



## Utility of postoperative hemoglobin testing following total shoulder arthroplasty



Elshaday S. Belay, MD <sup>a,\*</sup>, Etienne Flamant, BS <sup>b</sup>, Barrie Sugarman, BS <sup>b</sup>, Daniel E. Goltz, MD <sup>a</sup>, Christopher S. Klifto, MD <sup>a</sup>, Oke Anakwenze, MD, MBA <sup>a</sup>

<sup>a</sup> Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

<sup>b</sup> Duke University School of Medicine, Durham, NC, USA

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**Background:** Identifying areas of excess cost for shoulder arthroplasty patients can play a role in effective health care spending. The purpose of this study was to assess the utility of postoperative complete blood count (CBC) testing after total shoulder arthroplasty (TSA) and identify which patients benefit from routine CBC testing.

**Methods:** We performed a retrospective review of a cohort of patients who underwent primary TSA from January 2018 through January 2019. All patients in this cohort received tranexamic acid. Patient demographic characteristics and patient-specific risk factors such as American Society of Anesthesiologists score, Elixhauser index, body mass index, smoking status, and coagulopathy history were obtained. Perioperative values including length of surgery, preoperative and postoperative hemoglobin (Hgb) levels, and need for transfusion were also obtained.

**Results:** This study included 387 TSA patients in the final analysis. Comparison between the cohort requiring transfusion and the cohort undergoing no intervention revealed no statistically significant differences in age, sex, body mass index, American Society of Anesthesiologists score, or Elixhauser index. The group receiving transfusions was found to have significantly lower levels of preoperative Hgb (11.3 g/dL) and postoperative Hgb (8.1 g/dL) ( $P < .0001$ ). Additionally, the percentages of patients with abnormal preoperative Hgb levels ( $< 12$  g/dL) (72.3%) and postoperative day 1 Hgb levels  $< 9$  g/dL (81.8%) were significantly higher in the group receiving transfusions ( $P < .0001$ ). A multivariate regression model identified an abnormal preoperative Hgb level ( $< 12$  g/dL), with an odds ratio of 3.8 (95% confidence interval, 1.5–6.2;  $P < .001$ ), and postoperative day 1 Hgb level  $< 9$  g/dL, with an odds ratio of 3.3 (95% confidence interval, 0.4–6.1;  $P < .03$ ), as significant predictors of the risk of transfusion with a sensitivity of 64% and specificity of 96.2% with an area under the curve of 0.87.

**Conclusion:** Routine CBC testing may not be necessary for patients who receive tranexamic acid and have preoperative Hgb levels  $> 12$  mg/dL and first postoperative Hgb levels  $> 9$  mg/dL. This translates to potential health care cost savings and improves current evidence-based perioperative management in shoulder arthroplasty.

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Health care spending in the United States exceeds spending in any other country worldwide per capita and is expected to continue to increase over the next 2 decades.<sup>8</sup> The number of total shoulder arthroplasty (TSA) procedures performed annually is increasing; therefore, the perioperative spending associated with total arthroplasty patients is continuing to increase as well.<sup>16,19,20,30</sup> Identifying areas of excess cost for arthroplasty patients may play a role in improving effective health care spending.<sup>30</sup> It has been

shown that routine collection of postoperative laboratory testing such as the complete blood count (CBC) frequently does not change medical management and may not be cost-effective in general surgery, spine surgery, total hip arthroplasty (THA), and total knee arthroplasty (TKA) for the majority of patients.<sup>15,22,26</sup> Despite efforts to reduce unnecessary routine laboratory testing for inpatients, it remains commonplace for patients to undergo daily blood work testing while hospitalized, especially at large academic centers.<sup>4,5,9,28</sup> Specifically, there is a paucity of literature evaluating the necessity of routine postoperative CBC collection after TSA.

The information provided from CBC testing is useful for identifying patients at risk of postoperative anemia and, ultimately, the potential need for a blood transfusion.<sup>21</sup> Despite use of tranexamic

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\* Corresponding author: Elshaday S. Belay, MD, Department of Orthopaedic Surgery, Duke University Medical Center, 311 Trent Dr, Durham, NC 27710, USA.

E-mail address: [Elshaday.Belay@duke.edu](mailto:Elshaday.Belay@duke.edu) (E.S. Belay).

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acid (TXA), postoperative blood transfusion rates in shoulder arthroplasty still range between 2% and 10%.<sup>14,21</sup> Recent studies in THA and TKA have shown that additional CBC testing with a postoperative hemoglobin (Hgb) level > 9.9 mg/dL might not be necessary.<sup>15</sup> The purpose of this study was to assess whether routine postoperative CBC testing after TSA correlates with predicting medical intervention and identify which patients may benefit from routine CBC testing.

