A Model to Predict the Probability for Intraoperative Blood Transfusion During Lumbar Spinal Stenosis and Femoral Fracture Surgeries in Aged patients

Zhiyang Nie

Transfusion Department, Beijing Hospital, National Center of Gerontology; Institute of Geriatric Medicine, Chinese Academy of Medical Sciences, P.R.China.

Wanru Ma

Transfusion Department, Beijing Hospital, National Center of Gerontology; Institute of Geriatric Medicine, Chinese Academy of Medical Sciences, P.R.China.

Junhua Hu (✉ hujunhua3668@bjhmoh.cn)

Transfusion Department, Beijing Hospital, National Center of Gerontology; Institute of Geriatric Medicine, Chinese Academy of Medical Sciences, P.R.China.

Research Article

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Abstract

Background: Lumbar spinal stenosis and femoral fracture are common orthopedic problems in aged patients, and the probability of transfusion of red blood cell products during surgery is relatively high. The goal of this study was to predict the probability of transfusion of allogeneic red blood cells and the volume of blood consumption based on the clinical characteristics of patients before surgery.

Methods: The medical records of 565 patients over 65 years old who underwent posterior lumbar surgery for lumbar spinal stenosis and those of 586 patients over 65 years old receiving surgery for femoral fracture were reviewed. The clinical characteristics of the patients were subjected to multivariate regression analysis. The influence of these characteristics based on the odds ratio of each multivariate risk factor was assessed to predict the probability of intraoperative red blood cell transfusion. Non-linear regression was performed to predict the probability of intraoperative blood transfusion and the volume of blood used for patients with different scores.

Results: The factors that significantly influenced blood use during lumbar spinal stenosis surgery in aged patients ($P < 0.05$) included age > 75 years old, body mass index (BMI) > 24 , abnormal coagulation function, preoperative hemoglobin (Hb) ≤ 110 g/L, multisegmental lesions of the lumbar spine and secondary lumbar surgery. The factors that significantly influenced blood use during femoral fracture surgery in aged patients ($P < 0.05$) included age > 75 years old, BMI < 19 , abnormal coagulation function, preoperative Hb ≤ 110 g/L, administration of antiplatelet drugs (e.g., aspirin, clopidogrel), femoral shaft fracture, and the time from fracture to surgery exceeding 48 h. These factors were introduced into a multiple logistic regression model, and weighted scoring was performed according to their relative risk to establish a risk scoring system to predict the probability. More than 50% of patients receiving an intraoperative red blood cell transfusion during surgery for lumbar spinal stenosis or femoral fracture scored ≥ 1 .

Conclusion: The probability of transfusion of allogeneic red blood cells and the blood volume needed can be predicted preoperatively in aged patients undergoing lumbar spinal stenosis and femoral fracture surgeries. This can reduce the need for blood matching during surgery, allow adjustment of the blood inventory, and ensure safety.

Introduction

Owing to a deficiency in large evidence-based datasets and the lack of consensus among surgeons, there is a large difference in the probability of intraoperative blood use during surgery for different orthopedic conditions¹⁻². Until now, the focus of most studies on blood use in orthopedic surgery has been on joint replacement^{1,3}. However, lumbar spinal stenosis and femoral fracture are common orthopedic conditions in aged patients, and the probability of transfusion of red blood cell products during the perioperative period is relatively high. Finding a suitable blood management strategy for these patients has been a topic of serious attention. Retrospective studies make clear that most perioperative blood management still depends on the experience of clinicians, and different physicians have different blood use practices.

This does not contribute to the rational perioperative assessment or intraoperative use of blood⁴. Therefore, a blood consumption model was established to preoperatively predict the probability of transfusion of allogeneic red blood cells and the blood volume needed according to the clinical characteristics of the patients. These clinical characteristics will affect the blood loss and hemostasis of patients and the changes of their vital signs during surgery, the length of time in surgery, and the size of the surgical wounds, but cannot predict accidents that may occur during surgery. These clinical features must be observed preoperatively, but not during or after surgery⁵⁻⁷. Moreover, the influencing factors for different diseases may vary, so this scoring system is different from other preoperative scoring systems, such as the system proposed by the American Society of Anesthesiologists⁸.

