Anemia Severity and the Risks of Postoperative Complications and Extended Length of Stay Following Primary Total Elbow Arthroplasty

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Abstract

Background: Anemia is a modifiable risk factor that may influence postoperative complications following orthopedic surgical procedures. The objective was to determine the influence of preoperative anemia severity on postoperative complications and length of stay (LOS) following total elbow arthroplasty (TEA). **Methods:** The American College of Surgeons National Surgical Quality Improvement Program registry was queried from 2006 to 2019 for patients undergoing primary TEA. Using the World Health Organization definitions of anemia, patients undergoing TEA were stratified into 3 cohorts: nonanemia (hematocrit >36% for women, >39% for men), mild anemia (hematocrit 33%-36% for women, 33%-39% for men), and moderate-to-severe anemia (hematocrit <33% for both women and men). Patient demographics, surgical time, LOS, and postoperative complications were compared between the groups. A *P* value <.004 was considered significant. **Results:** After exclusion, 589 patients, of whom 369 (62.6%) did not have anemia, 129 (21.9%) had mild anemia, and 91 (15.5%) had moderate/severe anemia, were included. Increasing severity of anemia was associated with an increased average hospital LOS (2.30 vs 2.81 vs 4.91 days, *P* < .001). There was a statistically significant increase in blood transfusions (1.08% vs 7.75% vs 17.58%, *P* < .001), major complications (9.21% vs 17.83% vs 34.07%, *P* < .001), any complications (11.11% vs 23.26% vs 36.26%, *P* < .001), and extended LOS ≥6 days (6.23% vs 6.98% vs 31.87%, *P* < .001) with increasing severity of anemia. Multivariate analysis identified moderate-to-severe anemia was significantly associated with major complications and extended LOS (*P* < .001). **Conclusions:** Preoperative anemia is a modifiable risk factor for medical and surgical complications within 30 days of TEA.

Keywords: total elbow arthroplasty, NSQIP, anemia, complications, length of stay, reoperation, elbow replacement

Introduction

Total joint arthroplasty is a commonly used procedure for various pathologies of the major joints of the upper and lower extremities. Specifically, total elbow arthroplasty (TEA) was first developed in the 1970s to treat degenerative pathology from rheumatoid arthritis.[1,2] Today, TEA is a surgical procedure used for the management of posttraumatic arthritis, advanced rheumatoid arthritis, osteoarthritis, reconstruction after tumor resection, and complex distal humerus fractures in elderly patients.[3] With reported increases in utilization of 6.4% from 1993 to 2007 in the United States, understanding contemporary TEA outcomes is valuable.[4]

In comparison with total joint arthroplasty of the shoulder, hip, and knee, TEA has a higher complication rate and inferior implant survival.[5-7] Knowledge of the potential complications and risk factors is important to allow surgeons to medically optimize and properly screen patients prior to surgical intervention. Further study is needed regarding modifiable laboratory and electrolyte derangements in the upper extremity arthroplasty population as focus shifts to value-based care models.[8]

Anemia is a modifiable risk factor that is associated with general health status, strength, mortality, and other medical

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comorbidities with a prevalence between 21% and 35% for patients undergoing elective orthopedic procedures.[9] In total joint arthroplasty of the shoulder, preoperative anemia severity has been demonstrated to influence perioperative complications including blood transfusions and other major complications.[10-12] Furthermore, intraoperative blood transfusion has been shown to be associated with a higher risk of mortality and morbidity in surgical patients with severe anemia.[13,14] No studies to date have evaluated the impact of anemia severity on outcomes after primary TEA. Given the gap in the literature on this topic, the purpose of the study was to determine the influence of preoperative anemia severity on short-term postoperative complications and length of stay (LOS) following primary TEA. We hypothesized that increasing preoperative anemia severity would be associated with increased major complications and extended LOS.

Database and Patient Selection

This study was a retrospective review of prospectively collected data from the 2006-2019 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. The database was queried for patients ≥18 years of age undergoing TEA (Current Procedural Terminology code 24363: "Arthroplasty, elbow; with distal humerus and proximal ulnar prosthetic replacement"). Patients were excluded from this study if they had missing demographic data or if they were classified as ASA grade V. Cases involving polytrauma or elbow arthroplasty revision were excluded using International Classification of Diseases, 9th Revision codes. As the data were derived from a deidentified national surgical database, the study was exempt from institutional review board approval. Further details regarding data collection can be found on the ACS-NSQIP Web site.[15]

Variables and Outcomes Studied

Patient demographics included as part of the study were age, sex, race, body mass index (BMI), comorbidities (diabetes mellitus, smoking history, chronic obstructive pulmonary disease, congestive heart failure, hypertension, dialysis-dependent, disseminated cancer, chronic steroid use, ascites, dyspnea, and functional health status), and preoperative lab evaluation. The primary preoperative laboratory test of interest included hematocrit (HCT). Using the World Health Organization definitions of anemia, patients were stratified into 3 cohorts: nonanemia (hematocrit >36% for women, >39% for men), mild anemia (hematocrit 33%-36% for women, 33%-39% for men), and moderate-to-severe anemia (hematocrit <33% for both women and men).[9,10,16-18] Operative and postoperative data included

ASA grade, anesthesia administered, total operative time (minutes), and LOS.

