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Hematologic profile in reverse total shoulder arthroplasty: perioperative and postoperative blood loss

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Background: Few studies have investigated the amount of blood loss during reverse total shoulder arthroplasty (RTSA). The purpose of this study was to investigate blood loss in patients who underwent RTSA for massive irreparable rotator cuff tear (MIRCT) using the hemoglobin (Hb) balance method and total Hemovac amount and to identify predictors of blood transfusion in these patients.
Methods: We retrospectively reviewed 121 patients who underwent RTSA for MIRCT. The mean age was 71.2 ± 6.9 years, and 75 were women. Age, sex, body mass index, use of anticoagulants, American Society of Anesthesiologists physical status score, comorbidities (eg, hypertension, diabetes mellitus, cerebrovascular accident), preoperative Hb level, preoperative hematocrit level, preoperative prothrombin time/international normalized ratio, use of cement, and operative time were evaluated as values predicting blood transfusion.
Results: The overall blood loss was 846.6 ± 527.6 mL, which included 346 ± 231.2 mL of intraoperative blood loss and 500.3 ± 196.4 mL of postoperative blood loss. Values predicting blood transfusion were a lower preoperative Hb level ($P < .001$), hematocrit level ($P < .001$), hypertension ($P = .018$), and cerebrovascular accident ($P = .008$). Receiver operating characteristic analysis identified the following cutoff values for predicting transfusion: preoperative Hb level of 13.5 g/dL (90.3% sensitivity) and hematocrit of 40% (90.3% sensitivity).
Conclusions: RTSA for MIRCT is associated with blood loss during and after surgery. The amount of blood loss should be noted, and blood transfusion could be predicted by calculating the blood loss and predictive values. Lower preoperative Hb level, hematocrit, hypertension, and cerebrovascular accident are predictors of blood transfusion. Blood transfusion should be considered if a patient with preoperative Hb level <13.5 g/dL and hematocrit <40% has a history of hypertension or cerebrovascular accident.
Level of Evidence: Level IV; Case Series; Treatment Study

Keywords: Blood loss; reverse total shoulder arthroplasty; massive irreparable rotator cuff tear; blood transfusion; predictive values

This study was approved by Kyung Hee University Hospital Institutional Review Board (No. KHUH 2018-07-066).

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Reverse total shoulder arthroplasty (RTSA) is considered a useful treatment for massive irreparable rotator cuff tear (MIRCT) as it can improve the quality of life, enable pain-free range of motion, and restore the function and strength of the shoulder.[4,5] Several studies have been published that report RTSA to be a safe and effective surgical option for MIRCT.[9,19] On the other hand, perioperative complications such as blood loss requiring transfusion can occur, and previous studies have identified RTSA as an independent risk factor for postoperative blood transfusion.[11,12,16] Although RTSA is a known risk factor for blood loss, no study has assessed the total amount of blood loss (perioperative and postoperative blood loss) during RTSA for MIRCT. Malcherczyk et al[15] calculated the total blood loss according to the method suggested by Charrois et al[6]; however, they did not assess the amount of postoperative Hemovac drainage.

Previous studies have reported varying transfusion rates in total shoulder arthroplasty (TSA) or RTSA from 8.1% to 43%,[3,11,18] and several risk factors of blood transfusion have been investigated.[14] Millett et al[16] reported that preoperative hemoglobin (Hb) level is the strongest predictor of transfusion after TSA, whereas sex, body mass index (BMI), comorbidities, and use of aspirin have no impact. Hardy et al[12] also reported that lower preoperative Hb level and humeral cement fixation are predictors of transfusion after shoulder arthroplasty (TSA, humeral head arthroplasty, revision TSA, or RTSA) but that sex, older age, and comorbidities are not. Whereas Gruson et al[11] reported that the need for blood transfusion is high in older patients (>65 years old) and in female patients, Malcherczyk et al[15] reported that the transfusion risk is high in patients undergoing cemented shoulder arthroplasty, those with a low BMI, and those with coronary heart disease and that the total blood loss is considerably higher among male patients. Accordingly, the optimal predictive value for blood transfusion remained controversial; however, no previous study has investigated this issue only in patients undergoing RTSA for MIRCT.

The purpose of this study was to investigate the bleeding tendency in patients who underwent RTSA for MIRCT by using the Hb balance method to quantify the perioperative and postoperative (Hemovac drainage amount) blood loss. In addition, we aimed to confirm the previously reported predictive values for blood transfusion, particularly in patients who underwent RTSA for MIRCT.

