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ORIGINAL PAPER

Differences in total blood loss and transfusion rate between different indications for shoulder arthroplasty

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Abstract

Purpose In this study, the total blood loss, transfusion rate and number of transfused blood units in patients with different indications for shoulder arthroplasty: primary, fracture and secondary were compared. Risk factors for bleeding and transfusion were analysed.

Methods Medical records and the database of the institution's blood bank from 527 patients that received shoulder arthroplasty were analysed retrospectively. This study included 419 patients that were divided in three different groups: primary ($n = 278$), fracture ($n = 110$) and secondary (following prior osteosynthesis; $n = 31$) shoulder arthroplasty. The demographic and clinical data were collected. The total blood loss (TBL) was calculated and transfusions recorded.

Results The transfusion rate and mean amount of transfused blood units (BU) were higher in fracture (32.7% and 0.69BU, $p < 0.01$) and secondary arthroplasty (35.5% and 0.97BU, $p < 0.01$) than in primary arthroplasty (12.6% and 0.28BU). The overall transfusion rate was 19.6% at a mean TBL of 370 ml. However, patients with primary arthroplasty experienced significantly higher total blood loss than those after fracture arthroplasty ($p < 0.01$). Longer surgery time and male sex are significant risk factors for elevated blood loss. The pre-operative use of vitamin K antagonist, cemented arthroplasty, high BMI, coronary heart disease and ASA score > 2 are relevant risk factors for blood transfusion.

Conclusion The most important susceptible factor that affects the TBL is the surgery time. Transfusion rates are higher in patients with fracture arthroplasty than after primary arthroplasty.

Keywords Primary arthroplasty · Shoulder arthroplasty · Shoulder endoprosthesis · Bleeding · Total blood loss · Blood transfusion · Primary · Fracture · Secondary

Introduction

Shoulder arthroplasty (SA) is an important therapy option for patients with degenerative and some acute shoulder diseases [1, 2]. The treatment with SA mostly leads to good long-term results [3, 4]. While peri-operative bleeding is one of the most common complications (4–43%) and though blood transfusion may jeopardize patients' health via transfer of infectious diseases or occurrence of fever or anaphylactic reaction, the estimation of blood loss and transfusion rate and identification of possible risk factors are of major importance [5–10].

There are different indications for an implantation of a shoulder endoprosthesis. Main reasons for this kind of surgery are degenerative changes of the glenohumeral joint such as arthrosis or rotator cuff arthropathy. Other important indications for SA are fractures of the proximal humerus. Finally, the failure of previous osteosynthesis following proximal humerus fracture can be another reason for SA.

There are only few studies that have focused on possible risk factors for blood transfusion in patients after SA. As they demonstrate low haematocrit or haemoglobin-level, a high score in the American Society of Anaesthesiologists (ASA) Classification, increasing age and steroid use are independent factors for bleeding resulting in transfusion [5, 8, 9]. However, to date, there are no studies that have analysed total blood loss and possible risk factors for total blood loss in patients with SA.

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The most important aim of this study is to investigate the difference in the peri-operative total blood loss (TBL), the risk of blood transfusion (BT) and the amount of transfused blood units (BU) in patients that received SA for different indications (primary, fracture or secondary arthroplasty). The second intention of the study was to identify possible risk factors for these parameters.

Material and methods

Charts of 527 patients who had received shoulder arthroplasty (SA) at the author's institution between 2004 and 2016 were analysed. Patients that received revision SA, SA because of osseous tumors, with known coagulopathy disease or suffered from bleeding due to other reasons than arthroplasty (e.g. gastrointestinal bleeding) were excluded. Thus, 419 patients could be included into the study. The patients included in the study were divided into three groups. The first group consisted the patients that received primary shoulder arthroplasty because of degenerative shoulder disease, the second group the patients that received SA as a primary fracture treatment and the third group those with secondary arthroplasty after failed osteosynthesis. The study had the approval of the local ethic committee and was conducted in conformity with the principles of the revised version of the Declaration of Helsinki.