Postoperative Outcomes

Short-term postoperative complications (medical and surgical) were recorded and grouped into major and minor complications. Major complications included deep infections, organ infections, unplanned intubations, pulmonary emboli, ventilator use >48 hours, strokes, cardiac arrests, deep vein thromboses, sepsis, acute renal failures, blood transfusions, return to the operating room, and death. Minor complications included superficial infections, wound dehiscence, pneumoniae, renal insufficiencies, and urinary tract infections. For the purpose of this study, we compared outcomes of nonanemic versus mild anemia versus moderate-to-severe anemia. Rates and risk factors associated with 30-day complications, reoperations, and readmissions were evaluated. Extended LOS was defined as ≥6 days or 1 standard deviation above the mean LOS for the patients in this study.

Statistical Analyses

Bivariate analyses using Pearson χ^2 tests and analysis of variance were used to assess differences in patient demographics between anemia groups. All variables with a P value ≤.15 from unadjusted analysis were then entered into multivariate backward stepwise logistic regression model and adjusted for each other, to identify any significant independent predictors for major complication, minor complication, any complication, death, reoperation, readmission, and extended LOS. Results from multivariate regression models have been reported as adjusted odds ratios (ORs) with 95% confidence intervals (CIs). Due to the number of comparisons that were made in this study, and the ease of finding statistical significance, a Bonferroni correction was performed to reduce the probability of a type I error. As such, a P value <.004 was considered as the threshold for statistical significance. Statistical analysis was performed using SPSS version 24 (IBM, Armonk, New York).

Results

Patient Preoperative and Intraoperative Characteristics

After exclusion, 589 patients, of whom 369 (62.6%) did not have anemia, 129 (21.9%) had mild anemia, and 91 (15.5%) had moderate/severe anemia, were included in the study. Patients in the 3 groups differed regarding multiple demographics, including race, age, BMI, functional status, the presence of comorbidities (diabetes mellitus, hypertension, dialysis dependence, weight loss) and ASA class (Table 1).

Table 1. Demographics and Clinical Characteristics Among Patients Undergoing Total Elbow Arthroplasty.

Variable of Interest	No anemia[a] No. of patients	Mild anemia[b] No. of patients	Moderate/severe anemia[c] No. of patients	P value[d]
No. of patients	369	129	91	
Sex				
female	290	95	78	.099
male	79	34	13	
Race				
White	293	96	61	**.024**
Black	11	9	9	
Other	65	24	21	
Age, y				
< 65	181	37	23	**<.001**
≥ 65	188	92	68	
BMI, kg/m^2				
<25.00	100	41	38	**.036**
25.00-29.99	117	47	23	
30.00+	152	41	30	
Functional status				
Independent	353	114	73	**<.001**
Dependent	14	14	17	
Unknown	2	1	1	
Diabetes				
No	329	100	63	**<.001**
Yes	40	29	28	
Current smoker				
No	311	108	83	.214
Yes	58	21	8	
Dyspnea				
Moderate	16	10	6	.293
Exertion				
No	353	119	85	
Ventilator dependent				
No	369	128	91	.374
Yes	0	1	0	
History of COPD				
No	351	118	82	.121
Yes	18	11	9	
Ascites				
No	369	129	91	1.000
Congestive heart failure				
No	365	126	90	.521
Yes	4	3	1	
Hypertension				
No	177	52	30	**.023**
Yes	192	77	61	
Currently on dialysis				
No	369	129	89	**.024**
Yes	0	0	2	
Disseminated cancer				
No	368	129	87	**.003**
Yes	1	0	4	

(continued)

Table 1. (continued)

Variable of Interest	No anemia[a]	Mild anemia[b]	Moderate/severe anemia[c]	P value[d]
	No. of patients	No. of patients	No. of patients	
Steroid use				
No	293	100	75	.675
Yes	76	29	16	
>10% loss in body weight in the last 6 months				
No	369	128	89	**.029**
Yes	0	1	2	
Transfusion of ≥1 unit of PRBCs in 72 h before surgery				
No	369	129	87	**.001**
Yes	0	0	4	
ASA				
1	9	4	0	**<.001**
2	161	31	21	
3	185	87	60	
4	14	7	10	

Note. BMI = body mass index; COPD = chronic obstructive pulmonary disease; ASA = American Society of Anesthesiologists; PRBC = packed red blood cells. Bold values denote significant difference.
[a]Female: hematocrit >36%; male: hematocrit >39%.
[b]Female: hematocrit 33%-36%; male: hematocrit 33%-39%.
[c]Female: hematocrit <33%; male: hematocrit <33%.
[d]P value derived from Pearson χ^2 test.