Materials and methods

This was a retrospective case-control study to investigate blood loss in patients who underwent RTSA for MIRCT and to identify predictors of blood transfusion in these patients.

Patient selection and methods

We retrospectively reviewed all patients who underwent RTSA for MIRCT at our institution, performed by a single surgeon from January 2008 to January 2018. Rotator cuff tear lesions >5 cm were defined as MIRCT by Cofield.[7] In this study, we investigated only patients who underwent RTSA for MIRCT. We excluded patients with lesions other than MIRCT (eg, osteoarthritis, rheumatoid arthritis, postinfectious sequelae, or fracture), those who underwent conversion shoulder arthroplasty, those who underwent revision surgery for failed shoulder arthroplasty, and those with missing laboratory data.

During the study period, 204 patients underwent RTSA. After the application of our inclusion and exclusion criteria, 121 patients were finally enrolled for analysis.

The criterion for transfusion was Hb level <8 g/dL during or after the operation. The transfusion was performed in patients with a higher Hb level if they showed clinical symptoms such as tachycardia, hypoxia, dizziness, and hypotension.

Intraoperative blood loss was measured on the basis of the Hb balance. Blood volume was calculated using the method described by Nadler et al,[17] and Hb loss was estimated according to the following equation:

$$Hb_{loss} = blood\ volume\ \times\ (Hb_i - Hb_e) \times 0.001 + Hb_t$$

where Hb_i is the preoperative Hb concentration, Hb_e is the Hb concentration on postoperative day 1, and Hb_t is the total amount of allogeneic Hb transfused. A unit of transfused blood was considered to contain 52 g of Hb according to the modified cyanmethemoglobin method.[10] The estimated blood loss was then calculated according to the following formula:

$$Estimated\ blood\ loss\ =\ 1000 \times Hb_{loss}/Hb_i$$

The total Hemovac drainage amount was determined as the postoperative blood loss. The total blood loss was calculated by adding the perioperative blood loss (estimated using the Hb balance method) and the postoperative total Hemovac drainage amount.

Preoperative evaluations

The following demographic values were obtained as initial variables: age; sex; BMI; Hb, hematocrit, and prothrombin time/international normalized ratio (PT INR) values; preoperative use of oral anticoagulants; medical comorbidities (hypertension, diabetes mellitus, history of cerebrovascular accident); and American Society of Anesthesiologists (ASA) physical status score. The preoperative Hb, hematocrit, and PT INR values were measured within 2 days of the planned RTSA. Following the guideline on the perioperative management of antiplatelet therapy, all patients discontinued the use of oral anticoagulant 5 to 7 days before the operation; anticoagulants were prescribed again after removal of the Hemovac drain.[13]

Intraoperative and postoperative evaluation

The intraoperative and postoperative variables included mean arterial pressure; use of cement; operative time; estimated blood loss; postoperative Hb, hematocrit, and PT INR values; amount of transfused blood units; total Hemovac drainage amount; and days of Hemovac maintenance.

Operative techniques

All operations were performed by the senior author according to the standard procedure. The deltopectoral approach was used. The cephalic vein was mobilized medially and preserved in most cases. The "3 sisters" (anterior circumflex artery bordered by 2 anterior circumflex veins) were electrocauterized. In all cases, a Hemovac drain was inserted and sutured.

Postoperative treatment and rehabilitation

All patients underwent standard postoperative rehabilitation. The shoulder was immobilized with a sling, except during exercise, for 4 weeks after surgery. Passive pendulum exercise and forward flexion exercise were performed from the day after surgery. The Hemovac drain was kept under atmospheric pressure and removed when the total drainage amount was <10 mL.

Statistical analysis

Student *t*-test and analysis of variance were performed to compare the demographic variables (sex, BMI, preoperative use of anticoagulant, use of cement, ASA physical status score, and medical comorbidities). Any predictive values showing significance at univariate analysis were then subjected to the multivariate analysis to identify independent values for blood transfusion. To determine the cutoff points of continuous predictive values of blood transfusion, receiver operating characteristic (ROC) curves were generated. From these curves, the optimal cutoff points were decided (maximal sensitivity of the test). Significance was set at a level of .05 with associated 95% confidence intervals (CIs). The SPSS software package (version 21.0; IBM Corp, Armonk, NY, USA) was used for all statistical analysis.