## Methods

We performed a retrospective review of a cohort of patients who underwent primary TSA from January 2018 through January 2019. The electronic medical record from a single academic health system was queried using the Current Procedural Terminology code for primary TSA (23472), which included both anatomic and reverse TSA. Shoulder arthroplasty for fracture was excluded. Shoulder arthroplasty patients treated during the study period were reviewed for the availability of preoperative and postoperative Hgb values. Preoperative Hgb levels were collected in all patients within 6 weeks of the surgery date during a preanesthesia visit. Patients without these preoperative Hgb values were excluded. All patients in this cohort received TXA. The protocol for intravenous TXA was 1 g prior to incision and 1 g during wound closure; however, 2 g of topical TXA was alternatively used if there was a contraindication to intravenous TXA. By use of a validated formula, calculated blood loss was included, similarly to the hip and knee arthroplasty literature.<sup>28</sup> Hemoglobin loss ( $Hgb_{loss}$ ) was calculated by the following equation:  $Hgb_{loss} = (k1 \times Height^3 + k2 \times Weight + k3) \times (Hgb_{initial} - Hgb_{end}) \times 0.001 + Hgb_{transfused}$ , in which  $k1 = 0.3669$  for male patients or  $0.3561$  for female patients,  $k2 = 0.03219$  for male patients or  $0.03308$  for female patients, and  $k3 = 0.6041$  for male patients or  $0.1833$  for female patients;  $Hgb_{initial}$  is defined as the preoperative Hgb level; and  $Hgb_{end}$  is defined as the postoperative Hgb level. Total blood volume loss was calculated as  $1000 \times (Hgb_{loss}/Hgb_{initial})$  as previously described by Gao et al.<sup>10</sup>

Data for patient-specific variables were collected, including age, sex, American Society of Anesthesiologists score, Elixhauser index, and body mass index (BMI). The Elixhauser index was calculated from 31 specific parameters to measure the comorbidity burden.<sup>27</sup> Additional variables collected included the number of postoperative CBCs. Preoperative and postoperative Hgb levels were recorded for each patient throughout the course of admission. Postoperative Hgb levels were obtained within a set time interval each day beginning on postoperative day (POD) 1. Normal laboratory values were defined as an Hgb level > 13 g/dL for male patients and Hgb level > 12 g/dL for female patients. To simplify the cutoff for abnormal Hgb level, the lower Hgb cutoff of 12.0 g/dL was used to define an abnormal Hgb level for this study, as demonstrated by Howell et al.<sup>16</sup> Medical intervention, defined as a red blood cell transfusion in response to postoperative anemia, was recorded. A transfusion was indicated if the Hgb value was <8.0 g/dL for patients with oncologic or coronary artery disease and/or prior myocardial infarction or <7.0 g/dL for all other patients. No transfusions were required intraoperatively. The cost of CBC testing was found to be \$109 per test; this information was provided by the financial department of our institution's health system and was based on hospital charges and Medicare reimbursements.

## Statistical analysis

Categorical data were reported as percentages; continuous variables, means with standard deviations (SDs). The  $\chi^2$  test was used to compare binary variables across categorical groups,

whereas the Student *t* test was used to compare continuous variables. A multivariate logistic regression model was used to identify risk factors associated with the need for transfusion after TSA. This model controlled for age, sex, coagulopathy history, preoperative Hgb level < 12 g/dL, difference in preoperative to 24-hour postoperative Hgb level, number of postoperative CBCs, and length of surgery. The final model was created using parameters that reached significance at a level of  $P < .1$  in the bivariate analysis. The cutoff value of postoperative Hgb < 9 g/dL was determined by maximizing the area under the receiver operating characteristic (ROC) curve for the risk of transfusion. This was chosen to maximize both sensitivity and specificity by applying the Youden index to maximize the vertical distance of the ROC curve from the point (x, y) on the diagonal line (45° chance line).  $P < .05$  was considered statistically significant. Statistical analyses were performed using Wizard software (E. Millar, Chicago, IL, USA).

## Results

A total of 387 patients were included in the analysis, comprising 342 (88%) anatomic shoulder arthroplasty and 45 (11.7%) reverse shoulder arthroplasty patients. Regarding patient demographic characteristics, there were 207 female and 180 male patients and the mean age was 67.2 years (SD, 9.6 years) (Table I). Comparison between the cohort requiring transfusion and the cohort requiring no intervention revealed no statistically significant differences in the baseline characteristics of age (63.7 years vs. 67.3 years,  $P = .3$ ), female sex (72.3% vs. 53.9%,  $P = .2$ ), BMI (32.3 vs. 29.8,  $P = .4$ ), American Society of Anesthesiologists score (2.5 vs. 2.4,  $P = .4$ ), and Elixhauser index (1.3 vs. 1.2,  $P = .8$ ).

