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Risk Factors for the Postoperative Transfusion of Allogeneic Blood in Orthopedics Patients With Intraoperative Blood Salvage

A Retrospective Cohort Study

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Abstract: The purpose of this study is to explore the risk factors affecting the postoperative transfusion of allogeneic blood in patients undergoing orthopedics surgery with intraoperative blood salvage (IBS). A retrospective study of 279 patients undergoing orthopedic surgeries with IBS from May 2013 to May 2015 was enrolled. The binary logistic regression was used to find out the risk factors associated with postoperative transfusion of allogeneic blood in orthopedics patients with IBS, and then receiver operating characteristic (ROC) curve was drawn to determine the optimal threshold of the regression model.

Single factor analysis showed that age, American Society of Anesthesiologists (ASA) grade, preoperative hemoglobin, operation time, received autologous blood, the laying time of autologous blood, bleeding volume, and postoperative drainage volume had significant effects on postoperative allogeneic blood transfusion.

In binary logistic regression analysis, the independent factors predicting orthopedic patients with IBS need to transfuse allogeneic blood after surgeries were age (odds ratio [OR]=0.415, $P=0.006$), ASA grade (OR=2.393, $P=0.035$), preoperative hemoglobin (OR=0.532, $P=0.022$), and postoperative drainage volume (OR=4.279, $P=0.000$). The area under ROC curve was 0.79 and the predicted accuracy rate of the model was 81.58%.

After operation, the orthopedic patients with IBS still have a high allogeneic blood transfusion rate, and IBS is not a perfect blood protection method. The logistic regression model of our study provides a reliable prediction for postoperative transfusion of allogeneic blood in orthopedic patients with IBS, which have a certain reference value.

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Abbreviations: ASA = American Society of Anesthesiologists, BMI = body mass index, Hb = hemoglobin, IBS = intraoperative blood salvage, RBC = red blood cell, rHuEPO = recombinant human erythropoietin.

INTRODUCTION

Intraoperative blood salvage (IBS) was the technique relied on blood recycling equipment of collection, filtration, centrifugation, washing, and transfused back to the patients. Due to the rich blood supply area and the complexity of the orthopedic surgeries, patients often experienced significant perioperative blood loss and required allogeneic blood transfusion. It is reported that the incidence of allogeneic blood transfusion in adult spinal surgery is as high as 30%.¹ IBS plays an important role in orthopedic surgery because it can maximally save the blood and decrease complications of allogeneic blood transfusion.

Despite these benefits, it is still not clear whether IBS decrease the need for allogeneic blood transfusion in orthopedics patients. Recently, some studies have found that it was little or no advantage. So-Osman et al² found that there was no significant increase in hemoglobin level after total knee arthroplasty in the IBS group, and it could not reduce the transfusion of allogeneic blood. Other studies also reported that IBS did not reduce the rate of allogeneic blood transfusion and the volume of blood transfusion 3 days postoperatively.³ Yang et al⁴ found that red blood cells (RBCs) lost their deformability and became stomatocytes, and even RBC “ghosts” 48 h after incubation. It suggests that these fragile RBCs may be removed from circulation soon after transfusion. Thus it is important to identify the risk factors for postoperative transfusion of allogeneic blood in patients with IBS, so as to reduce the risk of allogeneic blood transfusion. The report has been written according to the STROBE statement for cohort studies.

PATIENTS AND METHODS

Study Participants and Design

We retrospectively evaluated 279 patients who were underwent orthopedics surgery with IBS from May 2013 to May 2015 (age ≥ 18 years old) for regression model. There were another 38 orthopedic patients with IBS we preserved to test the logistic regression model. This study was approved by the Ethics Committee of Affiliated Hospital of Zunyi Medical University. All patients and family members provided written informed consent. The authors declare that no financial or proprietary interests and no patient personal data were disclosed in the study.

Orthopedic surgery including spinal fusion (123 cases), hip and knee replacement (69 cases), pelvic fractures repair (53 cases), and spinal correction surgery (34 cases). All patients underwent general anesthesia, standardized in terms of drugs and procedures. All the patients received autologous transfusion by Cell Saver (Jingjing, China) apparatus. Blood was collected, processed, and reinfused to the patients by the trained anesthesiology technician. Allogeneic blood was provided by the blood bank of Zunyi. Blood cross matching test detection were qualified by Blood Transfusion Department of the Affiliated Hospital of Zunyi Medical University before transfusion.

