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ONLINE ARTICLES

Factors affecting blood loss and blood transfusion in patients with proximal humeral fractures

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Background: The aim of this study was to determine the amount of blood loss and the rate of blood transfusion in patients receiving surgery for proximal humeral fractures depending on the treatment and fracture classification. Moreover, factors associated with blood loss and blood transfusion were analyzed.
Methods: The study included 420 patients who had received surgery for proximal humeral fractures. Data from medical records were collected retrospectively. The calculated blood loss and the transfusion rate were analyzed depending on the type of surgery (plate fixation, arthroplasty, and others) or the fracture classification (2-, 3-, and 4-part fractures). The extent of blood loss and the need for transfusion were correlated with potential risk factors. A score to estimate the probability of blood transfusion was developed.
Results: Average blood loss was 284 mL, and the transfusion rate was 14.5% for all proximal humeral fractures. Shoulder arthroplasty was associated with higher blood loss (353 mL, $P < .01$) and a higher blood transfusion rate (27.3%, $P < .01$) than plate fixation (263 mL and 10.9%, respectively). The fracture classification had no effect on either factor. Significant risk factors for blood loss were male sex, body mass index, surgery time, time until surgery, and vitamin K antagonists. Age, blood loss, American Society of Anesthesiologists score greater than 2, vitamin K antagonists, coronary artery disease (CAD), peripheral artery disease (PAD), and renal disease were associated with a higher transfusion rate.
Conclusion: Blood loss could be affected by a shorter surgery time and by choosing an adequate time until surgery. The consideration of risk factors and the use of a transfusion risk score allow more elaborate ordering of cross-matched blood units and can decrease institutional costs.
Level of evidence: Level III; Retrospective Cohort Design; Treatment Study

Keywords: Proximal humeral fracture; plate; arthroplasty; total blood loss; transfusion; treatment; fracture classification

This study received approval from the local ethics committee (EK-MR-04_10_2017).

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Because of demographic changes, the incidence of fall-related proximal humeral fractures has tripled since 1970.[18] With a frequency of 6%, proximal humeral fractures are the third most common of all osteoporotic fractures. The majority of these injuries are found in female patients and patients older than 50 years.[7]

The treatment of proximal humeral fractures is often a controversial topic of discussion. Minimally displaced fractures can be treated conservatively with early physical therapy. The therapy for displaced fractures is dependent on bone quality, the patient's activity level, and surgical risk factors.[21] Some recent studies have described good functional outcomes in patients with proximal humeral fractures treated nonoperatively.[2] However, for relevant displaced fractures, surgical treatment should be performed. Active patients with good bone structure and moderate displacement of the fragments can be treated with internal fixation via intramedullary nails or locking plates. Shoulder arthroplasty is reserved for displaced, multifragmented fractures with poor bone quality, although there are some borderline cases in which either treatment method, arthroplasty or internal fixation, can be performed. Sole fractures of the greater or lesser tuberosity can be treated by screw fixation.[21]

One of the most common complications of surgical treatments in patients with proximal humeral fractures is perioperative bleeding with the associated blood transfusions. In patients with proximal humeral fractures, transfusions are associated with adverse events and prolonged hospital stays, as shown in the study of Kozanek et al.[11] The only study to date that has examined blood transfusion in patients with proximal humeral fractures, from Rojer et al,[20] revealed a transfusion rate of 15%. Age, admission hematocrit level, treatment method, and the estimated amount of blood loss varied significantly among the patients who received blood transfusion and those who did not. However, the authors did not specify how blood loss was estimated, and only a few risk factors were investigated. No anticoagulants were examined. Moreover, the risk factors for blood loss were not evaluated.[20]

The aims of this study were to quantify total blood loss and blood transfusion in patients with proximal humeral fractures and to determine possible risk factors for both of these parameters. Regarding the risk factors, the study focused on the type of surgical treatment, the fracture classification, and the use of anticoagulants. A score to estimate the probability of blood transfusion was developed.

Material and methods

A retrospective analysis of medical charts and of the database of the institution's blood bank was performed. Between 2004 and 2017, 542 patients received surgical treatment for proximal humeral fractures at our institution. The kind of surgery performed and the type of fracture were documented. The fractures were graduated according to the Neer classification system into 2-, 3-, and 4-part fractures.[17] The surgery types were divided into plate fixation, arthroplasty, and others. The latter group included intramedullary locking nails and all types of screw fixation.

Further parameters that were recorded from the electronic charts were as follows: sex; age; weight; height; time until surgery; length of surgery; approach; American Society of Anesthesiologists (ASA) score; comorbidities; use of anticoagulants; and preoperative and postoperative hemoglobin, hematocrit, and platelet levels. The perioperative transfusion amount was derived from medical records, anesthesia sheets, and the database of the institution's blood bank. Usually, patients underwent transfusions when the hemoglobin level fell below 8 g/dL, according to our transfusion protocol. If patients showed some clinical symptoms (tachycardia, low blood pressure, chest pain, or weakness) or had cardiac disease, the transfusion could also be triggered by a hemoglobin level under 10 g/dL. Total blood loss was calculated as described by Charrois et al.[4]

Patients were excluded from this study if they had other hemorrhagic complications, such as gastrointestinal bleeding; they had other relevant injuries to the long bones or trunk; they had a pathologic fracture due to a neoplastic disease; they received revision surgery; they had known coagulopathy disease; or relevant data were missing. The study was conducted in conformity with the principles of the revised version of the Declaration of Helsinki.