Patients And Methods

This study was approved by Ethics Committee of Beijing Hospital and conducted in accordance with local regulations and the declaration of Helsinki. Informed consent was obtained from all participants and/or their legal guardians.

Medical records of 565 patients over 65 years old who underwent posterior lumbar surgery for lumbar spinal stenosis and 586 patients over 65 years old receiving surgical treatment for femoral fracture from 2015 to 2018 in the National Center of Gerontology of China were reviewed. Their preoperative clinical data, including age, gender, body mass index, clinical test results and disease characteristics were collected. Actual blood consumption during surgery was defined as the primary outcome measure⁹. These data were sorted using Excel, and analyzed via SPSS 25 (IBM SPSS Statistics for Windows, Version 25.0 Armonk, NY: IBM Corp.) using uni- and multivariate regression models. $P < 0.05$ represented a statistically significant difference. The scores of these factors' influences on intraoperative red blood cell infusion were based on the odds ratio (OR) of each multivariate risk factor, and their sensitivity and specificity were evaluated using the receiver operating characteristic (ROC) curve. Non-linear regression was performed to predict the probability of intraoperative blood transfusion and the volume of blood used for patients with different scores.

Results

The average age of patients with lumbar spinal stenosis was 74.7 ± 6.4 years old, and the ratio of males to females was 231:334. The average body mass index (BMI) was 21.46 ± 2.88 . Red blood cell products were given to 72.1% of the patients during surgery, with an average amount of 2.1 U/patient.

The average age of patients receiving femoral fracture surgery was 81.5 ± 8.46 years old. The ratio of males to females was 170: 416, with an average BMI of 20.51 ± 2.93 . Red blood cell products were given to 78.2% of the patients during surgery, with an average amount of 2.25U/patient (Table 1).

Univariate Analysis of Risk Factors for Intraoperative Blood Transfusion

Potential risk factors for intraoperative transfusion of allogeneic red blood cells were analyzed to evaluate the risk of intraoperative blood use for these two conditions (Table 2). Characteristics of those who received blood compared to those who didn't during surgery for lumbar spinal stenosis revealed significant ($P<0.05$) differences between the groups for several demographic and clinical characteristics. Those who received blood were >75 years old, with $BMI>24$, had an abnormal coagulation function and preoperative hemoglobin ($Hb\leq 110$ g/L), presented with multi-segmental lesions of the lumbar spine and had a secondary lumbar surgery. Characteristics that significantly influenced the decision for blood use during femoral fracture surgery ($P<0.05$) included age >75 years old, $BMI<19$, abnormal coagulation function, preoperative $Hb\leq 110$ g/L, administration of antiplatelet drugs (e.g., aspirin, clopidogrel) before surgery, femoral shaft fracture, and the time from fracture to surgery exceeding 48 h.

Multivariate Regression Model of Risk Factors for Intraoperative Blood Transfusion

To establish a predictive model of intraoperative blood use, single factors with statistically significant differences were entered into a multiple logistic regression model and scored according to their relative risks, thus constructing a risk scoring system of intraoperative red blood cell transfusion for the two conditions. All parameters mentioned earlier were also significant in the multivariate model. To facilitate its application, we used the smallest odds ratio (about 1.299 for lumbar spinal stenosis surgery and 1.294 for femoral fracture surgery) as the respective score 1 (Table 3). The sensitivity, specificity and area under the ROC curve for lumbar spinal stenosis surgery were 75%, 73% and 0.73, respectively. The sensitivity, specificity and area under the ROC curve for predicting transfusion during femoral fracture surgery were 71%, 76% and 0.76, respectively.

Risk score

The patients were evaluated using the blood use risk scoring system, and the score value, proportion of patients receiving a red blood cell transfusion and the average and median transfusion volume for each patient were obtained (Tables 4 and 5). The results revealed that more than 50% of patients receiving an intraoperative red blood cell transfusion during surgery for lumbar spinal stenosis or femoral fracture scored ≥ 1 . Non-linear regression was performed to predict the probability of intraoperative blood transfusion and the average volume of blood used for patients with different scores.