Observation Index

Patient Characteristics

The information about name, gender, chronic disease, operation type, blood coagulation function, and therapeutic result were obtained from medical record.

Preoperative Factors

Preoperative factors included age, gender, American Society of Anesthesiologists (ASA) grade, weight, and preoperative hemoglobin.

Intraoperative Factors

Intraoperative factors included operation time, the amount of received autologous blood, count of received autologous blood, the laying time of autologous blood, and bleeding volume.

Postoperative Factors

Postoperative factors included drainage volume, whether infused allogeneic blood after orthopedic surgery and the amount of received allogeneic blood.

Case Inclusion Criteria

No basic diseases such as hypertension, diabetes, hematologic disease, and so on; no infectious diseases such as hepatitis B and tuberculosis; no malignant tumor; liver, kidney, and blood coagulation function are normal; and no clinical intervention measures significant affect the results (such as preoperative blood transfusion, recombinant human erythropoietin [rHuEPO], oral or injection of iron, etc.).

Case Exclusion Criteria

Missing data; the patient's condition suddenly increased after the operation (such as severe infection, bleeding again, etc.); incision with infection, or potential infection; and patients with multiple injuries or complex injuries, or reoperation.

Postoperative Blood Transfusion Guidelines

The standard of postoperative blood transfusion is strictly according to the document [2000] 184 of the Ministry of Health, which was set by the expert group of "technical specification for clinical blood transfusion."

Blood Transfusion Indications

- (1) Hemoglobin > 100 g/L infusion was not needed.
- (2) Hemoglobin < 70 g/L should be considered for infusion.

- (3) Hemoglobin between 70 and 100 g/L should according to patients' age, the degree of anemia, cardiopulmonary compensatory function, and metabolic rate considering whether to infusion.

Statistical Analysis

All the data were analyzed in SPSS18.0 (Chicago, Illinois, USA) software package. Continuous variable were compared by the *t* test, qualitative data were compared by the χ^2 test or Fisher exact probability test. The difference was statistically significant when $P < 0.05$. On the basis of the above analysis, binary logistic regression was used to find out the risk factors, the selection method of the independent variable is Enter. Receiver operating characteristic (ROC) curve was drawn to determine the optimal threshold of the regression model, the value of 0.05 as a standard test.

RESULTS

Patient Characteristics

The patients were divided into 2 groups: the group E ($n = 83$) receiving allogeneic blood transfusion after orthopedic surgery and the group C ($n = 196$) did not infuse allogeneic blood after orthopedic surgery (177 were males and 102 females). Average age was 51.13 ± 13.29 years old, average body mass index was 23.27 ± 3.64 . The patients were evaluated according to the American Society of Anesthesiologists (ASA) preoperatively. Among them, there were 4 ASA I patients (1.4%), 239 ASA II patients (85.7%), 37 ASA III patients (13.3%), and 3 ASA IV patients (1.4%). Patients with radical artery catheterization to monitor arterial pressure were 228 (81.7%), central venous catheterization were 279 (100%). Average operative bleeding volume was 678.51 ± 345.87 mL, average operation time was 238.58 ± 68.14 min, average amount of autologous blood transfusion was 408.44 ± 242.73 mL. Average blood losses after operation was 222.33 ± 98.04 mL, 83 patients (16.24%) need to receive allogeneic blood after operation, average received RBC was 2.48 ± 1.39 U.

Single Factor Analysis

To identify significant factors associated with postoperative transfusion of allogeneic blood in orthopedic patients with IBS, we performed continuous variable compared by the *t* test, qualitative data by the χ^2 test or Fisher exact probability test. The results showed that age, ASA grade, preoperative hemoglobin, operation time, received autologous blood, the laying time of autologous blood, bleeding volume, and postoperative drainage volume had significant effects on postoperative allogeneic blood transfusion, $P < 0.05$ (Table 1).

Multicollinearity Diagnosis

The tolerance and Variance Inflation Factor (VIF) were performed to access multicollinearity for risk factors in orthopedic patients with IBS. As we see, all the tolerance > 0.1 and VIF < 10, it indicated that there was no multicollinearity between each factors in our study (Table 2).