Surgery was performed under general anaesthesia. A standard deltopectoral approach was used for implantation of the arthroplasty. The cephalic vein was mobilized medially and bleeders were cauterized. The anterior circumflex artery and the concomitant two anterior circumflex veins ("three sisters") were coagulated. After intramedullary preparation of the humeral bone and preparation of the glenoid, the components of the prosthesis were implanted. The subscapularis tendon was reinserted. The inserted drain was normally removed on the second post-operative day. Mobilization and physical therapy started on the first post-operative day.

Patient demographics, diagnosis leading to surgery, procedure type, length of surgery, co-morbidities, use of anticoagulants, pre- and post-operative haemoglobin and haematocrit levels and post-operative transfusion amount were analysed from medical records, anaesthesia sheets and the database of the institution's blood bank. If not altered because of medical reasons, the cut of level for transfusion was a haemoglobin level < 8 g/dl.

Total blood loss (TBL) was calculated as described by Chrrois et al. [11]: total blood loss (ml of erythrocytes: 100% haematocrit) = compensated blood loss + non-compensated blood loss; compensated blood loss (ml) = number red blood cell units × ml red blood cells (RBC) per blood cell unit (170 ml per unit); non compensated blood loss (ml) = total blood volume × (pre-operative haematocrit–post-operative hematocrit); total blood loss volume (ml): in men = $604 + 0.0003668 \times [\text{height (cm)}]^3 + 32.2 \times \text{weight (kg)}$; in women = $183 + 0.000356 \times [\text{height (cm)}]^3 + 33 \times \text{weight (kg)}$.

We used linear regression, log-linear poisson regression and logistic regression to compare the outcome measures total blood loss, blood units and blood transfusion, respectively, between primary, fracture and secondary arthroplasty. The regression models were expanded to include each of the potential predictors: antiplatelet drugs, vitamin K antagonists, operation length, cementing, BMI, sex and ASA scores, as well as co-morbidities such as coronary artery disease, stroke, hypertension and pulmonary disease and also used a model including all of the predictors listed to account for confounding in the comparison of primary, fracture and secondary arthoplasty. The data were analyzed using the R program for statistical computing [12] and Microsoft Excel 2010 (Microsoft Corporation, Seattle, USA). The level of significance was set at $p < 0.05$.

Results

Of 419 patients included in this study, 278 received primary SA, 110 received fracture SA and 31 received secondary SA. Demographics and clinical data are summarized in Table 1. There were 67.3% female and 32.7% male patients. There were more female patients in the fracture SA (88.2%) and secondary SA (74.2%) subgroup than in the primary subgroup (58.3%). The patients receiving SA following fracture were older (mean 75.4 years in fracture SA and 73.0 years in secondary SA) than in primary arthroplasty (mean 70.6 years) group. The reverse SA was the most commonly used type of SA in all subgroups (Table 1.). In primary SA, the prosthesis was mostly uncemented unlike following fracture (Table 1). There were no significant differences in the ASA score between the groups.

Total blood loss and blood transfusion

The overall mean TBL was 369.3 ml. On average, 19.6% of the patients in this study received blood transfusion and mean 0.44 blood units per patient were transfused.

In the multivariate analysis, the mean TBL was significantly higher in the primary SA group (mean 389.0 ml) than in the fracture SA group (mean 319 ml, $p < 0.01$). There was no significant difference between the other groups (Fig. 1). Contrary to these results, the rate of BT was significantly lower in the primary SA (12.6%) than in the fracture SA (32.7%, $p < 0.01$) and secondary SA group (35.5%, $p < 0.01$). There was no significant difference in the BT rate between fracture SA and secondary SA group ($p = 0.75$; Fig. 2).