The data were analyzed with the R program for statistical computing (R Foundation for Statistical Computing, Vienna, Austria)[19] and Microsoft Excel 2010 (Microsoft, Seattle, WA, USA). Linear regression and logistic regression were used to compare total blood loss and the rate of blood transfusion first between different types of surgery (plate fixation, shoulder arthroplasty, and others) and second between different types of fracture (2-, 3-, and 4-part fractures). Univariate and multivariate analyses were performed to recognize possible risk factors associated with total blood loss and blood transfusion in patients with proximal humeral fractures. The level of significance was set at $P < .05$.

To derive a score to estimate the probability of a blood transfusion being needed, we used logistic regression to create a multivariate model including all of the potential risk factors available preoperatively and then applied stepwise backward elimination to reduce the number of factors and remove those that did not contribute significantly to the model. The coefficients of the resulting simplified models were checked for biological plausibility and then rescaled to create scores with maximum totals of 10.

Results

Patient characteristics

After consideration of the exclusion criteria, 420 patients could be included in this study. The most common treatment was plate fixation (n = 302), followed by shoulder arthroplasty (n = 99), whereas 19 patients received some other kind of treatment. According to the Neer classification system, the most frequent fracture types were 3-part fractures (n = 167), followed by 4-part (n = 133) and 2-part (n = 109) fractures. Four-part fractures were the main fracture type in patients receiving shoulder arthroplasty (59.6%), whereas 3-part fractures were most frequent in patients receiving plate fixation (46.7%).

Table I Patient characteristics by surgery

Variable	All, N = 420	Plate fixation, n = 302	Arthroplasty, n = 99	Other fixation, n = 19	*P* value
Sex, n (%)					
Female	331 (78.8)	234 (77.5)	89 (89.9)	8 (42.1)	
Male	89 (21.2)	68 (22.5)	10 (10.1)	11 (57.9)	
Age, yr	70.1 (14.1)	68.9 (14.2)	76.2 (9.72)	57.6 (19.7)	
Height, cm	166 (8.72)	166 (8.82)	163 (6.67)	171 (12.3)	
Weight, kg	76.9 (19.2)	76.7 (18.6)	76.0 (20.5)	83.2 (20.2)	.325
BMI, kg/m^2	27.9 (6.29)	27.7 (6.12)	28.6 (6.90)	28.4 (5.50)	.463
Hematocrit level, L/L	0.38 (0.04)	0.38 (0.04)	0.37 (0.04)	0.39 (0.05)	.008
Hemoglobin level, g/dL	12.9 (1.75)	12.9 (1.79)	12.5 (1.53)	13.5 (1.83)	.012
Platelet level, n (%)					.147
<100 count/mL	7 (1.67)	7 (2.32)	0 (0.00)	0 (0.00)	
100-149 count/mL	19 (4.52)	12 (3.97)	4 (4.04)	3 (15.8)	
150-199 count/mL	74 (17.6)	52 (17.2)	21 (21.2)	1 (5.26)	
>200 count/mL	320 (76.2)	231 (76.5)	74 (74.7)	15 (78.9)	
Surgery time, min	75.4 (27.6)	69.1 (24.1)	96.3 (27.8)	66.0 (26.2)	
Time until surgery, d	3.9 (3.6)	3.6 (3.2)	4.7 (4.2)	4.8 (4.3)	.016
Approach, n (%)					
Deltopectoral	152 (41.0)	51 (19.7)	97 (100)	4 (26.7)	
Delta-split	219 (59.0)	208 (80.3)	0 (0.00)	11 (73.3)	
ASA score, n (%)					
1-2	209 (51.4)	161 (55.1)	34 (35.4)	14 (73.7)	
3-4	198 (48.6)	131 (44.9)	62 (64.6)	5 (26.3)	
Hypertension, n (%)	223 (53.3)	157 (52.3)	57 (57.6)	9 (47.4)	.575
Diabetes mellitus, n (%)	84 (20.1)	58 (19.3)	23 (23.2)	3 (15.8)	.655
Coronary heart disease, n (%)	44 (10.5)	31 (10.3)	12 (12.1)	1 (5.26)	.726
Peripheral artery disease, n (%)	11 (2.63)	10 (3.33)	1 (1.01)	0 (0.00)	.586
Apoplexy, n (%)	33 (7.89)	22 (7.33)	11 (11.1)	0 (0.00)	.243
Renal disease, n (%)	36 (8.61)	26 (8.67)	9 (9.09)	1 (5.26)	.948
Lung disease, n (%)	52 (12.4)	36 (12.0)	15 (15.2)	1 (5.26)	.549
Antiplatelet drug, n (%)	132 (31.4)	95 (31.5)	34 (34.3)	3 (15.8)	.280
Vitamin K antagonists, n (%)	39 (9.29)	27 (8.94)	11 (11.1)	1 (5.26)	.733
NOACs, n (%)	9 (2.14)	3 (0.99)	5 (5.05)	1 (5.26)	.022
Fracture classification, n (%)					
2-part fracture	109 (26.7)	83 (28.5)	12 (12.1)	14 (73.7)	
3-part fracture	167 (40.8)	136 (46.7)	28 (28.3)	3 (15.8)	
4-part fracture	133 (32.5)	72 (24.7)	59 (59.6)	2 (10.5)	
Blood units	0.29	0.21	0.57	0.11	
Blood transfusion, n (%)					
No	359 (85.5)	269 (89.1)	72 (72.7)	18 (94.7)	
Yes	61 (14.5)	33 (10.9)	27 (27.3)	1 (5.26)	
Total blood loss, mL	283.9 (198.1)	262.6 (192.0)	353.1 (194.1)	261.1 (240.0)	

BMI, body mass index; *ASA*, American Society of Anesthesiologists; *NOAC*, non-vitamin K antagonist oral anticoagulants.
Data are presented as mean (range) unless otherwise indicated.