Binary Logistic Regression

Furthermore, we assigned variables (Table 3) and performed binary logistic regression, the selection method of the

TABLE 1. Single Factor Analysis for Postoperative Transfusion of Allogeneic Blood in Orthopedic Patients With IBS

Variables	Groups		P Value
	E	C	
Number	83	196	
Age, y	56.47 ± 13.01	48.87 ± 12.78	0.00
Gender (man/ woman)	38/45	120/76	0.02
BMI	22.86 ± 3.40	23.44 ± 3.73	0.22
ASA (I–II/III–IV)	62/21	175/21	0.00
Preoperative hemoglobin, g/L	118.99 ± 21.41	130.20 ± 17.59	0.00
Received autologous blood, mL	452.58 ± 312.09	387.75 ± 204.59	0.09
Operation time, min	259.49 ± 64.68	229.72 ± 67.79	0.00
The laying time of autologous blood, min	204.51 ± 68.40	185.30 ± 56.50	0.02
Count of autologous blood	1.16 ± 0.43	1.17 ± 0.51	0.86
Bleeding volume, mL	845.90 ± 450.70	607.63 ± 261.05	0.00
Postoperative drainage volume, mL	277.41 ± 91.41	198.81 ± 91.56	0.00

ASA = American Society of Anesthesiologists, BMI = body mass index, IBS = intraoperative blood salvage.

independent variable is Enter. We found that age, ASA grade, preoperative hemoglobin, and postoperative drainage volume were the independent risk factors for postoperative transfusion of allogeneic blood in orthopedic patients with IBS (Table 4). The -2 Log likelihood in the regression model was 270.865, Cox and Snell R Square was 0.219 and Nagelkerke R Square was 0.310. Latter, we got the regression equation from Table 4. $P = 1/1 + e^{-Y}$, $Y = -3.23 - 0.879X1 + 0.873X3 - 0.631X4 + 1.454X8$, P refer to probability of postoperative transfusion of allogeneic blood in orthopedics patients with IBS.

TABLE 2. Multicollinearity Diagnosis for Risk Factors in Orthopedic Patients With IBS

Model	Collinearity Statistics	
	Tolerance	VIF
Age	0.933	1.072
Gender	0.885	1.130
ASA	0.919	1.088
Preoperative hemoglobin	0.815	1.226
Operation time	0.673	1.486
The laying time of autologous blood	0.707	1.414
Bleeding volume	0.841	1.188
Postoperative drainage volume	0.886	1.129

ASA = American Society of Anesthesiologists, IBS = intraoperative blood salvage, VIF = Variance Inflation Factor.

TABLE 3. Assignment of Variables for Logistic Regression

Factors	Variables	Assignment
Receive allogeneic blood after operation	Y	0 = no, 1 = yes
Age	X1	1 = ≥ 60 , 2 = < 60
Gender	X2	1 = man, 2 = woman
ASA grade	X3	1 = I–II, 2 = III–IV
Preoperative hemoglobin	X4	1 = 60–90, 2 = 90–120, 3 = ≥ 120
Operation time	X5	1 = < 240 , 2 = ≥ 240
The laying time of autologous blood	X6	1 = < 180 , 2 = ≥ 180
Bleeding volume	X7	1 = < 500 , 2 = ≥ 500
Postoperative drainage volume	X8	1 = < 200 , 2 = ≥ 200

ASA = American Society of Anesthesiologists.

ROC Curve of Regression Model

ROC curve was drawn according to the predictive value of blood transfusion probability of logistic regression model (Figure 1). Area under the curve was 0.790, 95% CI was 0.732 to 0.847. Optimal critical value corresponded to P value was 0.206. Then put it to the formula $P = 1/1 + e^{-Y}$, $Y = -1.347$.

Predicted Accuracy Rate of the Regression Model

There were another 38 orthopedic patients with IBS we prereserved to test the logistic regression model. The Y value is calculated according to the regression equation. If $Y \geq -1.347$, the model is predicted as orthopedic patients with IBS need to transfuse allogeneic blood after surgery. While $Y < -1.347$, it predicted as no need. The predicted accuracy rate of the regression model was 81.58% (Table 5).