The anemia groups had similar proportions of principal anesthetic technique administered, and operative time was not statistically different between cohorts (160.8 vs 163.3 vs 154.5 minutes) ($P = .626$), Table 2.

Anemia Severity and Hospital LOS, Readmissions, Reoperations, and Complications

Upon univariate analysis, increasing severity of anemia was associated with increased average hospital LOS (2.30 vs 2.81 vs 4.91 days. $P < .001$) (Table 2). The proportion of patients requiring an extended LOS (≥6 days) significantly increased with increasing severity of anemia (6.23% vs 6.98% vs 31.87%, $P < .001$). Although reoperation and readmission rates increased with increasing severity of anemia, they were not significantly different (all Ps ≥ .054) (Table 3). There was a statistically significant increase in blood transfusions (1.08% vs 7.75% vs 17.58%, $P < .001$), major complications (9.21% vs 17.83% vs 34.07%, $P < .001$), and any complications (11.11% vs 23.26% vs 36.26%, $P < .001$) between groups (Table 3).

Multivariate Logistic Regression Analysis

After adjustment, mild anemia was not an independent predictor of major complication, minor complication, any complication, reoperation, readmission, and extended LOS (all Ps ≥ .018) (Figure 1). Moderate-to-severe anemia was an independent predictor of blood transfusion (OR: 15.69,

95% CI: 4.94-49.79, $P < .001$), extended LOS (OR: 5.14, 95% CI: 2.64-10.00, $P < .001$), major complication (OR: 3.85, 95% CI: 1.96-7.60, $P < .001$), and any complication (OR: 2.88, 95% CI: 1.47-5.67, $P = .002$) (Figure 2). When comparing mild anemia versus moderate-to-severe anemia, patients with moderate-to-severe anemia were more likely to undergo an extended LOS (OR: 5.66, 95% CI: 2.30-13.93, $P < .001$) (Figure 3).

Discussion

With increasing utilization of TEA, a comprehensive understanding of predisposing risk factors for complications becomes essential.[4] Using a nationwide surgical database, this study evaluates the impact of anemia on outcomes after TEA. Moderate-to-severe anemia was a risk factor for major complications and extended LOS. Patients with mild anemia, however, did not appear to be at increased risk after adjusting for multiple independent factors. These findings lend to the potential utility of preoperative laboratory risk stratification in this cohort of patients as orthopedic surgeons aim to optimize postoperative outcomes.

Anemia is a modifiable risk factor that is associated with general health status, strength, mortality, and other medical comorbidities with a prevalence between 21% and 35% for patients undergoing elective orthopedic procedures.[9] We found that increased severity of anemia resulted in greater length of hospital stay from 2.3 days in nonanemic patients to 4.9 days in severely anemic patients. Doan and

Table 2. Intraoperative and Postoperative Variables Among Patients Undergoing Total Elbow Arthroplasty.

Variable of Interest	No anemia[a] No. of patients	Mild anemia[b] No. of patients	Moderate/severe anemia[c] No. of patients	P value[d]
Principal anesthesia technique				
General	348	126	85	.570
MAC/IV sedation	8	0	2	
Other	1	0	0	
Regional	12	3	4	
Reoperation				
No	359	123	86	.289
Yes	10	6	5	
Readmission				
No	355	123	82	.054
Yes	14	6	9	
Total operative time, min	160.81	163.29	154.46	.626
Operative time cohorts, min				
≤148	183	66	48	.856
>148	186	63	43	
Length of hospital stay, d	2.30	2.81	4.91	**<.001**
LOS ≥6 d				
No	345	120	62	**<.001**
Yes	23	9	29	

Note. LOS = length of stay; MAC/IV = monitored anesthesia care/intravenous. Bold values denote significant difference.
[a]Female: hematocrit >36%; male: hematocrit >39%.
[b]Female: hematocrit 33%-36%; male: hematocrit 33%-39%.
[c]Female: hematocrit <33%; male: hematocrit <33%.
[d]P value derived from Pearson χ^2 test or analysis of variance.