Considering the demographic data according to the surgery type, we found significant differences between the treatment groups by sex, age, preoperative hemoglobin level, ASA score, and surgery time. In the arthroplasty group, there were more female patients (89.9%) than in the other groups. Patients receiving shoulder arthroplasty were on average older than other patients and more often had ASA scores greater than 2. Surgery lasted longer in the arthroplasty group, and there was also a difference in the use of non-vitamin K antagonist oral anticoagulants. However, only 9 patients received this medication. Demographic characteristics and clinical data are summarized in Table I.

Total blood loss and blood transfusion

Overall mean total blood loss was 284 mL, and 14.5% of patients with proximal humeral fractures needed blood transfusions. Blood loss was greater when shoulder arthroplasty was performed (353 mL) compared with plate

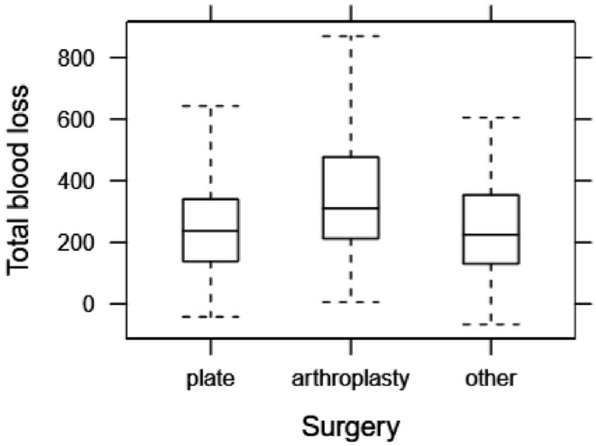

Figure 1 Total blood loss (in milliliters) by surgery type.

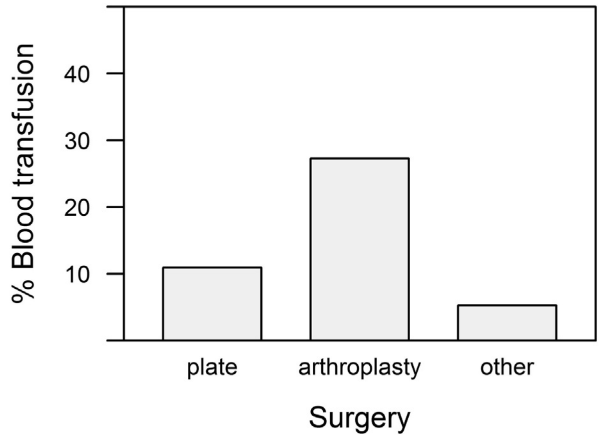

Figure 2 Blood transfusions by surgery type.

fixation (263 mL, $P < .001$; Fig. 1). Although blood loss with other fixation types was lower (261 mL) than with arthroplasty, the difference was not significant ($P = .13$). Correspondingly, the transfusion rate (27.3%) and the number of blood units (0.57) were higher in the arthroplasty group than in the plate fixation group (10.9% and 0.21 units, respectively; $P < .001$) or other fixation group (5.3% and 0.11 units, respectively; Fig. 2). Possibly because of the small number of patients in the other fixation group, the difference in the transfusion rate was not significant ($P = .18$). No significant differences in blood loss, blood transfusion, or number of blood units were noted between plate fixation and other fixation types ($P > .05$). The fracture classification had no effect on blood loss and blood transfusion, although both were greater in 4-part fractures than in other fractures (Figs. 3 and 4).

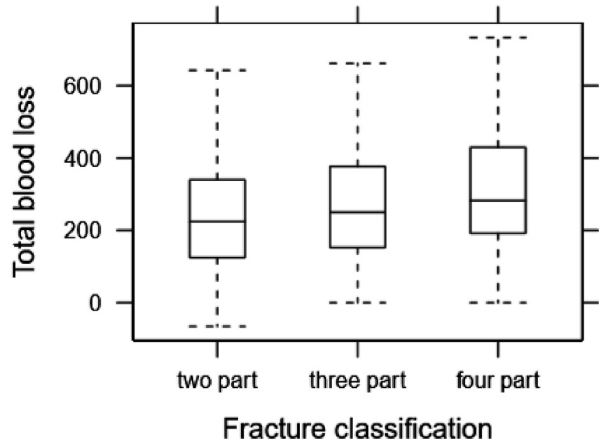

Figure 3 Total blood loss (in milliliters) by fracture classification.

Risk factors for total blood loss in all fractures

The univariate analysis revealed that prolonged surgery ($P < .001$) and a shorter time until surgery ($P < .001$) were associated with increased blood loss. In addition, sex ($P < .008$), body mass index (BMI) (P = .025), and the use of vitamin K antagonists ($P = .015$) affected blood loss. Multivariate analysis similarly indicated effects on blood loss from surgery time ($P = .029$), time until surgery ($P < .001$), ASA score ($P = .006$), and the use of new oral anticoagulants (P = .025) independent of other risk factors. The results of the univariate and multivariate analyses are shown in Tables II and III, respectively.

Risk factors for total blood loss in different surgery subgroups

In the next step, we analyzed the risk factors for blood loss and blood transfusion separately for the plate fixation and arthroplasty subgroups. The subgroup comprising other types of surgery included only a few patients, so it was not evaluated separately. To make the assessment more transparent, we have presented only the results of the multivariate analysis.