DISCUSSION

Orthopedic surgery often require allogeneic blood transfusion due to the operative region has rich blood supply, some parts such as the spine, shoulder, and pelvis cannot use a tourniquet, and so on, which making more intraoperative blood loss and postoperative recessive blood loss. If the patient is

TABLE 4. Binary Logistic Regression of Postoperative Transfusion of Allogeneic Blood in Orthopedics Patients With IBS

Variables	B	SE	Wald	OR (95% CI)	Sig.
X1	-0.879	0.321	7.493	0.415 (0.221–0.779)	0.006
X2	0.483	0.313	2.375	1.620 (0.877–2.994)	0.123
X3	0.873	0.413	4.457	2.393 (1.064–5.381)	0.035
X4	-0.631	0.275	5.282	0.532 (0.311–0.911)	0.022
X5	0.573	0.354	2.621	1.774 (0.886–3.550)	0.105
X6	0.340	0.362	0.886	1.405 (0.692–2.855)	0.347
X7	0.011	0.330	0.001	1.012 (0.530–1.931)	0.972
X8	1.454	0.338	18.485	4.279 (2.206–8.300)	0.000

CI = confidence interval, IBS = intraoperative blood salvage, OR = odds ratio, SE = standard error.

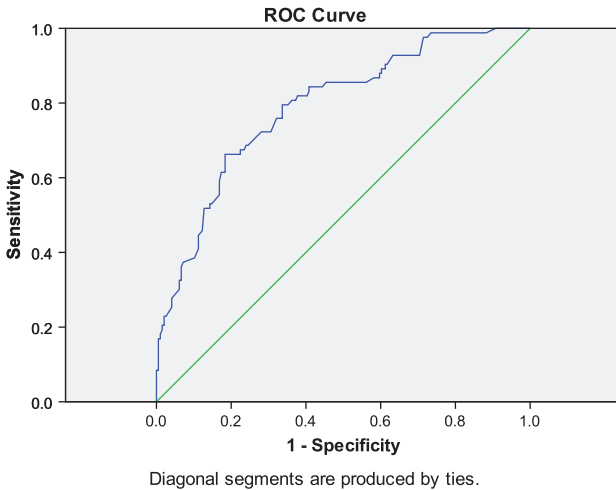


FIGURE 1. ROC curve of regression model. Area under the curve (AUC): 0.790 (95% CI was 0.732–0.847), cut-off value: 0.372, specificity: 0.816, sensitivity: 0.661. CI = confidence interval, ROC = receiver operating characteristic.

older, the body’s compensatory capacity decreased, anemia status cannot treat duly, will bring a number of related complications affect patient prognosis. IBS plays an important role in orthopedic surgery because it can maximally save the blood and decrease complications of allogeneic blood transfusion. Greenky et al⁵ reported that IBS can significantly reduce the volume of blood in the patients undergoing hip replacement surgery, but did not demonstrate the relevant circumstances and cost analysis of postoperation. Kumar et al⁶ found that IBS can reduce the incidence of allogeneic blood transfusion in patients with spinal surgery, postoperative complications did not increase as well as hospital costs. But other studies show that IBS cannot reduce the postoperative blood transfusion. One research shows that although IBS can significantly reduced the rate of blood transfusion (9% vs 40%), the rate of blood transfusion in patients with IBS was higher than that in the control group (46% vs 23%).⁷ Gause et al⁸ applied IBS in 188 patients with posterior decompression and spinal fusion, and found that IBS cannot reduce the demand for allogeneic blood transfusion, even may cause more bleeding after operation.

In our study, of the 279 patients with IBS, 83 orthopedics patients (16.24%) needed transfusion of allogeneic blood. This suggests that IBS does not completely avoid the risk of transfusion of allogeneic blood. By binary logistic regression, we found that age, ASA grade, preoperative hemoglobin, and postoperative drainage volume were the independent risk factors for postoperative transfusion of allogeneic blood in

orthopedic patients with IBS. Area under the ROC curve was 0.790, the predicted accuracy rate of the regression model was 81.58%; it shows that these factors have great significance to judge orthopedics patients whether need to transfuse allogeneic blood after surgery.