Table I Patient demographics

Factors	RTSA for MIRCT
Patients	121
Age (yr)	71.2 ± 6.9
Sex, male/female	46/75
BMI (kg/m^2)	23.9 ± 33.3
Anticoagulant use/no anticoagulant use	26/95
Hemoglobin (g/dL)	12.7 ± 1.4
Hematocrit (%)	37.7 ± 4.0
PT INR	0.97 ± 0.07
Cemented/cementless	89/32
Operation time (h)	1.36 ± 0.21
ASA physical status score	2.1 ± 0.5
Comorbidities	
Hypertension	47
Diabetes mellitus	31
Cerebrovascular accident	7

RTSA, reverse total shoulder arthroplasty; *MIRCT*, massive irreparable rotator cuff tear; *BMI*, body mass index; *PT INR*, prothrombin time/international normalized ratio; *ASA*, American Society of Anesthesiologists.

Results

The demographic characteristics of the 121 enrolled patients are summarized in Table I.

The mean intraoperative estimated blood loss was 346 ± 231.2 mL, and the total Hemovac drainage amount was 500.3 ± 296.4 mL. The mean total blood loss was 846.6 ± 527.6 mL. The mean duration of Hemovac maintenance was 6.0 ± 2.4 days. The overall transfusion rate was 51.2% (62/121), and the mean amount of transfused blood was 2.1 ± 0.8 units. The mean age was 73.1 years for patients who received transfusion and 69.1 years for those who did not receive transfusion (P = .002). The mean arterial pressure during surgery was 84.8 ± 7.3 mm Hg, and there was no significant difference according to comorbidities (none, 85.6 ± 8.5 mm Hg; hypertension, 84.6 ± 7.4 mm Hg; diabetes mellitus, 84.1 ± 6.2 mm Hg; and cerebrovascular accident, 85.0 ± 6.1 mm Hg; P = .880). There were no significant differences in total blood loss between various factors (Table II). No predictive value was significantly associated with the amount of transfused blood units.

Preoperative predictive values for increased total blood loss

Univariate analysis showed that total blood loss increased significantly with older age (P = .042); however, no other preoperative predictive value significantly increased the total blood loss. Although statistically insignificant, the total blood loss tended to increase with decreasing preoperative Hb levels (Table III).

Table II Comparison of blood loss between various factors

Factors	Blood loss (mL)	P value
Sex		.221
Male	312.4 ± 226.9	
Female	365.6 ± 233.6	
BMI (kg/m^2)		.537
<25	334.9 ± 195.5	
≥25	366.7 ± 293.1	
Anticoagulant		.192
No	292.7 ± 192.2	
Yes	359.8 ± 240.1	
Cement		.221
No	332.8 ± 236.3	
Yes	380.4 ± 217.7	
ASA physical status score		.647
1	283.9 ± 193.1	
2	342.5 ± 231.6	
3	377.0 ± 247.1	
Comorbidities		.226
None	384.8 ± 245.1	
Hypertension	322.5 ± 202.0	
Diabetes mellitus	302.7 ± 222.0	
Cerebrovascular accident	486.3 ± 338.8	

BMI, body mass index; *ASA*, American Society of Anesthesiologists.

Intraoperative and postoperative predictive values for increased total blood loss

Univariate analysis showed that total blood loss significantly increased with increasing PT INR measured on operation day. The other factors were not significantly associated with increased total blood loss (Table III). However, the total Hemovac drainage amount increased when cement was used and when the operation time was prolonged ($P = .033$ and $P = .006$, respectively).

Preoperative predictive values for blood transfusion

Multivariate analysis showed that age, sex, BMI, and use of oral anticoagulants did not significantly affect blood transfusion ($P = .148$, $P = .358$, $P = .524$, and $P = .122$, respectively). Preoperative Hb level (odds ratio [OR], 0.39; 95% CI, 0.24-0.65; $P < .001$), hematocrit level (OR, 0.71; 95% CI, 0.60-0.84; $P < .001$), hypertension (OR, 4.00; 95% CI, 1.27-12.59; $P = .018$), and cerebrovascular accident (OR, 23.32; 95% CI, 2.24-242.75; $P = .008$) had significance as independent predictive values for blood transfusion. Although statistically insignificant, the incidence of blood transfusion tended to increase in patients with diabetes mellitus ($P = .061$; Table IV).