To verify the reliability of the scoring system, the proportion of intraoperative blood transfusions and blood consumption of 182 patients with lumbar spinal stenosis and 194 patients with femoral fracture from January to December 2019 were predicted and compared with the actual blood transfusion proportion and blood transfusion volumes (Tables 6 and 7). The scores were divided into groups, on the basis of median blood transfusion volume. The model predictions were consistent with the actual surgical values, proving the feasibility of this evaluation method.

Discussion

Nowadays, anterior and posterior surgical approaches are used for lumbar spinal stenosis. To reduce the variation resulting from different surgical methods, only patients receiving posterior lumbar surgery were selected for the prediction of intraoperative blood use¹⁰.

Aged patients are less tolerant to anemia, so the probability of transfusion of allogeneic red blood cells increases during surgery⁹. This study demonstrated that the risk of blood use during surgery increases for patients over 75 years old with lumbar spinal stenosis or femoral fracture. The transmission risk of infectious diseases increases from blood transfusion, but usually has a long latency, so the risk of transfusion-related infection is not as important in the evaluation of allogeneic red blood cell transfusion in the older population. The short-term benefits obtained from allogeneic red blood cell transfusion will be more important to the condition of aged patients¹¹⁻¹³.

Hb concentration is the most common indication for judging whether red blood cells need to be transfused clinically¹⁴. Existing transfusion guidelines tend to set an upper threshold for hemoglobin of 10 g/dL, above which transfusion is not indicated, and a lower hemoglobin threshold of between 6 and 7 g/dL, below which transfusion is recommended¹⁵⁻¹⁸. It is difficult to obtain this indicator in time during surgery. Otherwise, the amount of blood used can be greatly affected by intraoperative bleeding and anesthesia. This analysis showed that preoperative anemia in patients with $Hb \leq 110g/L$ increased the probability of blood use during surgery, which is consistent with the conclusions of some previous studies^{9,19}. However, Hb concentration itself does not fully represent the tissue oxygen supply of patients²⁰⁻²². Increasingly more studies have illustrated that different patients have a different tolerance to anemia, which also causes a significant difference in the probability of clinical blood use. The results of this study illustrated that the decrease of platelet count preoperatively does not affect blood use during surgery. In this study, patients' platelet data were normally distributed according to the [Kolmogorov-Smirnov test](#) ($P > 0.05$). However, there were few samples with decreased platelet counts (23 in 1151 patients), which may lead to the statistical deviation. In addition, it has been discovered through clinical work that many patients who have no abnormality or a slight abnormality of prothrombin time or activated partial thromboplastin time in a routine coagulation examination actually have coagulation dysfunction²³. In recent years, it has been found that a thromboelastogram examination may be more diagnostic than a coagulation function examination. A thromboelastogram can predict the obstruction of coagulation function and the need for massive blood transfusion through dynamic evaluation of blood clot formation, blood clot strength and the blood clot dissolution process²⁴⁻²⁷.

BMI creates a different calculation for intraoperative blood use in different conditions. Low body weight increases the probability of intraoperative blood use in aged patients with femoral fracture, which may be due to the relatively small whole body blood volume of low body weight patients. Perioperative bleeding has a great influence on whole body blood volume. Low-weight patients have less subcutaneous fat, which is not conducive to local hemostasis and will lead to increased hidden blood loss^{9,28-29}. On the contrary, overweight patients have a greater probability of blood use during surgery for lumbar spinal stenosis in aged patients. Being overweight or obesity increases the burden on the lumbar spine, so

overweight patients have serious lumbar lesions or multi-level lesions that indirectly lead to a rise in the probability of blood use during surgery. Further, the central and peripheral venous pressures of patients are usually reduced by anesthesia during spinal surgery, which reduces the bleeding of surgical wounds. The cardiopulmonary compliance of obese patients decreases, and higher ventilation pressure is needed to overcome the low cardiopulmonary compliance, which gives rise to an increase of venous pressure and more bleeding³⁰⁻³¹.