Transfusions were indicated for Hgb levels < 8.0 g/dL for patients with oncologic or cardiac related comorbidities or < 7.0 g/dL for all other patients. Analysis showed that the preoperative Hgb level was lower in the transfused group than in the no-intervention group (11.3 g/dL vs. 13.9 g/dL,  $P < .0001$ ). The percentage of patients in the transfused group with abnormal preoperative Hgb levels (<12 g/dL) was also statistically significant, with 72.3% (8 of 11 patients) vs. 11.5% (43 of 376) in the no-intervention group ( $P < .0001$ ). Similarly, the percentage of patients with POD 1 Hgb levels < 9 g/dL who received transfusions during the hospital course was significant, with 81.8% (9 of 11) compared with 5.6% (21 of 376) in the no-intervention group ( $P < .0001$ ). Calculated blood loss was higher in the transfused group vs. the no-transfusion group: 218.8 mL vs. 170.0 mL ( $P < .0001$ ). However, the difference between preoperative and postoperative Hgb levels (24 hours after surgery) was not significant, with a mean decrease of 3.3 g/dL for patients in the transfused group vs. 2.6 g/dL for those with no intervention ( $P = .07$ ). There was no significant difference in operative time between the transfusion group, with 161.8 minutes (SD, 223.8 minutes), and the no-intervention group, with 142.3 minutes (SD, 49.6 minutes) ( $P = .3$ ) (Table II).

A multivariate logistic model was created to predict the risk of transfusion while controlling for age, sex, and calculated blood loss. This model revealed an abnormal preoperative Hgb level with an odds ratio (OR) of 3.8 (95% confidence interval [CI], 1.5–6.2;  $P < .001$ ), as well as a postoperative Hgb level < 9 g/dL with an OR of 3.3 (95% CI, 0.4–6.1;  $P < .03$ ), as an independent significant risk factor for transfusion in this cohort. When an abnormal preoperative Hgb level and a POD 1 Hgb level < 9 g/dL were combined, there was an increase in the predictive risk of transfusion with an OR of 4.3 (95% CI, 2.0–6.6;  $P < .001$ ) (Table III). Analysis of the ROC curve for an abnormal preoperative Hgb level and a POD 1 Hgb level < 9 g/dL for predicting transfusion risk demonstrated a sensitivity of 64% and specificity of 96.2% with an area under the curve of 0.87.

**Table I**  
Baseline characteristics of total cohort

Characteristic	Transfused (n = 11)	No intervention (n = 376)	P value
Age (SD), yr	63.7 (6.2)	67.3 (9.6)	.3
Female sex, n (%)	8 (72.3)	199 (53.9)	.2
BMI (SD)	32.3 (11.2)	29.8 (6.7)	.4
ASA score (SD)	2.5 (0.5)	2.4 (0.6)	.5
Elixhauser index (SD)	1.3 (0.8)	1.2 (1.1)	.8

SD, standard deviation; BMI, body mass index; ASA, American Society of Anesthesiologists.

**Table II**  
Comparison of Hgb level and blood loss following shoulder arthroplasty

Factor	Transfused (n = 11)	No intervention (n = 376)	P value
Preoperative Hgb level (SD), g/dL	11.3 (1.8)	13.9 (1.5)	.0001
Preoperative Hgb level < 12 g/dL, n (%)	8 (72.3)	43 (11.5)	.0001
Postoperative Hgb level (SD), g/dL	8.1 (0.8)	11.3 (1.4)	.0001
POD 1 Hgb level < 9 g/dL, n (%)	9 (81.8)	21 (5.6)	.0001
Calculated blood loss, mL	218.8 (43.6)	170.0 (32.1)	.0001
Preoperative to postoperative change in Hgb level (24 h) (SD), g/dL	3.3 (1.5)	2.6 (1.2)	.07
Operative time (SD), min	161.8 (223.8)	142.3 (49.6)	.3

Hgb, hemoglobin; SD, standard deviation; POD, postoperative day.

**Table III**  
Multivariate regression analysis for predictive risk of transfusion

Observed effect	OR (95% CI)	P value
Abnormal preoperative Hgb level	3.8 (1.5-6.2)	.001
POD 1 Hgb level < 9 g/dL	3.6 (0.4-6.1)	.03
Abnormal preoperative Hgb level + POD 1 Hgb level < 9 g/dL	4.3 (2.0-6.6)	.001

OR, odds ratio; CI, confidence interval; Hgb, hemoglobin; POD, postoperative day.

A total of 724 CBC tests were ordered for the full cohort. The average number of CBCs obtained per patient was 2.6 for patients who received a transfusion vs. 1.9 for those who did not receive a transfusion. When factoring cost for CBCs, this translates to spending \$77,870 on CBC tests for patients who did not require transfusions. After the parameters described in the predictive model are applied to this cohort, this would result in recommending against 592 CBC tests, with potential cost savings of \$75,799.