The mean preoperative Hb and hematocrit levels were 12.7 ± 1.4 g/dL and 37.7% ± 4.0%, respectively, and the optimal cutoff values were calculated using ROC curves. The area under the curve of Hb was 0.769, and the optimal cutoff value with a sensitivity of >90% was 13.5 g/dL (specificity, 47.5%; sensitivity, 90.3%). The area under the curve for hematocrit was 0.766, and the optimal cutoff value with a sensitivity of >90% was 40% (specificity, 42.4%; sensitivity, 90.3%). Hypertension and cerebrovascular accident were important predictive values for blood transfusion. Compared with patients without these comorbidities, the blood transfusion rate was 4 times and 23.32 times higher in patients with hypertension and cerebrovascular accident, respectively ($P = .018$ and $P = .008$, respectively).

Intraoperative and postoperative predictive values for blood transfusion

The use of cement, extended operation time, increased amount of total Hemovac drainage, and extended duration of Hemovac maintenance were not significant predictive values for blood transfusion ($P = .804$, $P = .314$, $P = .768$, and $P = .760$, respectively).

Discussion

The transfusion rate was 51.2% in this study, which was higher than the reported transfusion rates in other studies. Hardy et al[12] reported that the overall transfusion rate was 7.4% in patients with a mean age of 64.2 years who underwent humeral head arthroplasty, TSA, RTSA, or revision arthroplasty. Padegimas et al[18] reported a transfusion rate of 4.5%, which is lower than that found in our study, in patients with a mean age of 66.9 years who underwent hemiarthroplasty of the humeral head, TSA, RTSA, and revision arthroplasty. Gruson et al[11] reported that the

Table III Predictive values for increased total blood loss

Preoperative values	Univariate, *P* value
Age	.042
Sex	.221
BMI	.480
Use of anticoagulants	.192
ASA physical status score	.647
Comorbidities	
Hypertension	.208
Diabetes mellitus	.179
Cerebrovascular accident	.352
Lower hemoglobin level	.053
Lower hematocrit level	.595
Prolonged PT INR	.213
Intraoperative and postoperative values	
Use of cement	.321
Extended operation time	.955
Prolonged operation day PT INR	.035
Postoperative 1-day Hemovac amount	.797

BMI, body mass index; *ASA*, American Society of Anesthesiologists; *PT INR*, prothrombin time/international normalized ratio.

Table IV Preoperative predictive values for blood transfusion

Values	*P* value	OR (95% CI)
Hemoglobin	<.001	0.393
Hematocrit	<.001	0.707
Prolonged PT INR	.398	15.864
Age	.184	1.050
Sex	.358	1.673
BMI	.524	1.365
Use of anticoagulants	.122	2.478
Use of cement	.098	0.390
ASA physical status score	.964	0.977
Comorbidities	.122	2.478
Hypertension	.018	3.998
Diabetes mellitus	.061	2.991
Cerebrovascular accident	.008	23.319

OR, odds ratio; *CI*, confidence interval; *PT INR*, prothrombin time/international normalized ratio; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists.

transfusion rate was the highest in the reverse shoulder arthroplasty group (74%), and they identified reverse shoulder arthroplasty as an independent risk factor for postoperative transfusion. Malcherczyk et al[15] recently reported that transfusion rate was higher in patients who underwent RTSA (14.4%) than in those who underwent TSA (8.77%), and the mean age was higher in the RTSA group (72.8 years) than in the TSA group (65.2 years). In our study, the transfusion rate was higher probably because we included only patients who underwent RTSA, and the mean age was older (71.2 years). Furthermore, it may also be because many patients had comorbidities such as hypertension, diabetes mellitus, or cerebrovascular accident (70.2% [85/121]).

The total blood loss in this study was about 846.6 mL, which is equivalent to about 3 units of packed red blood cells. Millett et al[16] reported that the estimated blood loss from shoulder arthroplasty, including TSA, humeral head arthroplasty, and revision TSA, was 362 mL, and Gruson et al[11] reported an estimated blood loss of 379.8 mL in the transfusion group. Malcherczyk et al[15] reported a total blood loss in RTSA of 392.7 mL. The total blood loss from surgery was similar in this study (about 346 mL). In those studies, the Hemovac drain was removed on postoperative day 2 regardless of the drainage amount; however, in this study, Hemovac was maintained until the drainage amount was <10 mL. Thereby, we were able to accurately measure not only the perioperative blood loss but also the postoperative blood loss, which were summed to obtain the total blood loss.