On multivariate analysis of the plate fixation group, age ($P = .039$), BMI ($P = .013$), and ASA score ($P = .03$) had an impact on blood loss. As a surgery-specific factor, time until surgery could additionally influence total blood loss ($P < .001$).

The risk factors for bleeding in arthroplasty patients were different from those in the plate fixation group. Only sex ($P = .027$) and the use of vitamin K antagonists ($P = .002$) affected total blood loss.

Risk factors for blood transfusion in all fractures

In the univariate analysis, an ASA score above 2 ($P < .001$), peripheral artery disease ($P = .019$), renal disease (P

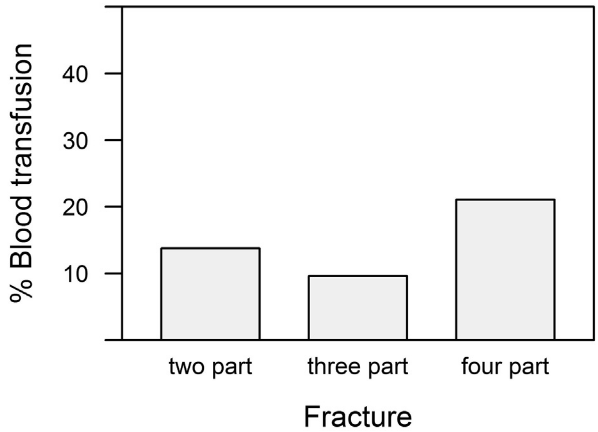

Figure 4 Blood transfusions by fracture classification.

< .001), the use of vitamin K antagonists ($P < .001$), low preoperative hemoglobin ($P < .001$) and hematocrit ($P < .001$) levels, and surgery type ($P < .001$, arthroplasty vs. plate fixation) were the most important risk factors for blood transfusion. Other significant risk factors were age ($P < .001$), platelet level ($P = .03$), estimated blood loss ($P < .001$), and coronary heart disease ($P = .005$). In the multivariate analysis, only age ($P = .029$), BMI ($P = .018$), estimated blood loss ($P < .001$), and especially ASA score greater than 2 (odds ratio, 3.71; $P = .028$) remained as significant risk factors for the need for blood transfusion after adjustment for all other risk factors. The results of the univariate and multivariate analyses are demonstrated in Tables IV and V, respectively.

Risk factors for blood transfusion in different surgery subgroups

If the multivariate analysis was performed only for the plate fixation subgroup, total blood loss ($P < .001$) and ASA score ($P = .019$) were independent factors for the transfusion risk. Both of these factors were also associated with higher transfusion rates in patients who had received shoulder arthroplasty ($P < .001$ for total blood loss and $P = .003$ for ASA score). In the plate fixation group, age ($P = .016$) and hematocrit level ($P < .001$) were additional independent risk factors for transfusion.

Transfusion risk score

After the determination of the risk factors for blood transfusion, a risk score was constructed. To develop the score, we began with a reduced version of the full multivariate model (Table V) including the type of surgery and those risk factors able to be determined preoperatively. This model was reduced iteratively using stepwise backward elimination to include only those factors that continued to add a significant

Table II Results of univariate analysis regarding surgery type, fracture classification, and other risk factors for total blood loss in patients with surgical treatment for proximal humeral fractures

Variable	Difference (95% CI)	*P* value
Surgery		
Arthroplasty vs. plate fixation	90.5 (38.2 to 142.8)	<.001
Other fixation vs. plate fixation	−1.5 (−108.3 to 105.3)	.999
Arthroplasty vs. other fixation	−92.0 (−205.1 to 21.1)	.134
Fracture		
3- vs. 2-part fracture	24.9 (−33.2 to 83.1)	.572
4- vs. 2-part fracture	22.7 (−40.8 to 86.2)	.677
4- vs. 3-part fracture	−2.2 (−58.1 to 53.6)	.995
Approach: deltopectoral vs. delta split	32.8 (−26.9 to 92.5)	.280
Sex: male vs. female	63.7 (17.0 to 110.4)	.008
Age, per yr	0.2 (−1.2 to 1.6)	.749
BMI, per kg/m^2	3.4 (0.4 to 6.4)	.025
Platelet level		
100-149 vs. <100 count/mL	53.8 (−136.6 to 244.2)	.732
150-199 vs. <100 count/mL	64.4 (−105.5 to 234.3)	.579
>200 vs. <100 count/mL	4.3 (−159.8 to 168.3)	.999
Surgery time, per 10 min	13.9 (6.6 to 21.3)	<.001
Time until surgery, per d	−13.6 (−18.8 to −8.4)	<.001
ASA score: 3-4 vs. 1-2	36.8 (−1.7 to 75.4)	.061
Hypertension	14.5 (−23.2 to 52.2)	.451
Diabetes mellitus	−27.2 (−74.1 to 19.7)	.254
Coronary heart disease	5.7 (−55.6 to 67.0)	.855
Peripheral artery disease	17.4 (−100.4 to 135.1)	.772
Apoplexy	22.0 (−48.0 to 91.9)	.537
Renal disease	13.8 (−53.3 to 80.8)	.687
Lung disease	−6.0 (−63.0 to 51.2)	.839
Antiplatelet drug	21.1 (−19.3 to 61.4)	.306
Vitamin K antagonists	80.0 (15.9 to 144.1)	.015
NOACs	−107.3 (−237.2 to 22.5)	.105
Surgery—adjusted		
Screw vs. plate fixation	54.9 (−23.4 to 133.2)	.222
Arthroplasty vs. plate fixation	3.0 (−115.4 to 121.3)	.998
Arthroplasty vs. screw fixation	−52.0 (−191.8 to 87.8)	.650
Fracture—adjusted		
3- vs. 2-part fracture	−19.4 (−80.3 to 41.6)	.734
4- vs. 2-part fracture	−17.4 (−84.4 to 50.0)	.813
4- vs. 3-part fracture	2.0 (−55.5 to 59.5)	.996

CI, confidence interval; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *NOAC*, non-vitamin K antagonist oral anticoagulants.