These results correlated with the amount of transfused BU. There were fewer BU transfused in primary SA (0.28) than in fracture SA (0.69, $p < 0.01$) and secondary SA (0.97, $p <$

Table 1 Demographic and clinical characteristics of all patients included in this study. Regarding to age, BMI, haematocrit level, haemoglobin level, surgery time, number of blood units and total blood loss, the numbers between brackets describe the standard deviation. In all other cases, the numbers between brackets describe the percentage of involved patients

Variable	All $N = 419$	Primary $N = 278$	Fracture $N = 110$	Secondary $N = 31$	p value
Sex:					
female	282 (67.3%)	162 (58.3%)	97 (88.2%)	23 (74.2%)	
male	137 (32.7%)	116 (41.7%)	13 (11.8%)	8 (25.8%)	
Age (years)	72.1 (9.74)	70.6 (9.53)	75.4 (9.78)	73.0 (8.69)	
BMI (kg/m^2)	28.4 (5.74)	28.7 (5.13)	28.5 (7.13)	25.7 (4.70)	0.023
Coronary heart disease:					0.380
no	362 (86.4%)	236 (84.9%)	97 (88.2%)	29 (93.5%)	
yes	57 (13.6%)	42 (15.1%)	13 (11.8%)	2 (6.45%)	
Haematocrit level (l/l)	0.39 (0.05)	0.40 (0.04)	0.36 (0.05)	0.37 (0.05)	
Haemoglobin level (g/l)	131 (17.4)	136 (16.0)	121 (16.2)	126 (17.3)	
Prosthesis type:					
Reverse arthroplasty	342 (81.6%)	209 (75.2%)	108 (98.2%)	25 (80.6%)	
Total anatomic arthroplasty	65 (15.5%)	57 (20.5%)	2 (1.82%)	6 (19.4%)	
Stemless arthroplasty	12 (2.86%)	12 (4.32%)	0 (0.00%)	0 (0.00%)	
Surgery time (min)	91.5 (28.9)	89.2 (28.8)	93.7 (27.7)	104.8 (31.2)	0.012
Antiplatelet drug:					0.203
no	325 (77.6%)	220 (79.1%)	79 (71.8%)	26 (83.9%)	
yes	94 (22.4%)	58 (20.9%)	31 (28.2%)	5 (16.1%)	
Vitamin K antagonist:					0.131
no	379 (90.5%)	256 (92.1%)	94 (85.5%)	29 (93.5%)	
yes	40 (9.55%)	22 (7.91%)	16 (14.5%)	2 (6.45%)	
Cemented:					
no	220 (52.5%)	194 (69.8%)	16 (14.5%)	10 (32.3%)	
yes	199 (47.5%)	84 (30.2%)	94 (85.5%)	21 (67.7%)	
ASA:					0.143
1–2	187 (48.3%)	131 (52.0%)	44 (41.5%)	12 (41.4%)	
3–4	200 (51.7%)	121 (48.0%)	62 (58.5%)	17 (58.6%)	
Blood transfusion:					
no	337 (80.4%)	243 (87.4%)	74 (67.3%)	20 (64.5%)	
yes	82 (19.6%)	35 (12.6%)	36 (32.7%)	11 (35.5%)	
Number of blood units	0.44 (0.98)	0.28 (0.80)	0.69 (1.11)	0.97 (1.56)	
Total blood loss (ml)	369.3 (204.6)	389.0 (197.9)	319.6 (206.1)	369.2 (233.8)	

0.01). There was no difference in the number of transfused BU among fracture SA and secondary SA ($p = 0.53$).

Risk factors for total blood loss

Male patients had 128 ml more TBL than female patients ($p < 0.01$). A longer surgery time also rises the risk for elevated TBL ($p < 0.01$). Patients under vitamin K antagonist before surgery had a 63.5 ml higher TBL than patients without this therapy. However, the results were not statistically significant ($p = 0.06$). None of the other included parameters had significant influence on TBL in patients with SA (Table 2).

Risk factors for blood transfusion and number of blood units

The most important risk factors for blood transfusion in patients with SA are cemented arthroplasty and the previous therapy with vitamin K antagonist even though surgery was not performed before the coagulation was normalized. Patients under vitamin K antagonists had a 3.83-fold elevated risk for blood transfusion ($p < 0.01$). Other risk factors for BT are high BMI, coronary heart disease and ASA score > 2 (Table 3). All of these parameters are also risk factors for a higher amount of transfused BU.