Age, ASA grade, and preoperative hemoglobin are the key concerns when anesthesia doctors make preoperative assess, they are closely related with the needs of blood transfusion, is 1 of the important indicators to determine whether need blood transfusion after surgery.⁹ Most patients in the department of orthopedics were elderly patients or multiple trauma patients, their physiological function and organ reserve capacity is poor, and the ability to tolerate anesthesia and surgery often decline due to a variety of basic diseases.¹⁰ Most physicians will choose infuse allogeneic RBC to increase hemoglobin level to meet the requirement of operation, so that the blood transfusion indications are go down. However, transfusion of allogeneic blood may enhance postoperative infection rate length of hospital stay and even mortality.^{11,12} In our study, though some of them with a lower hemoglobin level (the lowest value of 73 g/L), and ASA reached III–IV, allogeneic blood transfusion and any intervention did not perform due to the doctors believed the patients had a certain ability to tolerate anesthesia and surgery. In spite of IBS, the older, the lower preoperative hemoglobin level, and the higher ASA will increase the incidence of allogeneic blood transfusion. This is similar to the published literature reported by Gombotz et al.^{13,14} It suggested that the recovery of the RBC could not completely restore the hemoglobin to preoperative levels, this may be owing to the high suction and high-speed centrifugal force in the process of blood salvage, which produce a mechanical trauma to damage RBC membrane, leading to a decline in the ability of RBCs and reduce its function and lifespan.¹⁵ Therefore, perioperative blood protection measures should be further improved. Since these factors can predict before elective surgery, if patients’ condition were suitable, intravenous iron, oral iron, rHuEPO,¹⁶ traditional Chinese medicine and other treatments for early intervention, can obtain better therapeutic effect.

After the process of centrifuge and washing, a large amount of blood coagulation factors, plasma proteins, and platelets can be lost, so that the blood coagulation function can be affected by a large number of autologous blood transfusion. Component detection of surgical drainage in patients with IBS were reported by some authors, they found D-dimmer thrombin increased and fibrinogen, platelet activity decreased in surgical drainage blood.¹⁷ This suggests that the coagulation function may be decreased after the infusion of autologous blood, postoperative drainage volume may increase relatively, resulting in the increased possibility of postoperative anemia. Our study did not find that IBS would directly lead to anemia in patients after surgery, and coagulation function could not be checked due to conditional restriction. Most of the literature reported that as long as 30% of normal coagulation factors in vivo can maintain normal coagulation function, so it would be no difference on coagulation function when the amount of autologous blood are not too much. Currently, it is widely agreed that autologous blood volume <2000 mL has little effect on coagulation function.¹⁸

It has been reported more reinfusion of autologous blood, the hemoglobin level decreased more significantly after surgery,¹⁹ RBCs lost their deformability and became “ghosts” 48 h after incubation.⁴ But “received autologous blood” and “the laying time of autologous blood” were not placed in the equation of binary logistic regression. The amount of

TABLE 5. Predicted Accuracy Rate of the Regression Model

Model Prediction Results	Actual Results		Accuracy Rate, %
	Need	No Need	
Need	15	3	83.33
No need	4	16	80.00
Total accuracy			81.58

autologous was so little and autologous blood was too short to placed may be the cause, specific mechanism remains to be further research.

Although our study did not come to the conclusion that IBS can significantly reduce allogeneic blood transfusion, there were a total of 113,955 mL autologous blood transfusion, was equivalent to saving RBC 570 U. So for surgery with a high risk of bleeding, especially without adequate blood supply, we also actively recommend the use of IBS, controlled hypotension, hemostatic drugs, and other means should be used to improve blood protective measures as well.²⁰

While there are some deficiencies in our study: The study was a retrospective study, and a single center research, the collected data and disease may have bias, the selected factors may missing some of the variables. To evaluate a multi-factor regression model, sample size of 279 cases are still lacking, the results still need to be interpreted with caution. We hope that we can carry out more prospective clinical research in the future, and can evaluate the relationship between perioperative blood transfusion and IBS more accurately, so as to provide reliable basis for reducing the transfusion of allogeneic blood.

In conclusion, there is still have a high allogeneic blood transfusion rate after surgery of orthopedics patients with IBS, IBS cannot be a perfect blood protective measure. Age, ASA grade, preoperative hemoglobin, and postoperative drainage volume were independent risk factors for postoperative transfusion of allogeneic blood in orthopedic patients with IBS. The logistic regression model of our study provides a reliable prediction for postoperative transfusion of allogeneic blood in orthopedic patients with IBS. Therefore, it should not be over reliance on IBS, the perioperative period still needs to take into account and improve the blood protective measures, so as to reduce the risk of allogeneic blood transfusion.

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