Table III Results of multivariate analysis regarding surgery type, fracture classification, and other risk factors for total blood loss in patients with surgical treatment for proximal humeral fractures

Variable	Difference (95% CI)	*P* value
Sex: male vs. female	40.4 (−14.9 to 95.6)	.151
Age, per yr	1.1 (−0.6 to 2.8)	.208
BMI, per kg/m^2	3.3 (−0.0 to 6.7)	.051
Platelet level		
100-149 vs. <100 count/mL	−2.6 (−213.9 to 208.8)	>.999
150-199 vs. <100 count/mL	1.2 (−176.9 to 179.3)	>.999
>200 vs. <100 count/mL	−41.8 (−213.7 to 130.1)	.804
Surgery time, per 10 min	0.9 (0.1 to 1.7)	.029
Time until surgery, per d	−12.0 (−17.5 to −6.6)	<.001
ASA score: 3-4 vs. 1-2	63.9 (18.5 to 109.3)	.006
Hypertension	2.3 (−40.0 to 44.5)	.916
Diabetes mellitus	−19.9 (−73.2 to 33.4)	.463
Coronary heart disease	−42.5 (−116.5 to 31.6)	.260
Peripheral artery disease	−11.7 (−147.1 to 123.8)	.866
Apoplexy	7.1 (−75.9 to 90.0)	.867
Renal disease	18.7 (−61.7 to 99.0)	.648
Lung disease	−1.2 (−63.9 to 61.6)	.971
Antiplatelet drug	2.2 (−46.6 to 50.9)	.930
Vitamin K antagonists	67.0 (−6.2 to 140.1)	.073
NOACs	−167.3 (−313.3 to −21.4)	.025

CI, confidence interval; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *NOAC*, non-vitamin K antagonist oral anticoagulants.

contribution to the risk of blood transfusion until no further factors could be eliminated from the model.

Table VI and Figure 5 show model-based predictions of transfusion risk derived from the resulting additive score model together with the actual observed transfusion rates in patients grouped by score. The score shows good agreement between the estimated probability of blood transfusion and observed transfusion rates, although the results for patients with a high risk of transfusion are harder to judge owing to the paucity of data in this group (Table VI, Fig. 5).

Discussion

After surgery for proximal humeral fractures, postoperative anemia may develop, requiring blood substitution. The transfusion of blood units is known to be associated with risk factors such as increased infection risk. In addition, over-transfusion may impair patients' health and lead to unnecessary costs.[3,9] Expenses may also be generated by an inadequate cross-matching policy in the routine

Table IV Results of univariate analysis regarding surgery type, fracture classification, and other risk factors for blood transfusion in patients with surgical treatment for proximal humeral fractures

Variable	OR (95% CI)	*P* value
Surgery		
Arthroplasty vs. plate fixation	3.05 (1.57-5.94)	<.001
Other fixation vs. plate fixation	0.65 (0.08-5.01)	.872
Arthroplasty vs. other fixation	0.21 (0.03-1.68)	.182
Fracture		
3- vs. 2-part fracture	0.57 (0.23-1.41)	.317
4- vs. 2-part fracture	1.05 (0.44-2.55)	.989
4- vs. 3-part fracture	1.85 (0.81-4.21)	.188
Approach: deltopectoral vs. delta split	2.14 (0.88-5.21)	.094
Sex: male vs. female	0.80 (0.38-1.71)	.570
Age, per yr	1.05 (1.03-1.08)	<.001
BMI, per kg/m^2	0.95 (0.90-1.00)	.050
Hematocrit level		
0.3-0.34 vs. <0.3 L/L	0.08 (0.02-0.39)	.001
0.35-0.39 vs. <0.3 L/L	0.03 (0.01-0.13)	<.001
>0.4 vs. <0.3 L/L	0.01 (0.00-0.07)	<.001
Hemoglobin level		
10.0-11.9 vs. <10.0 g/dL	0.14 (0.04-0.51)	.001
12.0-13.9 vs. <10.0 g/dL	0.05 (0.01-0.16)	<.001
>14.0 vs. <10.0 g/dL	0.02 (0.00-0.10)	<.001
Platelet level		
100-149 vs. <100 count/mL	0.08 (0.01-1.09)	.059
150-199 vs. <100 count/mL	0.20 (0.03-1.34)	.111
>200 vs. <100 count/mL	0.14 (0.02-0.85)	.030
Surgery time, per 10 min	1.05 (0.95-1.17)	.328
Time until surgery, per d	1.01 (0.94-1.09)	.787
Total blood loss, per 100 mL	1.37 (1.19-1.58)	<.001
ASA score: 3-4 vs. 1-2	5.70 (2.74-11.85)	<.001
Hypertension	1.59 (0.90-2.80)	.111
Diabetes mellitus	1.05 (0.53-2.05)	.896
Coronary heart disease	2.83 (1.36-5.90)	.005
Peripheral artery disease	4.64 (1.28-16.78)	.019
Apoplexy	1.50 (0.61-3.68)	.373
Renal disease	4.12 (1.91-8.88)	<.001
Lung disease	1.86 (0.90-3.83)	.093
Antiplatelet drug	1.23 (0.69-2.18)	.490
Vitamin K antagonists	3.97 (1.89-8.34)	<.001
NOACs	0.68 (0.10-4.59)	.696
Surgery—adjusted		
Screw vs. plate fixation	0.59 (0.13-2.82)	.707
Arthroplasty vs. plate fixation	1.36 (0.03-68.44)	.981
Arthroplasty vs. screw fixation	2.30 (0.04-135.37)	.879
Fracture—adjusted		
3- vs. 2-part fracture	0.22 (0.04-1.26)	.104
4- vs. 2-part fracture	0.97 (0.20-4.74)	.999
4- vs. 3-part fracture	4.52 (0.97-21.01)	.056

OR, odds ratio; *CI*, confidence interval; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *NOAC*, non-vitamin K antagonist oral anticoagulants.