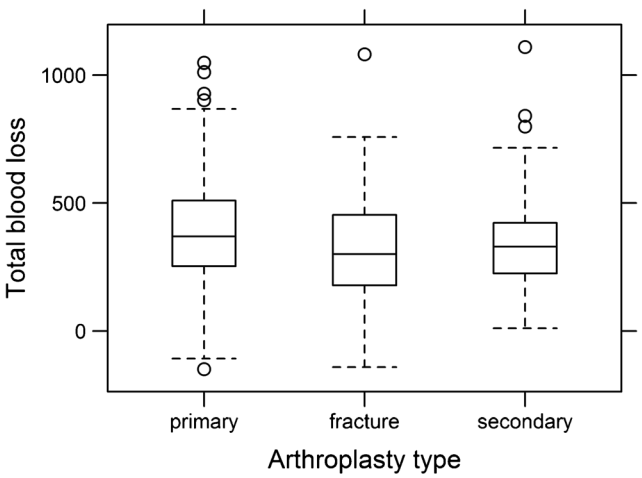

Fig. 1 Total blood loss in patients with primary, fracture and secondary shoulder arthroplasty

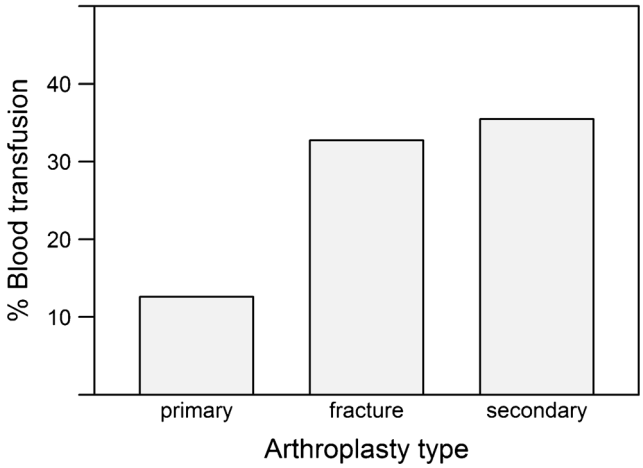

Fig. 2 Blood transfusion rate in patients with primary, fracture and secondary shoulder arthroplasty

Discussion

The incidence of shoulder arthroplasty increased in the last few years [1, 2]. While bleeding is one of the most common complications, the investigation of the incidence of the blood loss, transfusion and associated risk factors in different arthroplasties and also in SA gain increasing importance [5, 8, 9]. To our knowledge, this study may be the first comparative assessment of estimated blood loss in different indications for shoulder arthroplasty (primary-degenerative SA, fracture SA or secondary SA after failed osteosynthesis). Additionally, it investigated the differences in blood transfusion rates and amount of blood units depending on the indication for the shoulder prosthesis. Further goal of the study was to identify risk factors for elevated blood loss and raised transfusion rate in SA.

Table 2 Comparison of total blood loss between different prosthesis indications and possible risk factors associated with total blood loss. Results also include tests in each data set of the possible effects of confounders

Contrast	Estimate (lwr, upr)	*p* value
Primary–fracture	69.4 (16.23; 122.57)	0.007
Primary–secondary	19.77 (− 69.61; 109.15)	0.860
Fracture–secondary	− 49.63 (− 145.62; 46.36)	0.440
Antiplatelet drug (yes/no)	9.73 (− 37.19; 56.64)	0.684
Vitamin K antagonist (yes/no)	63.53 (− 2.89; 129.96)	0.061
Operation time (min)	1.65 (0.98; 2.31)	0.000
Cemented (yes/no)	37.08 (− 7.88; 82.04)	0.106
BMI (kg/m^2)	2.85 (− 0.58; 6.27)	0.103
Coronary heart disease (yes/no)	38.36 (− 18.55; 95.27)	0.186
Stroke (yes/no)	35.91 (− 38.8; 110.63)	0.345
Hypertension (yes/no)	− 3.57 (− 43.58; 36.44)	0.861
Pulmonary disease (yes/no)	− 8.90 (− 68.66; 50.86)	0.770
male-female	128.7 (87.22; 170.18)	0.000
ASA 3–4 vs. 1–2	− 0.16 (− 41.56; 41.24)	0.994
Primary–fracture (adjusted)	68.08 (6.54; 129.62)	0.026
Primary–secondary (adjusted)	27.94 (− 65.19; 121.06)	0.759
Fracture–secondary (adjusted)	− 40.14 (− 136.81; 56.52)	0.590