colleagues[11] demonstrated similar stepwise increased LOSs following total shoulder arthroplasty from 1.6 days to 3.0 days as severity of anemia worsened. As orthopedic surgery transitions into value-based care through bundled payment models, cost-controlling measures such as limiting short-term complications, readmissions, and reoperations remain paramount. Length of hospital stay has consistently been demonstrated to be a significant driver of in-hospital costs.[4,19] In this study, we defined an extended LOS as ≥6 days. Preoperative anemia and its sequelae could prove to be a costly but modifiable preoperative condition and warrants further investigation in the upper extremity arthroplasty population. A better understanding of the impact of anemia severity on extended LOS and 30-day complications should be considered by orthopedic surgeons and patients to control expenditures and improve outcomes. While this study addresses a knowledge gap on this topic, future studies should evaluate more granular details regarding specific risk factors for anemia and reasons for prolonged LOS.

Common complications following TEA include wound drainage, hematoma formation, infection, delayed healing, nerve injury, and implant failure.[20-23] Short-term (30-day) and mid-term (90-day) complication rates after TEA range from 2.7% to 39% depending on operating room setting and

severity of complications of interest.[19,24,25] The inclusion of TEA adds to the available literature on patients with anemia undergoing arthroplasty and the risk for subsequent complications. Few groups have studied preoperative anemia severity in patients undergoing total joint arthroplasty of the shoulder, hip, and knee, which showed an increase in intraoperative and postoperative medical complications.[10,18] The major complication rate in this study had a stepwise increase (9.2% to 34.1%) as anemia severity increased in patients undergoing TEA. These findings mimic results in the existing literature for shoulder arthroplasty with complication rates increasing from 3.1% in nonanemic patients to 30.8% in severely anemic patients.[12] A large majority of minor complications in this study included superficial surgical site infections and pneumonia. Major complications were mainly a result of reoperations and blood transfusions. Despite the increase in major complications in the anemia cohorts, severe debilitating complications including reintubation, pulmonary embolism, stroke, acute renal failure, and death were minimal in comparison with other studies involving noncardiac surgery and arthroplasty of the shoulder, hip, and knee.[10,13,26] The results of this study demonstrate a noticeable increase in complications for this subset of patients undergoing TEA. Further prospective investigations comparing the administration of preoperative

Table 3. Univariate Analysis of Postoperative Complications of Patients Following Total Elbow Arthroplasty.

Complication Type	Complications and rates			
	No anemia[a]	Mild anemia[b]	Moderate/severe anemia[c]	P value[d]
Superficial incisional SSI	2 (0.54)	1 (0.78)	1 (1.10)	.784
Wound disruption	1 (0.27)	3 (2.33)	1 (1.10)	.060
Pneumonia	3 (0.81)	2 (1.55)	0 (0.00)	.544
Progressive renal insufficiency	0 (0.00)	0 (0.00)	0 (0.00)	1.000
Urinary tract infection	1 (0.27)	1 (0.78)	0 (0.00)	.608
Deep incisional SSI	2 (0.54)	1 (0.78)	1 (1.10)	.784
Organ/space SSI	3 (0.81)	2 (1.55)	1 (1.10)	.605
Unplanned intubation	2 (0.54)	1 (0.78)	1 (1.10)	.784
Pulmonary embolism	3 (0.81)	0 (0.00)	0 (0.00)	.742
On ventilator >48 h	1 (0.27)	0 (0.00)	0 (0.00)	1.000
Stroke/CVA	0 (0.00)	1 (0.78)	1 (1.10)	.139
Cardiac arrest	0 (0.00)	0 (0.00)	2 (2.20)	**.024**
Myocardial infarction	1 (0.27)	1 (0.78)	0 (0.00)	.608
DVT/thrombophlebitis	1 (0.27)	0 (0.00)	1 (1.10)	.333
Sepsis	3 (0.81)	0 (0.00)	1 (1.10)	.470
Septic shock	3 (0.81)	1 (0.78)	0 (0.00)	1.000
Acute renal failure	0 (0.00)	0 (0.00)	0 (0.00)	1.000
Blood transfusion	4 (1.08)	10 (7.75)	16 (17.58)	**<.001**
Reoperation	10 (2.71)	6 (4.65)	5 (5.49)	.289
Death	1 (0.27)	0 (0.00)	2 (2.20)	.096
Major complication	34 (9.21)	23 (17.83)	31 (34.07)	**<.001**
Minor complication	7 (1.90)	7 (5.43)	2 (2.20)	0.113
Any complication	41 (11.11)	30 (23.26)	33 (36.26)	**<.001**
Any readmission	14 (3.79)	6 (4.65)	9 (9.89)	.054
Extended length of stay (≥6 d)	23 (6.23)	9 (6.98)	29 (31.87)	**<.001**

