Estimated blood loss and anemia predict transfusion after total shoulder arthroplasty: a retrospective cohort study

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Background: Reported blood transfusion rates after total shoulder arthroplasty (TSA) range from 4.5% to 43%, and reported risk factors include race, female sex, prosthesis type (reverse), revision, age, anemia, low preoperative hemoglobin, and number of comorbidities. The purpose of this study was to develop a predictive model for transfusion in anatomic/hemi and reverse shoulder arthroplasty patients and to estimate the transfusion rate in a community hospital setting.

Methods: A retrospective cohort of 265 shoulder arthroplasties (79 anatomic, 182 reverse, and 4 hemiarthroplasties) performed consecutively by 1 surgeon at 1 institution from May 2013 to May 2016 was assembled. Two patients were excluded for insufficient data, leaving 263 patients for analysis. Sensitivity, specificity, area under the curve, and cut points using estimated blood loss (EBL), history of anemia, and preoperative hemoglobin level were calculated, based on a logistic regression model.

Results: The overall transfusion rate was 2.3% (6/265). Higher EBL (P = .003), lower preoperative hemoglobin level (P = .030), and history of anemia (P = .088) were predictive of transfusion with a sensitivity of 80.0% and a specificity of 99.6%. In this cohort, patients with a history of anemia had transfusion risk when an EBL of ≥300 mL was combined with a preoperative hemoglobin level <10.9, resulting in a sensitivity of 1.0 and a specificity of 0.96. Factors associated with transfusion in univariate models included arthroplasty for fracture (P < .001), cemented stem (P < .001), length of stay (P < .001), EBL (P < .001), operative time (P < .001), and preoperative hemoglobin (P = .004) and hematocrit levels (P = .004).

Conclusion: Patients with a history of anemia, a preoperative hemoglobin level <10.9, and an intraoperative EBL ≥300 mL are at high risk for transfusion after TSA.

Patients undergoing shoulder arthroplasty are at risk for transfusion. Reported rates of transfusion after shoulder arthroplasty are variable and high, and range from 4.5% to 43%. As the demand for shoulder arthroplasty continues to rise, understanding risk factors predictive of transfusion has become more important.

Transfusion of blood or blood components is a common medical procedure that carries inherent risks, including disease transmission, hemodynamic overload, and allergic reactions including anaphylaxis. Medical comorbidities and perioperative allogeneic red blood cell transfusion are risk factors for surgical site infection after shoulder arthroplasty. Some patients may elect to decline blood transfusion for religious or moral reasons. No established clinical practice guidelines exist for transfusion in shoulder arthroplasty. The decision for transfusion for acute postoperative blood loss anemia of red blood cells (RBCs) is typically indicated when hemoglobin is less than 7-8 g/dL, depending on patient comorbidities and presence of hemodynamic instability.

Whereas several studies have investigated transfusion rates and risk factors associated with transfusion at academic institutions, little has been published regarding transfusion rates in a community setting. The purpose of this study was to determine the incidence of transfusion at a high-volume community hospital and to identify which variables are predictive of transfusion. Risk factors associated with transfusion also were identified. Finally, we quantified the factors predictive of transfusion to assist with preoperative planning and counseling for both the surgeon and patient.

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Methods

Study subjects

We obtained Institutional Review Board approval to conduct a retrospective chart review of all shoulder arthroplasty cases performed by a single surgeon from May 24, 2013, through May 24, 2016, at a busy urban hospital in the Midwest. We identified all 265 shoulder arthroplasty cases during this interval, 2 of which had insufficient preoperative laboratory data, leaving 263 cases for multivariable analysis.

Anticoagulation protocol

Patients who took warfarin for anticoagulation were instructed to stop the medication 5 days preoperatively; those on apixaban or similar medications stopped a minimum of 2 days preoperatively. Baseline International Normalized Ratio and prothrombin time were obtained prior to surgery to confirm no coagulopathy was present. Patients scheduled for surgery electively who took clopidogrel or aspirin were instructed to stop their medication 10 days before surgery; all who took nonsteroidal anti-inflammatory medication were instructed to stop 10 days before surgery. Patients taking warfarin, clopidogrel, apixaban, or aspirin were restarted on the prescribed medication on postoperative day 1. Patients who were not otherwise anticoagulated were given aspirin 325 mg twice daily for 3 weeks. All patients wore sequential compression devices while hospitalized for DVT prophylaxis.