Table 3 Comparison of blood transfusions between different prosthesis indications and possible risk factors associated with blood transfusion. Results also include tests in each data set of the possible effects of confounders

Contrast	OR (95% CI)	*p* value
Fracture vs. primary	3.36 (1.98; 5.73)	0.000
Secondary vs. primary	3.85 (1.68; 8.50)	0.002
Secondary vs. fracture	1.15 (0.49; 2.58)	0.748
Antiplatelet drug (yes/no)	1.29 (0.72; 2.25)	0.387
Vitamin K antagonist (yes/no)	3.83 (1.89; 7.71)	0.000
Operation time (min)	0.99 (0.99; 1.01)	0.829
Cement (yes/no)	4.78 (2.57; 9.26)	0.000
BMI (kg/m^2)	0.94 (0.89; 0.98)	0.006
Coronary heart disease (yes/no)	2.35 (1.20; 4.48)	0.013
Stroke (yes/no)	1.82 (0.78; 4.01)	0.161
Hypertension (yes/no)	1.59 (0.95; 2.74)	0.080
Pulmonary disease (yes/no)	0.94 (0.43; 1.93)	0.873
Male vs. female	0.87 (0.48; 1.54)	0.633
ASA 3–4 vs. 1–2	3.37 (1.90; 6.20)	0.000
Fracture vs. primary (adjusted)	1.81 (0.92; 3.59)	0.089
Secondary vs. primary (adjusted)	2.17 (0.79; 5.74)	0.128
Secondary vs. fracture (adjusted)	1.20 (0.45; 3.15)	0.711

In this study, the measured TBL in primary SA (mean 389 ml) was greater than in fracture SA (mean 319 ml, $p < 0.01$) and nearly equal to secondary SA (mean 369 ml, $p = 0.86$). Comparing with other studies, the mean estimated TBL in SA (369.3 ml) is lower than in knee (789 ml) or hip arthroplasty (984–1358 ml) [13, 14]. Relevant risk factors for raised TBL in SA are male sex and extended surgery time.

The possible reason for the higher TBL in male patients is their muscle mass that makes exposure difficult. Careful and distinctive preparation of the soft tissue is required, which could be associated with pronounced bleeding. The fact that surgery time is a significant risk factor for elevated blood loss is not really surprising. Noteworthy is that it is the only risk factor for TBL that can be affected by the surgeon.

The overall transfusion rate estimated in this study was 19.6% in which it corresponds with findings of other studies. The transfusion risk in the study of Anthony et al. and Padegimas et al. was approximately 4%, whereas Gruson et al. reported that 43% of patients after SA receive blood transfusion [5, 8, 9]. In hip and knee arthroplasty, the transfusion rates have been reported to be between 8 and 70% [13–15]. In

comparison to hip or knee arthroplasty, the transfusion rate in SA is located in lower part of this range.

The transfusion rate in SA was significantly higher in the fracture SA subgroup (32.7%, $p < 0.01$) and secondary SA subgroup (35.5%, $p < 0.01$) than in primary SA (12.6%). One of the reasons for elevated transfusion rate in fracture subgroups can be that the patients cannot be appropriately prepared for the surgery as compared to the patients receiving elective SA. On the other hand, elevated transfusion rates in both groups, secondary and fracture SA, can be associated with the demographic and clinical characteristics (age, haematocrit-level).

The study revealed that the risk of transfusion is higher in patients with cemented SA, higher BMI, coronary heart disease, ASA score > 2 and therapy with vitamin K antagonists. Risk factors for elevated BT are different as the risk parameters for TBL.