**Discussion**

Shoulder arthroplasty is a procedure with increasing utilization in the United States.<sup>16,25,31</sup> Perioperative management for shoulder arthroplasty has often been inferred from THA and TKA.<sup>6,30</sup> Howell et al<sup>16</sup> highlighted that routine CBCs after TKA and THA did not add value for patients with normal preoperative Hgb levels who also received TXA.<sup>15</sup> Their study concluded that patients who did not receive TXA or who had abnormal preoperative Hgb values would warrant postoperative CBC testing. In their cohort, the cost savings translated to \$144,773 in associated hospital charges. To improve health care resource utilization in shoulder arthroplasty, the purpose of this study was to evaluate postoperative CBC testing after TSA with similar parameters to identify which patients may benefit from routine CBC testing.

In this study, we aimed to control for patient-specific risk variables as potential risk factors for postoperative anemia as identified in previous studies. In addition, all patients included in this cohort received TXA, which has also been identified as an independent risk factor for transfusion and postoperative anemia.<sup>3,7</sup> In contrast to findings from Howell et al,<sup>15,16</sup> in our TSA group, there was no significant correlation between age, female sex, BMI, or Elixhauser

index and postoperative anemia or transfusion. This finding can be explained by the overall lower incidence of transfusion in TSA, as compared with lower-extremity surgery, and the addition of TXA to prevent postoperative anemia and transfusion.<sup>21</sup> All patients in this study received TXA as this model was thought to be most representative of current practice management.<sup>3,10</sup> However, without TXA utilization, there may have been subtle differences between sex and coagulopathy history for risk of anemia and transfusion.

Although transfusion is an uncommon event after TSA, it has significant implications in arthroplasty, with reported increased risks of infection, longer hospitalization, and readmission.<sup>12,23</sup> In this study, the overall transfusion rate was 2.8%, which is in agreement with national averages ranging from 2% to 10%.<sup>3,21</sup> As such, a key factor for assessing the need for transfusion is postoperative CBC values (Hgb and hematocrit levels). In this cohort, significant differences were found with the group that received transfusion with abnormal preoperative Hgb levels (72%) and postoperative Hgb levels < 9 mg/dL on POD 1 (82%). This finding supports evidence from the THA and TKA literature reporting that an abnormal preoperative Hgb level is a significant independent risk factor for postoperative anemia and transfusion.<sup>11,13,15,18</sup> Although calculated blood loss was higher in the transfused group, the regression model revealed that blood loss alone was not an independent risk factor for transfusion. This finding was thought to be related to an inconsistent difference from preoperative to postoperative Hgb levels, which suggests there may be inherent error or bias when measuring blood loss. This outcome has been rarely reported, which emphasizes that the drop in preoperative and postoperative Hgb levels does not directly correlate to risk of transfusion.

Ultimately, this study aimed to translate the aforementioned findings into evidence-based recommendations. On the basis of the

multivariate regression model to predict transfusion, an abnormal preoperative Hgb level, as well as a first postoperative Hgb level < 9 g/dL, was identified as the most relevant risk factor, with a sensitivity of 64% and specificity of 96.2%. Although the sensitivity of our model was equivalent to that of Howell et al.<sup>16</sup> the specificity in our model was higher (96.2% vs. 82.9%).<sup>15</sup> With this model in mind, we suggest considering against routine postoperative CBC testing for patients after TSA with preoperative Hgb levels > 12 mg/dL and patients who have POD 1 Hgb levels > 9 mg/dL who receive TXA. These recommendations would not replace clinical decision making or clinical evaluation of postoperative anemia but instead act as supporting evidence for judgment with obtaining laboratory testing, which has been reported in the THA, TKA, and spine literature.<sup>1,26</sup> This may have a significant long-term impact on improving risk stratification for shoulder arthroplasty and overall health care resource utilization as more bundled-payment models may become prevalent in shoulder arthroplasty.<sup>2,17,24,29,32,33</sup>

This study, as a retrospective study, is not without limitations. There are inherent variations between institutions and/or practice groups regarding the indication for transfusion and perioperative management, so these results may not directly translate to all cases. For example, a clinician may have different parameters for obtaining postoperative laboratory values or performing transfusion from those stated in this study. Similarly, postoperative Hgb values from a late case may have different utility with an early blood draw. Additionally, the cost savings reflected in our study may be variable between institutions or practice groups.

## Conclusion

Routine CBC testing may not be necessary for patients who receive TXA and have preoperative Hgb levels > 12 mg/dL and first postoperative Hgb levels > 9 mg/dL. This translates to potential health care cost savings and improves current evidence-based perioperative management in shoulder arthroplasty.

## Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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