Aged patients increasingly are taking aspirin, clopidogrel or other anti-platelet aggregation drugs to reduce the risk of cardiovascular and thrombotic events, and many patients will take them during the perioperative period³²⁻³³. It is necessary to weigh the increased risk of perioperative bleeding caused by continuous use of these drugs and the increased risk of thromboembolic events after withdrawal³⁴⁻³⁷. According to this analysis, patients with femoral fracture who took these antiplatelet aggregation drugs for a long time before surgery had an increased probability of blood transfusion during surgery, but the relative risk was not high. However, most surgeries for lumbar spinal stenosis are elective. Patients who have taken antiplatelet aggregation drugs for a long time should stop taking the drugs for more than seven days before surgery, thus reducing the influence of these drugs on intraoperative bleeding³⁸⁻⁴⁰.

Interestingly, the results of this study illustrated that patients with chronic diseases such as coronary heart disease, diabetes, hypertension or renal insufficiency have no increased risk of blood use during lumbar spinal stenosis or femoral fracture surgery. This may be because these blood transfusion decisions are determined by the experience of clinicians, who generally set a higher threshold for perioperative blood transfusion in the elderly and are more inclined to use red blood cell products during surgery. Currently, the internationally recognized restrictive blood transfusion strategy usually sets the blood transfusion threshold at 80 g/L for perioperative patients⁴¹⁻⁴², and suggests that there is no need to relax the blood transfusion threshold for patients with a history of coronary heart disease^{2,43-44}. However, some studies have established that the survival time of patients with existing heart diseases tends to decrease in the restricted blood transfusion strategy group, implying that critically ill patients with heart and vascular diseases may benefit from higher Hb levels⁴⁵.

Different factors affecting blood use during surgery must be considered for different conditions⁴⁶. Lumbar spinal stenosis in most aged patients is caused by degenerative diseases or long-term strain, so there is a high probability that two or more vertebral segments will be affected³⁰. If multi-segment surgery is performed at the same time, the wound will be larger than that of patients with single-segment lesions, the amount of bleeding will increase, and the probability of red blood cell transfusion will increase. Previous studies have shown that if multiple segments at the same site are operated separately, this will increase intraoperative blood loss, which is consistent with our analysis⁴⁷⁻⁴⁹. Femoral shaft fractures are mostly caused by severe trauma, and the amount of bleeding can reach 1000-1500 mL. If it is an open or comminuted fracture or a fracture of the distal 1/3 of the femur, it is easy to puncture the popliteal artery and vein. The amount of bleeding may be greater because the blood vessel is located posterior to the fracture site, and the distal end of the fracture often is angled backward towards these vessels. If it is a

closed fracture of the femur, the recessive blood loss may far exceed the dominant blood loss. Therefore, if there is a long time between the fracture and the surgery,, the Hb concentration will decline gradually, which will markedly increase the probability for red blood cell infusion during surgery⁵⁰. Unfortunately, there was no detailed record of the amount of time between fracture occurring and the patient being treated in the emergency room, as this could translate to dehydration and affect the initial Hb as well. Therefore, the clinical information of the patients we analyzed was the one closest to the time of surgery to minimize the impact of the above factors on the results of the study.

This research has several limitations. The data analyzed in this study were retrospectively extracted from clinical medical records, so the detection time points of some test results were not uniform. The records of past medical history of some patients may not be completely consistent with the actual situation. Moreover, the blood transfusion treatment decisions made for these patients were not based on fixed guidelines, but on the judgment of different surgeons, so there is some variation^{44,51}. In addition, the population analyzed in this study was from a single department of a single medical institution, and the number of cases with complete clinical case data was small, so the statistical power is limited. This predictive model needs to be tested and improved in a larger and more diverse population.

Conclusion

Routine preoperative blood preparation is required for lumbar spine and femoral fracture surgeries in aged patients. The probability of transfusion of allogeneic red blood cells and the blood volume needed can be predicted preoperatively in aged patients undergoing lumbar spinal stenosis or femoral fracture surgeries using our scoring system. The cross-matching test should be carried out preoperatively for lumbar spinal stenosis patients with a blood risk score≥1, as well as femoral fracture patients. The cross-matching blood volume was based on the score, which can effectively reduce the workload of blood matching during surgery, allow adjustment of the blood inventory, and ensure safety.