These findings are confirmed by other investigations in which the use of a cemented prosthesis and a higher ASA score or high number of co-morbidities were associated with elevated risk for blood transfusion [5, 8, 9, 16, 17]. Also, coronary heart disease was approved as risk factor for blood transfusion by Kandil et al. COPD and diabetes mellitus influenced the BT rate in this study too [17]. The possible explanation for this is that patients with multiple diseases have higher risk for use of drug affection blood coagulation and have higher risk of anaemia [18].

To the contrary of findings described here, in most other investigations, female sex was a risk factor for blood transfusion [8, 16, 17, 19]. One exception is the study of Padegimas et al., where in a univariate analysis, the male patients were more likely to receive blood transfusion [9].

One of the most important risk factors for blood transfusion is the therapy with vitamin K antagonists. In our patient population, the therapy was changed before the surgery into low molecular weight heparin. In case of emergent surgery, haemostasis was normalized by substitution of fresh frozen plasma or prothrombin complex concentrate. The surgery was performed not until prothrombin time and international normalized ratio were optimized. Despite this procedure, patients with vitamin K antagonist therapy receive BT more often and receive more BU. Reason for this is probably the use of post-operative venous thromboembolism prophylaxis in therapeutic dose. Likewise, the use of post-operative venous thromboembolism prophylaxis was a risk factor for blood transfusion in univariate but not in multivariate analysis as shown by Hardy et al. [16].

Otherwise, the use of antiplatelet drugs did not affect the risk of blood transfusion in our study. Similarly, in the study of Gruson et al., the use of antithrombotic agents had no influence on the blood transfusion risk [8].

Another interesting finding of this study is that the TBL was higher in the primary arthroplasty group, although the BT was elevated in the secondary SA and fracture SA group. Other studies also demonstrate that the amounts of blood loss do not have to correlate with the transfusion rate. The study from Gruson et al. in an investigation with 196 patients with different SA showed that there was no significant difference of estimated blood loss in patients who received blood transfusion and patients, who did not (379.8 vs. 341.5 ml; $p = 0.14$) [8]. Analysing the risk factors in this study, it is clear that the indication for blood transfusion is not only dependent on the amount of blood loss, but also on many other factors such as the patient's age, co-morbidities, surgery type and use of drugs affecting blood coagulation.

The retrospective nature of this investigation is one weakness of the study. Another limitation is that because of the retrospective study design, there were no study related standards for blood transfusion. However, the general guidelines in our clinic determine a cut of level for transfusion when the haemoglobin level was lower than 8 g/dl. If the patients presented symptomatic anaemia, the transfusion could be performed above the haemoglobin level of 8d/dl. On the other hand, the study has several strengths. The most important of them are the large number of patients included in the investigation and the strict inclusion criteria. Another advantage of the study is the method for the estimation of total blood loss including both the compensated and hidden blood loss. The measurement of blood loss by count of the blood volume in intra-operative suction container and post-operative drainage as performed in other investigations is subject to several confounders such as the use of irrigation fluid. Also, the hidden blood loss is in these cases not taken in account. We believe that the method of Charrois et al. used in this study is more precise for the estimation of blood loss.

In conclusion, this study shows that the estimated total blood loss in patients with primary SA was higher than in fracture SA and averaged 389.0 ml. The main influenceable risk factor for TBL is the surgery time. Secoundly, this analysis demonstated that patients undergoing SA have a 19.6% risk for blood transfusion. The transfusion rate is higher in patients receiveing SA because of a proximal humerus fracture or because of secondary arthroplasty. Preoperative use of vitamin K antagonist, cemented arthroplasty, high BMI, coronary heart disease and ASA score > 2 are relevant risk factors for blood transfusion and a higher number of transfused blood units.

Compliance with ethical standards

The study had the approval of the local ethic committee and was conducted in conformity with the principles of the revised version of the Declaration of Helsinki.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the

institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The study had approval of the local ethic committee (EK-MR-07_12_2016).

For this type of study, formal consent is not required.

Conflict of interest DM; JH; AK; AA; BG: These authors have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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BFE: is Consultant to Smith & Nephew & CONMED; he received payments for lectures by Smith & Nephew & CONMED.

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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