Surgical procedure

All patients received both regional anesthesia in the form of an interscalene block and general anesthesia. All patients were prepared with 2% chlorhexidine/70% alcohol and draped with occlusive iodine-impregnated drape and received appropriate preoperative antibiotics within 1 hour of incision. Operating rooms have laminar flow. All patients were placed in beach chair position, and all patients received a standard deltopectoral approach. A cemented stem was placed in 23 patients. For glenoid fixation in anatomic shoulder arthroplasty and for cemented stems, antibiotic cement was used (Cobalt-G cement; Zimmer Biomet, Warsaw, IN, USA). The Comprehensive Shoulder Replacement system was used for all patients. The wound was approximated with Vicryl for the deltopectoral approach in anatomic shoulder arthroplasty for all 265 patients. No drain was used in any patients. The wound was approximated with Vicryl for the deltopectoral approach in anatomic shoulder arthroplasty for all 265 patients. No drain was used in any patients.

Transfusion guidelines

Generally accepted guidelines for transfusion were followed, which included a hemoglobin level less than or equal to 7.0 g/dL in stable asymptomatic patients as well as symptomatic patients with hypotension, tachycardia, orthostasis, or chest pain and a hemoglobin level less than 8.0 g/dL. Two patients with high intraoperative estimated blood loss (>800 mL) also received transfusion at the discretion of the anesthesiologist. Asymptomatic postoperative anemia in high-risk patients including cardiac or pulmonary disease also received transfusion if ordered by the medical physician. A strict transfusion protocol was not used during the study period; rather, clinical judgment dictated treatment. Transfusions were given only to patients who consented to receive blood; no patients refused a recommended transfusion.

Data collected and variable definitions

Patient age, sex, comorbidities, body mass index (BMI), operative time, preoperative use of antiocoagulants, preoperative and postoperative hemoglobin and hematocrit levels, intraoperative use of topical thrombin, type of procedure, length of stay, and indications for surgery were recorded. ASA classification (guidelines from the American Society of Anesthesiologists) was determined by the anesthesiologist. Number of patients who received transfusions as well as any transfusion reactions were recorded. Cases also were categorized as complex if they deviated from primary arthroplasty per Gruson’s criteria and included removal of previous hardware, malunions or nonunions, or glenoid bone grafting; arthroplasty for fracture also was defined as complex.

Preoperative hemoglobin and hematocrit levels were obtained from patients within 3 months before surgery. And postoperative hemoglobin and hematocrit levels were obtained on postoperative day 1. The changes in value were compared with baseline levels and recorded. Anemia was defined according to the World Health Organization (WHO) as preoperative hemoglobin <12 g/dL for women and <13 g/dL for men.

Statistical analysis

Demographics and clinical characteristics of patients in the cohort are summarized using means and standard deviations for parametric continuous variables, medians and interquartile ranges (IQRs) for nonparametric continuous variables, and counts with percentages for categorical variables. We further investigated each potential risk factor using univariate logistic regression to determine which factors may be important in developing the predictive model. We used logistic regression to build the predictive model. A priori potential predictors, based on previous literature and clinical knowledge, included sex, type of surgery (reverse shoulder arthroplasty or anatomic/hemi), revision arthroplasty, advancing age, preoperative anemia, higher intraoperative blood loss, number of comorbid conditions, hypertension, BMI, renal disease, history of anemia, case complexity, use of a cemented stem, and race. From this list, we further examined variables that would be known pre- or intraoperatively with \( P < .25 \). We selected this \( P \) value to maximize the likelihood that we do not miss any potential predictors on the first screen. Using an iterative process, we introduced the most statistically significant variables first, 1 at a time, evaluating the predictive capacity of each variable in combination with variables already in the model. Variables that no longer contributed substantially to the predictive capacity of the model, based on estimated sensitivity (SE) and specificity (SP), were removed (or not included), until the final model was achieved, which produced the highest SE and SP with the fewest variables.

As the sample size was set at a cohort of 265 subjects and a transfusion rate of 2.3% (\( n = 6 \)), we calculated power to detect an area under the curve (AUC) of 0.99, as observed in our data, assuming an AUC under the null hypothesis of 0.65 and a highly conservative 2-sided alpha level of 0.005, as we made multiple univariate comparisons. We also assumed a lower false positive rate of 0 and an upper false positive rate of 1.0, with a standard deviation ratio of 1.0. With these assumptions, we had 88% power to detect the difference observed in this study. We had 100% power of obtaining at least suggestive results (\( P = .05 \)). Power was calculated...
and 182 (68.7%) were reverse shoulder arthroplasties (Table I). Using Gruson’s criteria modified by the authors to include arthroplasty for fracture, 11.9% of primary cases (n = 29/244) were classified as complex. Six patients required transfusion; all underwent reverse shoulder arthroplasty. The overall transfusion rate was 2.3%.

