritis patients. Kai et al. [4] also reported the HBL reached 1084 ml, accounting for 82% of total blood loss after hip hemiarthroplasty. HBL could deteriorate postoperative hemoglobin drop, resulting in increased blood transfusion requirement. Clarifying HBL will be of great importance for anesthesiologists to determine the strategies of perioperative blood transfusion. However, until now few published literatures have examined the hidden blood loss in posterior spinal fusion surgeries for adolescent idiopathic scoliosis. In this study, we retrospectively explored the amount of HBL in adolescent idiopathic scoliosis surgery and analyzed the influential factors of HBL.

The previous study reported that 23.4% patients required postoperative transfusion in posterior spinal fusion surgeries for adolescent idiopathic scoliosis [5]. Furthermore, we also found that a considerable number of patients still encountered anemia after the operation at our medical center, which requiring transfusion. Postoperative anemia will have a negative effect on the illness recovery and extended length of stay. This phenomenon may be associated with hidden blood loss. Therefore, clarifying the relationship between hidden blood loss and postoperative transfusion will be available to guide perioperative blood transfusion.

Materials And Methods

Patients

Institutional review board approval was waived as patients' private information was not retrieved. We retrospectively reviewed the medical date of 765 patients undergoing posterior spinal fusion surgeries for adolescent idiopathic scoliosis from January 2014 to December 2018 in our hospital. All the surgeries were performed by highly experienced surgeons using a uniform approach. Inclusion criteria were patients (1) younger than 18 years and diagnosed adolescent idiopathic scoliosis; (2) underwent posterior spinal fusion surgery; (3) obtained stable perioperative fluid balance and hemodynamics. Exclusion criteria were patients (1) with coagulation disorders or perioperative infection; (2) with anticoagulant drugs; (3) with intraoperative blood loss greater than 2.5 L on account to larger bias with excessive blood loss[6]; (4) suffered cerebrospinal fluid leakage.

Date Extraction

Demographic information were collected from electronic medical record including age, sex, height, weight, body mass index (BMI), preoperative and postoperative hematocrit (Hct) and hemoglobin (Hb), American Society of Anesthesiologists (ASA) classification, preoperative Cobb angle, prothrombin time and activated partial thromboplatin time; Surgery information included operation time, pedicle screw number, bone mineral density, the number of surgical segments, whether undergoing osteotomy, the use of tranexamic acid, intraoperative blood loss, postoperative drainage volume, and allogeneic and autologous blood transfusion volume.

Blood Loss Management and Calculation of HBL

Intraoperative blood loss was recorded by the anesthesiologist, which was mainly comprised of the blood in the suction apparatus and in the soaked gauzes that were used during the entire operation. Postoperative blood loss was calculated though measuring the blood volume in the hemovac. Most of the hemovac was removed on the third postoperative day, if the drainage tube can not be removed when calculating the blood loss, we measured the blood in the drainage tube on the day when the blood was taken. The total visible blood loss was calculated as the sum of intraoperative blood loss and postoperative drainage. The blood loss during the operative procedure could be collected by blood salvage technique and reinfusion to the patient as autologous blood, which was decided by the anesthesiologist. Patients were given blood transfusion when hemoglobin level was below 70 g/dL, or below 80 g/dL with a significant symptom of anemia, such as increased heart rate hypotension. We calculated the patients blood volume (PBV) according to the formula described by Nadler et al. [7] PBV (L) = $k1 \times \text{height (m)}^3 + k2 \times \text{weight (kg)} + k3$, ($k1 = 0.3669$, $k2 = 0.03219$, $k3 = 0.6041$ for male, and $k1 = 0.3561$, $k2 = 0.03308$, $k3 = 0.1833$ for female). The total red cell volume can be calculated through multiplying the PBV and the patients Hct together. Therefore, the reduction in Hct would reflect the change in red cell volume [8]. As the hemorrhage is continuing, the fluid persist transfusing to sustain the patients circulating volume. The linear formula proposed by Gross was found intimately following logarithmic formula [9]. According to Gross formula [9], total blood loss = PBV ($Hct_{pre} - Hct_{post}$)/Hct_{ave}, where Hct_{pre} is the initial preoperative Hct, Hct_{post} was Hct on the second or the third day postoperatively, and Hct_{ave} is the average of the Hct_{pre} and the Hct_{post}. Hidden blood loss was calculated by subtracting the visible blood loss from the total blood loss according to the formula of Sehat et al. [10] The formula was