Table V Results of multivariate analysis regarding surgery type, fracture classification, and other risk factors for blood transfusion in patients with surgical treatment for proximal humeral fractures

Variable	OR (95% CI)	*P* value
Sex: male vs. female	0.93 (0.26-3.34)	.917
Age, per yr	1.06 (1.01-1.11)	.029
BMI, per kg/m^2	0.89 (0.80-0.98)	.018
Hematocrit level		
0.3-0.34 vs. <0.3 L/L	0.07 (0.00-1.50)	.097
0.35-0.39 vs. <0.3 L/L	0.02 (0.00-0.47)	.012
>0.4 vs. <0.3 L/L	0.01 (0.00-0.23)	.004
Hemoglobin level		
10.0-11.9 vs. <10.0 g/dL	0.51 (0.03-9.04)	.854
12.0-13.9 vs. <10.0 g/dL	0.48 (0.03-8.73)	.829
>14.0 vs. <10.0 g/dL	0.12 (0.00-5.74)	.376
Platelet level		
100-149 vs. <100 count/mL	0.15 (0.00-18.73)	.592
150-199 vs. <100 count/mL	1.03 (0.03-38.36)	>.999
>200 vs. <100 count/mL	0.95 (0.03-31.31)	>.999
Surgery time, per 10 min	1.01 (0.99-1.03)	.286
Time until surgery, per d	1.10 (0.97-1.24)	.146
Total blood loss, per 100 mL	1.99 (1.55-2.55)	<.001
ASA score: 3-4 vs. 1-2	3.71 (1.15-11.91)	.028
Hypertension	0.86 (0.32-2.26)	.754
Diabetes mellitus	1.35 (0.44-4.20)	.600
Coronary heart disease	1.61 (0.45-5.77)	.462
Peripheral artery disease	2.76 (0.23-33.41)	.425
Apoplexy	2.58 (0.51-13.03)	.252
Renal disease	4.11 (0.95-17.78)	.059
Lung disease	0.88 (0.21-3.67)	.857
Antiplatelet drug	0.70 (0.25-1.96)	.493
Vitamin K antagonists	1.07 (0.25-4.52)	.924
NOACs	1.36 (0.04-50.81)	.869

OR, odds ratio; *CI*, confidence interval; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *NOAC*, non-vitamin K antagonist oral anticoagulants.

preoperative preparation. For these reasons, it is fundamental to assess risk factors for bleeding and substitution of blood units. To our knowledge, this is the first study that has quantified total blood loss and blood transfusion in patients with proximal humeral fractures and has determined possible risk factors for both of these parameters.

Blood loss and blood transfusion

The transfusion rate in this study in all patients was 14.5% and is similar to that reported by Rojer et al,[20] with 15%. The transfusion rate in patients with proximal humeral fractures is lower than that described in patients with other fractures such as femoral neck fractures (53%) or extracapsular femoral fractures (36%).[22,23]

The blood loss averaged 283.9 mL and was higher than that reported in the studies of Liu et al[13] and Zhao et al[24] (172-205 mL) but similar to that described by Lu et al[14] (129-278 mL). However, in each of these studies, only plate fixation was examined and the authors took only the intraoperatively observed blood loss into account.[13,14,24] Measuring intraoperative blood loss by counting the blood volume in an intraoperative suction container may be falsified in different ways, for example, by the use of irrigation fluids. We believe that the method of Charrois et al[4] used in our study is more precise for the estimation of blood loss because it takes hidden blood loss into account as well.

The transfusion rate and amount of blood loss were significantly higher in patients receiving arthroplasty than in patients undergoing plate fixation or other fixation methods. This finding could be explained by the more extensive soft-tissue approach and greater manipulation of the bone resulting from the preparation for the implantation of the shoulder arthroplasty. The fracture classification had no significant influence either on blood loss or on transfusion rates. However, there was a slight tendency toward more blood loss in fractures with multiple parts.

Table VI Risk factor scoring for risk factors included in model

	Score
Surgery	
Other fixation	0
Plate fixation	2
Arthroplasty	3
ASA score	
1-2	0
3-4	2
Hematocrit level (L/L)	
≥0.40	0
0.35-0.39	1
0.30-0.34	2
<0.30	5
Maximum total	10

ASA, American Society of Anesthesiologists.

Risk factors for blood loss

Surgery type, male sex, and higher BMI were further parameters leading to elevated blood loss. Again, an explanation for this could be the need for more extensive surgical soft-tissue manipulation in male or obese patients.