Demirkale et al[8] reported that using the closed suction drain in total knee arthroplasty will increase the blood loss and risks of blood transfusion. Shi et al[21] reported less blood loss and transfusion requirement in patients who received 12-hour natural drainage than in those who received continuous negative pressure drainage after total knee arthroplasty. There has been no study about drain pressure after shoulder arthroplasty. In this study, Hemovac drains of all subjects were maintained at atmospheric pressure to decrease the volume of blood loss. Therefore, we could not study the impact of Hemovac pressure on blood loss as there was no subject for comparison.

Previous studies reported various risk factors for transfusion. In particular, most studies reported that lower preoperative Hb level was related to the need for transfusion. Sperling et al[22] reported that the likelihood of transfusion decreased by 35% with an increase in preoperative Hb level of 1 g/dL. Schumer et al[20] reported that the likelihood of transfusion was about 4 times higher when the preoperative Hb level was <12.5 g/dL (cutoff value). In this study, the optimal preoperative Hb level requiring blood transfusion was 13.5 g/dL, which was higher than that reported in previous studies. The likelihood of transfusion was about 2.5 times higher when the preoperative Hb level was below the cutoff.

Padegimas et al[18] identified the cutoff value of preoperative hematocrit using ROC analysis and reported that the risk for transfusion increased by >10% when the preoperative hematocrit was <39.6%. In this study, we also calculated the cutoff value for preoperative hematocrit through ROC analysis, and the identified cutoff (about 40%) was similar to that in the previous study. In addition, the risk for transfusion increased by 1.4 times when the preoperative hematocrit level was <40%. Although the area under the curve of ROC analysis of preoperative Hb and hematocrit levels did not significantly differ, OR analysis showed that preoperative Hb level had a greater impact on blood transfusion.

Schumer et al[20] and Padegimas et al[18] reported that the risk for transfusion increased with the number of comorbidities, and Ahmadi et al[2] reported that the postoperative transfusion rate was higher in patients with diabetes and cardiac disease. On the other hand, Hardy et al[12] reported that the total number of comorbidities (hypertension, cardiac disease, diabetes, and tobacco use) did not affect the risk for transfusion. In this study, hypertension and cerebrovascular accident were significant predictive factors; the risk for blood transfusion increased by 4 times with hypertension and by 23 times with cerebrovascular accident. Although statistically insignificant, the risk for transfusion tended to increase with diabetes mellitus.

Gruson et al[11] reported old age and female sex as other predictive factors. Hardy et al[12] reported intraoperative blood loss and cement fixation of the humeral component as independent risk factors for blood transfusion; however, they found that old age and female sex did not have a significant impact on blood transfusion. Factors such as use of anticoagulants (eg, aspirin, clopidogrel, or low-molecular-weight heparin), BMI, and ASA physical status have also been investigated, although the results varied across studies. In this study, we found that age, sex, BMI, ASA physical status, use of cement, and anticoagulants were not significant predictors of blood transfusion.

Abildgaard et al[1] reported that using tranexamic acid (TXA) decreased perioperative blood loss and the possibility of postoperative drain output in primary shoulder arthroplasty. In addition, Vara et al[23] reported that TXA can significantly reduce the blood loss, Hb loss, and drain output in primary RTSA. Nonetheless, both studies did not mention whether TXA can reduce the transfusion rate. TXA was not used in this study, but it can be considered to decrease the volume of total blood loss after RTSA. Further studies concerning the relationship between TXA and transfusion rate are needed.

Our study has a few limitations. First, transfusion was performed when the Hb level decreased to <8 g/dL in most patients; however, transfusion was performed at a higher Hb level in some older patients and in those with comorbidities presenting with clinical symptoms. Therefore, the criteria for transfusion were not enforced strictly. Second, the number of patients with cerebrovascular accident was small. Third, although hypertension, the most common cardiac comorbidity, was analyzed as a predictive factor, other cardiac diseases were not assessed. Fourth, it is difficult to generalize the result from this study as this was a single-institution and single-surgeon study. However, if studies calculating blood loss with similar methods are available, such a study will be worthwhile and helpful to predict blood transfusion and to calculate the exact blood loss when RTSA is conducted.

Conclusion

The total blood loss in RTSA for MIRCT is about 847 mL. Of the total blood loss, perioperative blood loss accounts for about 40% and postoperative blood loss accounts for about 60%, suggesting that there was a substantial blood loss after surgery. Preoperative Hb and hematocrit levels as well as medial comorbidities, such as hypertension and cerebrovascular diseases, should be examined to predict blood transfusion before surgery. A preoperative Hb level of <13.5 g/dL and hematocrit level of <40% may be significant predictive values for blood transfusion.

Disclaimer

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