Hidden blood loss = total blood loss − visible blood loss;

When perioperative blood transfusion was performed, Hidden blood loss = total blood loss + allogeneic blood transfusion + autologus blood transfusion − visible blood loss.

Statistical Analysis

All date analyses was performed using IBM SPSS 22.0 software. Categorical variables are presented as frequencies and the chi-squared test was took to compare dichotomous variables, normally distributing continuous variables are presented as means ± SD deviations and independent sample t test was used to compare intergroup difference. The Pearson correlation (used for the normal date), Spearman correlation analysis (used for the non-normal date) and multivariate linear regression analysis were performed to identify risk factors of HBL, including 13 quantitative variables (age, ASA classification, BMI, preoperative Hct, preoperative Cobb angle, prothrombin time, activated partial thromboplatin time, bone mineral density, operation time, segment number, pedicle screw number, autologous blood transfusion, allogeneic blood transfusion, postoperative drainage) and qualitative variables (osteotomy, tranexamic acid and gender). In the qualitative variables, osteotomy and the tranexamic acid were set as “1”. Non-osteotomy and non-tranexamic acid were set as “0”. The binary logistic regression model was established to identify the the relationship between hidden blood loss and postoperative transfusion. Statistically significant continuous variables were converted to categorical variables through their cut-off points, which was determined by receiver operating characteristic curve (ROC). The level of statistical significance was set at $P < 0.05$.

Results

Demographic and clinical characteristics

A total of 765 patients undergoing posterior spinal fusion corrective surgeries for adolescent idiopathic scoliosis, 128 males and 637 females, were enrolled in the analysis. The mean hidden blood loss was 693.5±473.4 ml, accounting for 53.9% of the total blood loss. The demographic and clinical characteristics are summarized in Table 1. The mean total blood loss were 1285.7±437.5 ml. The mean change of Hct level was 11.0±10.9 %, and the mean Hb loss was 36.8±13.9 g/L. Approximately 690 (90.2%) of patients required intraoperative blood transfusions, and the mean transfusion volume was 672.4±657.1 ml. A total of 205 (26.8%) patients required transfusions of suspended red blood cells after the operation, and the mean transfusion volume was 126.5±242.9 ml.

Table 1 Information of demographic characteristics

Parameters	Statistic
Total patients	765
Gender(M/F)	128/637
Age	14.5±1.7
Weight, kg	47.9±7.9
Height, cm	161.2±8.0
Total blood loss, ml	1285.7±437.5
Intraoperative blood loss, ml	926.8±521.1
Hidden blood loss, ml	693.5±473.4
Postoperative drainage, ml	464.2±200.2
Change of Hct(%)	11.0±10.9
Intraoperative transfusion volume, ml	672.4±657.1
Postoperative transfusion volume, ml	126.5±242.9
Change of Hb, g/L	36.8±13.9
Mean operation time, min	250.1±60.5
Mean BMI, kg/m2	18.4±2.8

Analysis of risk factors for HBL in patients undergoing scoliosis surgery

The Pearson or Spearman correlation analysis for hidden blood loss shown the following parameters with a $p<0.05$ (table 2): gender ($p=0.000$), operation time ($p=0.002$), preoperative Hct ($p=0.000$), preoperative Cobb angle ($p=0.024$), tranexamic acid ($p=0.000$), allogeneic blood transfusion ($p=0.000$) and segment number ($p=0.040$). To further explore the association between HBL and the risk factors mentioned above, we performed multivariate linear regression analysis. The results proposed that preoperative Hct ($p=0.003$) and allogeneic blood transfusion ($p<0.0001$) were independent risk factors for HBL, while tranexamic acid ($p=0.003$) was negatively related to HBL(table 3).