On average, patients were 69 years old (SD 9.6) and were predominantly white (88.3%) (Table I). The majority were female (59.7%) and had a median of 4 comorbidities (IQR 2, 6), with the most common being hypertension (74%). The median operative time was 55 minutes (IQR 63, 83), and the median estimated blood loss was 200 mL (IQR 100, 300).

Factors significantly associated with transfusion in univariate models included arthroplasty for fracture (both proximal humerus fractures and periprosthetic fractures) (odds ratio [OR] 37.85, 95% confidence interval [CI] 6.34, 225.93; P < .001), cementing the stem (OR 25.26, 95% CI 4.34, 146.91; P < .001), length of stay (OR 2.89, 95% CI 1.63, 5.14; P < .001), estimated blood loss (OR 101.5%, 95% CI 1.01, 1.03; P < .001), operative time (OR 1.02, 95% CI 1.01, 1.03; P < .001), preoperative hemoglobin level (OR 0.36, 95% CI 0.18, 0.73; P = .004), and preoperative hematocrit level (OR 0.64, 95% CI 0.49, 0.83; P = .004) (Table II). Factors that were suggestive of an association with transfusion but did not meet our conservative P value cutoff included case complexity (OR 7.89, 95% CI 1.07, 58.32; P = .043), history of anemia (OR 25.70, 95% CI 2.0, 331.92; P = .013), WHO anemia (OR 13.43, 95% CI 1.54, 116.97; P = .019), renal disease (OR 8.13, 95% CI 1.38, 48.02; P = .021), and a history of anemia (OR 13.43, 95% CI 1.54, 116.97; P = .019), WHO anemia (OR 8.13, 95% CI 1.38, 48.02; P = .021). Factors not associated with transfusion were race, sex, age, preoperative use of anticoagulants, number of comorbidities, obesity, BMI, diabetes, and hypertension (P > .005 for all). Although all patients with transfusion underwent reverse shoulder arthroplasty, type of surgery was not significantly associated with transfusion risk (P = .254).

For the predictive model, we examined only factors that would be available pre- or intraoperatively to determine which could potentially predict transfusion. Two patients in the cohort had incomplete preoperative hemoglobin values and were excluded for incomplete preoperative hemoglobin value.

Table I
Demographics and clinical characteristics of the cohort

| Variable                        | N  | Study subjects |
|---------------------------------|----|----------------|
| Age, yr, mean ± SD             | 265| 69.0 ± 9.6     |
| Race                            | 265|                |
| White                           | 234 (88.3) |
| Black                           | 31 (11.7) |
| Sex                             | 265|                |
| Female                          | 158 (59.6) |
| Male                            | 107 (40.4) |
| BMI, mean ± SD                  | 265| 32.9 ± 7.4     |
| Obese, Y/N                      | 265| 46 (17.4)      |
| No. comorbidities, median (IQR)| 265| 4 (2.6)        |
| Diabetes, Y/N                   | 265| 58 (21.9)      |
| Hypertension, Y/N               | 265| 196 (74.0)     |
| Anemia, Y/N                     | 265| 3 (1.1)        |
| WHO anemia, Y/N                 | 265| 75 (28.4)      |
| Renal disease, Y/N              | 265| 17 (6.4)       |
| ASA class                       | 265|                |
| I or II                         | 100 (37.7) |
| III or IV                       | 165 (62.3) |
| Complex case, Y/N               | 244| 29 (11.9)      |
| Arthroplasty for fracture, Y/N  | 265| 17 (6.4)       |
| Cementing stem, Y/N             | 265| 23 (8.7)       |
| Type of surgery                 | 265|                |
| Anatomic/hemi                   | 83 (31.3) |
| Reverse                         | 182 (68.7) |
this model were 80.0% and 99.6%, respectively, similarly suggesting good model performance. The area under the receiver operating characteristic curve was 0.99, suggestive of excellent model performance (Fig. 2).

Based on the predictive model containing these 3 perioperative variables, we determined cutoff points for each of the variables in the model. Having a history of anemia, a preoperative hemoglobin of <10.9, and an estimated blood loss of >300 mL provided good discrimination between those who did and those who did not require a transfusion, with an SE of 100% and an SP of 96%.