The only influenceable risk factors for blood loss are the surgery time and the time until surgery. A shorter surgery time and a longer delay of the surgical procedure are associated with lower blood loss. In particular, patients operated on during the first 2 days after trauma showed more blood loss than patients with delayed surgery. To our knowledge, this is the first study showing these correlations. An interaction between surgery delay and altered transfusion requirements was not found in fractures of other anatomic locations.[8]

Score	Probability	95% CI	Transfusions	Total	%
0	0.16	(0.04, 0.63)	0	9	0.00
1	0.40	(0.13, 1.26)	0	4	0.00
2	1.02	(0.41, 2.53)	0	78	0.00
3	2.59	(1.32, 5.04)	3	81	3.70
4	6.40	(4.04, 10)	2	66	3.03
5	14.97	(11.06, 19.95)	13	87	14.94
6	31.17	(23.93, 39.46)	20	52	38.46
7	53.81	(40.9, 66.22)	9	19	47.37
8	74.98	(59.02, 86.17)	1	1	100.00
9	88.52	(74.63, 95.28)	5	7	71.43
10	95.20	(85.62, 98.51)	3	3	100.00

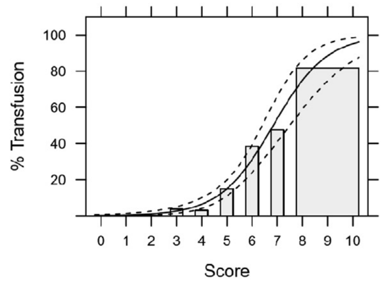

Figure 5 Model-based predicted blood transfusion risk with 95% confidence intervals (*CI*) in patients with proximal humeral fractures for full range of scores together with observed transfusion rates.

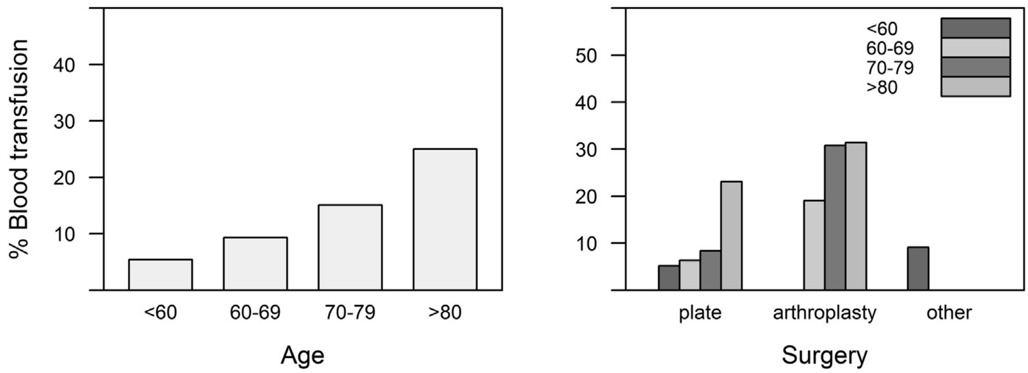

Figure 6 Blood transfusions by age (in years).

One of the most important factors leading to increased blood loss is the use of vitamin K antagonists. It is also 1 of only 2 factors in this study that affected both blood loss and blood transfusion. Of course, in patients taking vitamin K antagonist medication, the international normalized ratio was optimized preoperatively. However, the use of thromboembolism prophylaxis in therapeutic doses probably leads to significantly more blood loss in those patients. In contrast, the use of antiplatelet drugs had no influence on either blood loss or blood transfusion. Other studies based on different anatomic locations have revealed divergent results regarding the use of antiplatelet drugs and bleeding complications, sometimes confirming the effect on increased blood loss or transfusion rates and sometimes not.[5,6,12,15,16] In contrast, the use of vitamin K antagonists had no influence on bleeding complications in patients with proximal femoral fractures.[6,15]

If the subgroups regarding the surgical treatment in the multivariate analysis were analyzed separately, different risk factors for blood loss could be identified for patients with plate fixation surgery or arthroplasty. Apparently, the use of vitamin K antagonists affects the risk of bleeding in patients receiving arthroplasty more than in patients receiving plate fixation. The explanation for this may be that during shoulder arthroplasty surgery, more extended bone and soft-tissue manipulation is needed compared with plate fixation. This freshly created surface in bone and soft tissue is naturally susceptible to new bleeding, especially if the patients are receiving thromboembolism prophylaxis in therapeutic doses. According to the ASA score, most of the patients in the arthroplasty group had scores greater than 2, so in consideration of other factors, this does not seem to play such an important role as in the plate fixation group. In contrast, time until surgery seems to influence blood loss more in patients with plate fixation than in patients receiving arthroplasty.

Risk factors for transfusion

The risk factors affecting transfusion were mostly different from those affecting blood loss. Only surgery type and the use of vitamin K antagonists influenced both of these parameters.

The need for blood transfusion is strongly related to the patient's age and to the hemoglobin and hematocrit levels at the patient's hospital admission. As Figure 6 reveals, patients older than 80 years have higher blood transfusion risk compared with younger patients. This trend is also affirmed if the plate fixation group and arthroplasty group are analyzed separately (Fig. 6). Consequently, the assumption of Rojer et al[20] that older patients receive more transfusions only because they more frequently receive arthroplasty is not supported. Age was similarly highlighted as a risk factor for transfusion in other fractures such as proximal femoral fractures.[8,9,22]