Table 2 Results of the Pearson or Spearman correlation analysis for hidden blood loss

Parameters	**Sig (2-tailed)**	***P***
Age	0.102	0.058
Gender	0.137	**0.000**
BMI	-0.006	0.873
ASA	0.021	0.567
Preoperative Cobb angle	0.082	**0.024**
Preoperative Hct	0.145	**0.000**
Preoperative APTT	0.049	0.176
Preoperative PT	-0.005	0.901
Operation time	0.112	**0.002**
Bone mineral density	-0.066	0.068
Segment number	0.074	**0.040**
Pedicle screw number	0.053	0.146
Osteotomy	0.027	0.449
Autologous blood transfusion	0.009	0.803
Allogeneic blood transfusion	0.194	**0.000**
Postoperative drainage	-0.017	0.631
Tranexamic acid	-0.159	**0.000**

Table 3 Results of multivariate linear regression analysis for hidden blood loss

	Unstandardized		Standardized		
coefficient	β	SE	β	t	P Value
Constant	-66.169	255.887		-0.259	0.796
Gender	95.745	49.444	0.075	1.936	0.053
Preoperative Cobb angle	0.792	1.502	0.019	0.528	0.598
Segment number	-15.017	7.815	-0.078	-1.922	0.055
Operation time	-0.393	0.308	-0.050	-1.274	0.203
Tranexamic acid	-126.394	41.730	-0.103	-3.029	**0.003**
Preoperative Hct	18.205	6.114	0.116	2.978	**0.003**
Allogeneic blood transfusion	0.256	0.027	0.388	9.307	**0.000**

HBL was independent risk factor for postoperative transfusion in scoliosis corrective surgery

As illustrated in table 4, univariate analysis showed that variables including gender, BMI, preoperative Hb, segment number, Pedicle screw number, HBL and postoperative drainage had statistical differences between postoperative transfusion and postoperative non-transfusion group. Statistically significant continuous variables were transformed into categorical variables by their cut-off points. These variables were further analyzed by binary logistic regression and results revealed that HBL > 850 ml ($P < 0.001$, OR: 8.845, 95%CI: 5.806-13.290) was the independent risk factor for postoperative blood transfusion (table 5).

Table 4 Univariate analysis between postoperative transfusion group and non-transfusion group in scoliosis corrective surgery

Parameters	**Transfusion group**	**Non-Transfusion group**	P
Age	14.3±1.8	14.5±1.7	0.504
Gender,male/total(%)	17/205(8.3%)	111/560(19.8%)	**0.000**
BMI, kg/m2	18.0±3.3	18.6±3.0	**0.018**
Preoperative Hb, g/L	130.3±11.5	136.8±11.2	**0.000**
Preoperative Cobb angle, degree	48.9±12.6	47.2±10.6	0.055
Preoperative Hct(%)	38.7±3.0	40.3±2.9	0.949
Preoperative PLT,10^9/l	228.7±52.7	232.4±48.1	0.364
Preoperative INR	1.06±0.07	1.05±0.08	0.151
Preoperative PT, s	12.1±0.9	12.0±0.9	0.061
Preoperative APTT, s	32.4±4.0	30.9±4.0	0.983
Preoperative BUN, mmol/L	4.4±1.1	4.4±1.1	0.593
Preoperative SCR, μmol/L	47.2±9.5	49.5±10.0	0.536
ASA ([illegible]/[illegible])	94/111	296/264	0.087
Segment number, n	10.7±2.3	9.9±2.5	**0.028**
Operation time, min	256.0±63.3	247.9±59.3	0.101
Pedicle screw number, n	15.6±2.3	15.0±2.7	**0.010**
Osteotomy, n(%)	30(14.6%)	72(12.9%)	0.549
Postoperative drainage, ml	545.3±225.1	434.5±181.6	**0.009**
Tranexamic acid, n(%)	22(10.7%)	80(14.3%)	0.230
Intraoperative blood loss, ml	997.6±641.1	900.9±555.9	0.057
HBL, ml	1005.9±594.1	579.2±358.7	**0.000**