List Of Abbreviations

OR = odds ratio

ROC = receiver operating characteristic

BMI = body mass index

Hb = hemoglobin

FIB = fibrinogen

PT = prothrombin time

APTT = activated partial thromboplastin time

Declarations

Ethics approval and consent to participate

The study was approved by Ethics Committee of Beijing Hospital and carries the study number 2020BJYYEC-277-02. The study was conducted in accordance with local regulations and the declaration of Helsinki.

Consent for publication Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding None.

Authors' contributions

Dr. Hu contributed to the conception of the study and helped perform the analysis with constructive discussions;

Dr. Nie contributed significantly to the data extraction from the medical charts and performed the data analyses and wrote the manuscript.;

Dr. Ma contributed to analysis and manuscript preparation;

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Tables

Table 1. Basic data and clinical characteristics of patients

Lumbar spinal stenosis		Femoral fracture	
Age (y)	74.7±6.4	Age (y)	81.5±8.46
Sex (M: F)	231: 334	Sex (M:F)	170: 416
BMI	21.46±2.88	BMI	20.51±2.93
Comorbidities	124 (22%)	Comorbidities	86 (14.7%)
Preoperative hemoglobin (Hb, g/L)	128.2±14.87	Preoperative Hb (g/L)	112±18.33
Preoperative platelet count (×10 ⁹ /L)	205.2±53.87	Preoperative platelet count (×10 ⁹ /L)	205.1±75.96
Abnormal coagulation function	52 (9.2%)	Abnormal coagulation function	49 (8.4%)
Administration of antiplatelet drugs	185 (32.7%)	Administration of antiplatelet drugs	239 (40.8%)
Secondary operation	35 (6.2%)	Time from fracture to operation (h)	78.5±35.7
Segments of lesions (single: multiple)	445: 120	Fracture site	
		Fracture in the shaft of femur	74 (12.6%)
		Subtrochanteric fracture of femur	197 (33.6%)
		Intertrochanteric fracture of femur	26 (4.4%)
		Neck of femur	289 (49.3%)

Table 2. Analysis of risk factors for intraoperative transfusion of allogeneic red blood cells

Disease	Risk factor	P	Odds ratio(95% CI)
Lumbar spinal stenosis	Age>75	0.00035	1.302 [1.109-1.424]
	Gender	0.355	1.162 [0.722-1.602]
	BMI<19	0.671	0.799 [0.299-1.299]
	BMI>24	0.0216	1.248 [1.061-1.527]
	Abnormal coagulation function (decreased FIB or increased PT/APTT) ^a	0.032	2.545(1.412-4.284)
	Preoperative Hb ≤110g/L	0.010	1.570 [1.189-1.904]
	Preoperative platelet count<150/nL	0.106	1.395 [0.855-1.935]
	Complications (including diabetes, coronary heart disease, hypertension and renal insufficiency)	0.938	0.985 [0.635-1.335]
	Administration of antiplatelet drugs (e.g., aspirin, clopidogrel)	0.52	1.14[0.210-2.070]
	Multilevel lesions (≥2 lumbar vertebrae)	0.007	3.911 [2.927-4.687]
	Secondary operation of lumbar spine	0.0054	2.037 [1.726-2.616]
Femoral fracture	Age>75	3.593×10 ⁻¹⁰	2.175 [1.980-2.287]
	Sex	0.978	1.005 [0.065-1.945]
	BMI<19	7.508×10 ⁻⁷	2.099 [1.691-2.348]

BMI>24	0.321	1.865 [0.875- 2.855]
Abnormal coagulation function (FIB decreased or PT/APTT increased)	0.005	3.691 [2.931- 4.492]
Preoperative Hb ≤110g/L	1.119×10 ⁻¹⁵	1.555 [1.354- 1.758]
Preoperative platelet count<150/nL	0.106	1.395 [0.615- 2.175]
Complications (including diabetes, coronary heart disease, hypertension and renal insufficiency)	0.874	1.037 [0.187- 1.887]
Administration of antiplatelet drugs (e.g., aspirin, clopidogrel)	0.0045	1.590 [1.301- 1.815]
Femoral shaft fracture	0.007	3.011 [1.929- 4.077]
Time from fracture to operation exceeding 48 h	0.0370	1.220 [1.046- 1.394]

a [FIB-fibrinogen PT-prothrombin time APTT-activated partial thromboplastin time

Table 3. Predictive scoring system of allogeneic red blood cell transfusion during surgery