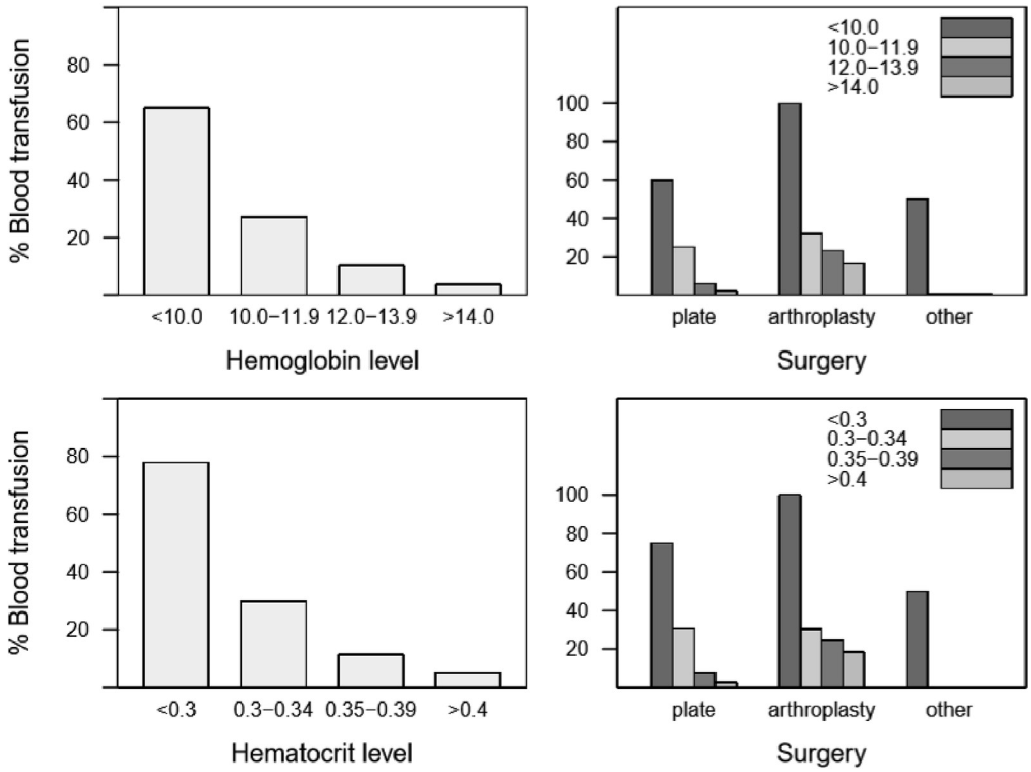

Figure 7 Blood transfusions by hemoglobin level (in grams per deciliter) and hematocrit level (in liter per liter).

As mentioned earlier, admission hemoglobin and hematocrit levels are also associated with blood transfusion. Hemoglobin levels under 10 g/dL are associated with a much higher transfusion risk (65%) than higher admission hemoglobin levels (transfusion risk between 4% and 27%; Fig. 7). This tendency can also be observed when analyzing the different surgery types separately. These results are in accordance with previous observations in patients with femoral fractures.[9,10,22] Adunsky et al[1] showed that patients with hip fractures who have hemoglobin levels under 12 g/dL have a 5-fold increased transfusion risk. Desai et al[8] demonstrated that for every 1-g/dL decrease in hemoglobin level, patients had a 30% increased risk of blood transfusion.

Both parameters mentioned earlier, age and hemoglobin level, are related to each other, because older patients often show lower admission hemoglobin levels. On the other hand, age is associated with a higher ASA score, which is another risk factor for transfusion in this study. Patients with multiple illnesses and specifically patients with coronary heart disease, peripheral artery disease, and renal disease are at higher risk of receiving blood transfusions after surgical treatment of proximal humeral fractures. These results are not really surprising because it is commonly accepted to use liberal transfusion protocols for patients with coronary heart disease. Owing to common pathophysiology, peripheral artery disease may be associated with coronal artery disease. The explanation for the higher transfusion risk in patients with renal disease could be the renal anemia often occurring in these patients. Multiple morbidities and higher ASA scores are also independent risk factors for blood transfusions in patients with femoral fractures.[15]

If the surgical subgroups were analyzed separately, there were only a few independent risk factors for transfusion. ASA score and total blood loss were represented in both groups. In the plate fixation group, age additionally influenced the risk of transfusion independently.

Transfusion risk score

The cross-matching policy of blood units can be costly and can sometimes overstretch the resources of the blood bank. Therefore, it is important to recognize preoperatively those patients who are at increased risk of requiring blood transfusions. The transfusion risk score developed in this study showed good agreement between the estimated and real probability of blood transfusion in our study group. If the accuracy of the predicted risk levels can be validated in an independent study cohort, the score could help to decide, on admission, whether cross-matched blood should be ordered. We recommend that for patients receiving a score of up to 4 points, only antibody screening should be performed. Above this value, the probability of blood transfusion rises higher than 15%, so for these patients, cross-matched blood units should be ordered.

This study has some limitations. The most important limitation is the retrospective nature of this investigation. Because of the retrospective study design, there were no study-related standards for blood transfusion, which is another weak point. However, in our clinic, there are general guidelines that determine cutoff levels for the transfusion policy.

On the other hand, this study has several strong points. The large number of patients included raises the study's statistical power. Another strength is the strict exclusion criteria, which have not always been considered in similar studies. Finally, in this study, not only was observed blood loss included but both compensated blood loss and hidden blood loss were considered. In our opinion, this is the more precise and accurate method for the estimation of blood loss.

Conclusion

The rate of blood transfusion and the amount of blood loss are higher in patients receiving shoulder arthroplasty than in patients with plate fixation because of proximal humeral fractures. This finding should be taken into account in borderline cases if decisions regarding the operative treatment have to be made. Shorter surgery time and optimal time until surgery can reduce intraoperative blood loss. The consideration of risk factors and the use of a transfusion risk score allow more elaborate ordering of cross-matched blood units and can decrease institutional costs.

Disclaimer

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