Table 5 Results of binary logistic regression analysis for postoperative transfusion in scoliosis corrective surgery

Variables	β	SE	P	OR	95%CI
Gender	1.347	0.319	**0.021**	3.845	2.056-7.192
Segment number > 11	0.569	0.221	**0.010**	1.766	1.145-2.724
BMI > 16.7 kg/m2	-0.241	0.215	0.262	0.786	0.516-1.198
Preoperative Hb > 128 g/L	-1.065	0.213	**<0.001**	0.345	0.227-0.523
Pedicle screw number > 14	-0.189	0.243	0.436	0.828	0.514-1.333
Postoperative drainage > 425 ml	0.978	0.211	**<0.001**	2.658	1.759-4.017
HBL > 850 ml	2.180	0.208	**<0.001**	8.845	5.806-13.290

Discussion

Posterior spinal fusion corrective surgeries for adolescent idiopathic scoliosis are often associated with significant intraoperative blood loss [11–13]. The amount of visible blood loss can be easily measured in perioperative period, which arouses the attention of clinician and intraoperative hidden blood loss causing by hemolysis as well as oozing into tissue spaces is easily underestimated. Xu et al. [3] reported that the average HBL after posterior lumbar interbody fusion surgery on lumbar spinal stenosis was 423 ml, accounting for 61% of total blood loss, together with a percentage of 47% in the total blood loss in the study of Derong et al [14], which was beyond our expectations. Our study showed that the mean HBL for scoliosis surgery was 693.5 ml, accounting for 53.9% of the total blood loss. These results indicated that HBL occupied a considerable proportion in the perioperative blood loss, therefore surgeons and anesthesiologists should pay more attention to physiologic derangement HBL related to.

The concept of HBL was first put forward in 2004 by Sehat et al. [2], however, the underlying mechanism for HBL has not been well clarified. It has reported that the HBL was mainly because of extravasation of the blood into the surgical-site surrounding tissue, blood hemolysis and continuous blood loss after operation. Research has shown that the main reason for HBL was the extravasation of the blood into the tissues through using labeled red blood cells [15–17]. In our study, extensive surgical area for scoliosis surgery provide a wide storage space for bleeding, which consequently, leading to more hidden blood loss compared with transforaminal lumbar interbody fusion surgery [18, 19]. Therefore, it need to be more rigorous in the paravertebral tissue incisions and wound sutures in scoliosis corrective surgery for physicians. Pattison et al. [20] showed that hemolysis was another possible cause for HBL. Faris et al. [21] reported that the employ of unwashed, filtered and reinfused blood increase hemolysis. Furthermore, in this study, intraoperative allogeneic blood transfusion was an independent risk factor for HBL in multiple linear regression analysis. Thereby we speculated that hemolysis of erythrocyte induced by allogeneic blood transfusion might be, at least in part, responsible for HBL in posterior spinal fusion surgeries. Further prospective studies are needed to elucidate the underlying mechanism of HBL.