Disease	Risk factor	P-Value	Odds ratio [95%CI]	Points
Lumbar spinal stenosis	Age>75	0.00037	1.63 [1.473-1.788]	1
	BMI>24	0.0225	1.299 [1.066-1.532]	1
	Abnormal coagulation function (FIB decreased or PT/APTT increased)	0.0466	2.491 [1.055-3.927]	2
	Preoperative Hb ≤110g/L	0.000746	1.520 [1.162-1.877]	1
	Multilevel lesions (≥2 lumbar vertebrae)	0.01174	3.508 [2.628-4.388]	3
	Secondary operation of lumbar spine	0.00015	1.983 [1.538-2.428]	2
Femoral fracture	Age>75	0.00022	1.974 [1.821-2.128]	2
	BMI<19	0.00008	2.020 [1.692-2.349]	2
	Abnormal coagulation function (FIB decreased or PT/APTT increased)	0.00462	3.432 [2.652-4.213]	3
	Preoperative Hb ≤110g/L	0.000001	1.536 [1.334-1.738]	1
	Take antiplatelet drugs (e.g., aspirin, clopidogrel)	0.0039	1.59 [1.333-1.847]	1
	Femoral shaft fracture	0.004	2.878 [1.804-3.952]	2
	The time from fracture to operation exceeded 48 hours	0.025	1.294 [1.115-1.474]	1

Table 4. Predicted score of intraoperative allogeneic red blood cell transfusion and actual blood use in aged patients aged patients with lumbar spinal stenosis

Score	Number of patients	Proportion of patients with blood transfusions	Average blood transfusion volume(U)	Median blood transfusion volume(U)
0	50	28.0%	0.5	0
1	40	47.5%	1.29	1
2	189	59.8%	1.78	2
3	71	64.8%	2.63	3
4	116	68.1%	2.46	3
5	50	84.0%	2.88	3
6	39	82.1%	3.12	3
7	6	100%	3.5	3.5
8	1	100%	4.00	4
9	3	100%	4.00	4
10	-	-	-	-

Table 5. Predicted score of intraoperative allogeneic red blood cell transfusion and actual blood use in aged patients with femoral fracture

Score	Number of patients	Proportion of blood transfusion	Average blood transfusion volume(U)	Median blood transfusion volume(U)
0	33	24.1%	0.57	1
1	181	42.6%	1.80	2
2	163	55.3%	2.26	2
3	106	60.9%	2.43	3
4	27	66.7%	2.71	3
5	33	72.8%	3.28	3
6	24	79.2%	3.54	3
7	12	83.3%	3.79	4
8	3	100%	4.00	4
9	1	100%	4.00	4
10	3	100%	4.00	4
11	-	-	-	-
12	-	-	-	-

Table 6. Comparison of predicted and actual proportion of blood transfusion and average blood transfusion volume in patients with lumbar spinal stenosis

Score	Number of patients	Predicted proportion of blood transfusion	Actual proportion of blood transfusion	Predicted average blood transfusion volume (U)	Actual average blood transfusion volume (U)	Median blood transfusion volume(U)
0	15	24.4%	26.7%	0.29	0.50	0
1	13	46.9%	46.2%	1.36	1.20	1
2-3	84	62.6%	59.5%	2.10	2.03	2
4-6	67	80.2%	71.6%	2.94	2.57	3
7-10	3	94.3%	100.0%	3.61	3.67	4

Table 7. Comparison of predicted and actual proportion of blood transfusion and average blood transfusion volume in patients with femoral fracture

Score	Number of patients	Predicted proportion of blood transfusion	Actual proportion of blood transfusion	Predicted average blood transfusion volume (U)	Actual average blood transfusion volume (U)	Median blood transfusion volume(U)
0	11	22.3%	27.3%	0.62	0.67	1
1-3	149	52.2%	51.0%	2.08	1.95	2
4-6	28	67.7%	71.4%	2.82	3.13	3
7-12	6	89.6%	83.3%	3.77	3.67	4