Discussion

The transfusion rate after shoulder arthroplasty (2.3%) was lower in this cohort than rates reported in the literature, which can vary from 4.5% to 43%, despite a diverse patient population and a similar rate of complex cases. We found that 3 known perioperative risk factors in combination were predictive of transfusion: estimated blood loss, history of anemia, and preoperative hemoglobin.

Previous studies have reported that lower preoperative hemoglobin is predictive of risk for transfusion after shoulder arthroplasty and that a preoperative hematocrit of 39.6% or less carried an increased risk of transfusion. Our study confirms the findings of Padegimas et al and quantifies that higher intraoperative blood loss and lower preoperative hemoglobin are predictive of the need for transfusion after shoulder arthroplasty. Despite the consistencies between our results and previously reported transfusion rates, wide variability in transfusion risk after shoulder arthroplasty remains unexplained.

Other risk factors for transfusion have been less consistent and include female sex, procedure type, revision arthroplasty, advancing age, preoperative history of anemia, higher intraoperative blood loss, cementing the stem, and a number of comorbid conditions. Transfusion has been found to be more likely in patients with a preoperative diagnosis of fracture or fracture nonunion, and we did find fracture to be helpful in predicting transfusion in a univariate model. In addition, Ryan et al. found that insurance status, hospital region, and annual hospital caseload were additional risk factors associated with transfusion after shoulder arthroplasty.

Factors suggested to explain the difference in transfusion rates include hospital volume, regional or demographic factors, patient characteristics, different costs and availability of blood products, varying indications for transfusion, or case complexity.

Case complexity previously has been defined as shoulder arthroplasty cases that deviated from standard primary replacement and included hardware removal, malunions, nonunions, and glenoid bone grafting. These criteria were modified in this study to include arthroplasty for fracture. In Gruson’s original study, no cases were performed for fracture and 13.6% of the cases were classified as complex with a transfusion rate of 43%. By comparison, using Gruson’s criteria modified to include arthroplasty for fracture, 11.9% of our study population was classified as complex, with a transfusion rate of 2.3%. Because less than 20% of our complex cases required transfusion compared with the approximately 50% reported in the previous literature, it is likely that there are other factors that contribute to the difference in observed transfusion rates.

The source population is a high-volume hospital (30+ shoulder arthroplasty cases/year) in the Midwest, and both higher case volume and the Midwest region have been found to lower the relative risk of transfusion in a recent analysis of nationwide data. Comparing our results to National Inpatient Sample data, the transfusion rate in the Midwest was 4.3% and the transfusion rate in high-volume hospitals was 5.5%, compared with the average overall transfusion rate of 6.7%. Our rates of transfusion still compare favorably to these rates based on National Inpatient Sample data, even when comparing regional and volume-based transfusion rates.

This study has several limitations. Because of its retrospective nature, no strict protocols were employed in the collection of the data. Rather, data were abstracted from clinical records and not explicitly obtained for research purposes. As such, data on some potential confounders (e.g., specific comorbid conditions) were not available, though it should be noted that because the aim of the study was to build a predictive model, controlling for confounding is not of primary concern. Additionally, the decision to perform a transfusion was not protocol-based and therefore could have varied over the course of the study. The decision for transfusion was based on the judgment of the treating physician, using accepted clinical practices. Furthermore, the study population was a convenience sample from 1 institution and a single practice, limiting the generalizability of the predictive model. It will need to be tested and refined in larger, more diverse populations. Lastly, there was limited statistical power because of the small number of transfusion cases available for review.
The study has several strengths. First, all assessments were made by a single physician, reducing the likelihood of variability in decision making and treatment. Participant follow-up was excellent and very little missing data resulted, alleviating concerns of data missing-not-at-random. Finally, data used for the model were collected prior to the knowledge of transfusion status, suggesting that misclassification would likely be nondifferential by outcome, leading to an underestimation of the effect.

Conclusion

It appears that the predictive power of combining lower preoperative hemoglobin, higher estimated blood loss intraoperatively, and a medical history of anemia is helpful when assessing the risk for transfusion after shoulder arthroplasty. Using these factors will allow surgeons to better educate patients and predict the risk of transfusion. It may help with preoperative planning, such as preoperative autologous donation, or intraoperative decision making, including use of tranexamic acid. Other univariate factors including case complexity, arthroplasty for fracture, cementing the stem, preoperative laboratory tests, and history of renal disease also may inform the discussion of transfusion risk for patients undergoing shoulder arthroplasty.

Disclaimer

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