In this study, we investigated and examined the potential risk factors for HBL involved scoliosis corrective surgery by multivariate linear regression analysis. The results showed preoperative Hct was another independent risk factor for HBL. That is, patients with higher preoperative Hct seem to be in a state of hemoconcentration. More red blood cells would be lost during intraoperative bleeding, which resulted lower Hct when combined with infusion dilution. We speculated that this may be one of the reasons for the more HBL. Our study found that the use of tranexamic acid was negatively related to HBL. Tranexamic acid is a kind of synthetic lysine analog, which was often used in orthopedic surgery as an antifibrinolytic drug. Previous studies have shown that tranexamic acid can effectively reduce the total amount of intraoperative bleeding and the need for blood transfusion in scoliosis corrective surgery [22, 23], but there are few reports on whether tranexamic acid can reduce the HBL involved scoliosis corrective surgery. In transforaminal thoracic interbody fusion, Wang et al. found the application of tranexamic acid significantly reduced HBL [24]. They recommended that tranexamic acid was used as a standard drug to reduce HBL during perioperative period. In current study, tranexamic acid was used at a loading dose of 1 g before skin incision, HBL was significantly reduced compared to the control group in posterior spinal fusion surgery. Therefore, intraoperative use of tranexamic acid may contribute to reducing HBL in scoliosis corrective surgery. However, the sample size of these studies was relatively small, the effect of tranexamic acid on HBL including drug dosage still needs to be confirmed in more rigorous prospective studies with a large sample size.

Excessive blood loss can lead to relevant postoperative complications [25], especially for minors, because their compensatory ability is less sound than that of adults. Wen et al believed a positive association between HBL and operative complications although postoperative complications was not an independent risk factor of HBL [16]. The amount of HBL should be of sufficient concern to clinicians. In this research, the incidence of postoperative blood transfusion was as high as 26.8%. Compared with intraoperative blood transfusion, postoperative anemia is not easily detected in time. Therefore, we explored whether the amount of HBL was related to postoperative transfusion. The binary logistic regression showed that HBL was the independent risk factors for postoperative transfusion for scoliosis corrective surgery. As a result, patients with HBL greater than 850 ml, especially those with anemia, should be closely monitored postoperatively in case of potential complications.

There were several limitations in this study. since this study is a descriptive study, it would be apt to cause bias. In the future, the further prospective studies are still needed to confirm the risk factors for HBL in scoliosis corrective surgery. In addition, the Hct was measured twice before surgery in some patients and the latest one was extracted to calculated HBL. Whether the latest measurements reflect preoperative Hct levels is still controversial. Finally, we could not rule out the effect of racial differences on HBL because most patients included in this study were native residents.

Conclusions

In conclusion, a large amount of HBL was incurred in adolescent idiopathic scoliosis patients undergoing posterior spinal fusion surgeries, which is much more than what we expected formerly in posterior spinal fusion surgeries. Allogeneic blood transfusion and preoperative Hct were independent risk factors for HBL, while tranexamic acid was negatively related to HBL. HBL and its influential factors should be taken into account when considering the perioperative transfusion management in scoliosis corrective surgery. In addition, HBL greater than 850 ml was independent risk for postoperative transfusion in scoliosis corrective surgery. Physicians should pay more attention to these patients with hidden blood loss greater than 850 ml in case of postoperative anemia.

Abbreviations

HBL: Hidden blood loss; Hct: Hematocrit; Hb: Hemoglobin; BMI: Body mass index; ASA: American society of Anesthesiologists; PLT: platelet; INR: International Normalized Ratio; APTT: Activated partial thromboplastin time; PT: Prothrombin time; BUN: blood urea nitrogen; SCR: serum creatinine

Declarations

Acknowledgements

None

Authors' contributions

LPW participated in the design of the study, wrote the manuscript and performed the study, XXS and MHL collected and analyzed the data. JLL and YQC designed and supervised the entire study. LPW was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

Funding

NO

Availability of data and materials

The datasets generated during and analyzed during the current study are not publicly available due to hospital regulations but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

No patients' private information is involved. The retrospective study was waived for the ethical approval and informed consent by the ethic committee of Yijishan Hospital of Wannan Medical College. We confirm that all methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests from a commercial party related directly or indirectly to the subject of this article.

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