Note. N (%): number of complications (%). *Major complications*: deep surgical site infections (SSIs), organ infections, unplanned intubations, pulmonary emboli, ventilator use >48 hours, strokes, cardiac arrest, myocardial infarctions, deep vein thrombosis (DVT), sepsis, acute renal failures, blood transfusions, return to the operating room, and death. *Minor complications*: superficial SSIs, wound dehiscence, pneumoniae, renal insufficiencies, and urinary tract infections. CVA = cerebrovascular accident. Bold values denote significant difference.
[a]Female: hematocrit >36%; male: hematocrit >39%.
[b]Female: hematocrit 33%-36%; male: hematocrit 33%-39%.
[c]Female: hematocrit <33%; male: hematocrit <33%.
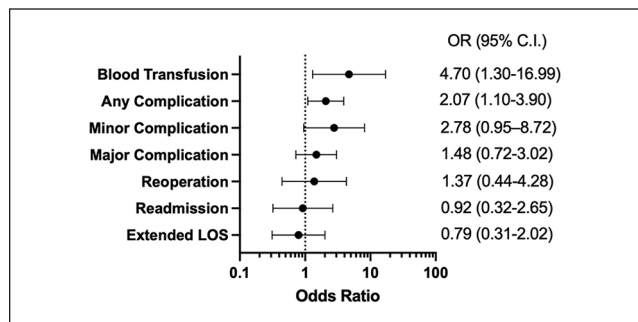[d]P value derived from Pearson χ^2 test.

Figure 1. Forest plot of postoperative complications following total elbow arthroplasty: mild anemia versus nonanemia.
Note. OR = odds ratio; C.I. = confidence interval; LOS = length of stay.

transfusion in patients with moderate-to-severely anemia and the effect on complications would be valuable additions to the literature.

There are a few limitations to the study that should be considered. The parameters by which anemia was defined in this study used preoperative HCT laboratory values. Despite not being an absolute indicator of anemia, the authors chose this laboratory value to be consistent with prior literature.[9,16] Notably, the labs were not always collected immediately prior to surgery, as the number of days preoperatively that HCT was collected varied. The etiology of each patient's anemia was also not available for further study in the ACS-NSQIP. Intraoperative use of tranexamic acid was not available for study and may affect the results found in the study. In addition, the database lacks granular clinical information, such as patient-reported outcome measures, that would be useful to evaluate between the 3 cohorts. Clinical outcomes specific to elbow arthroplasty, such as stiffness, long-term infection, aseptic loosening, loss of bone stock, triceps insufficiency, and periprosthetic fracture, are not documented. Complications
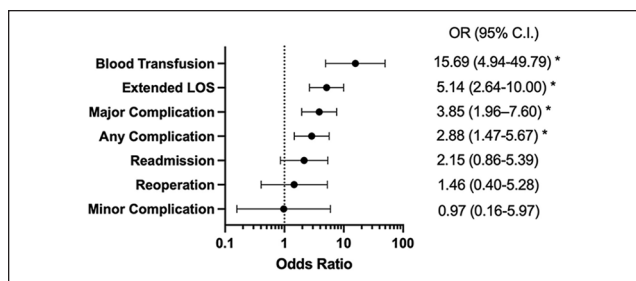
Figure 2. Forest plot of postoperative complications following total elbow arthroplasty: moderate-to-severe anemia versus nonanemia.
Note. OR = odds ratio; C.I. = confidence interval; LOS = length of stay.
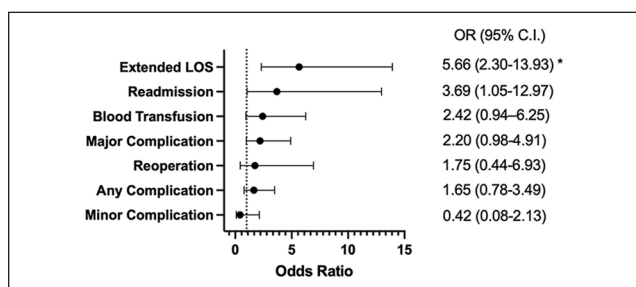*Significant at the *P* < .004 level.

Figure 3. Forest plot of postoperative complications following total elbow arthroplasty: mild anemia versus moderate-to-severe anemia.
Note. OR = odds ratio; C.I. = confidence interval; LOS = length of stay.
*Significant at the *P* < .004 level.

and reoperation evaluation were limited to 30 days postoperatively, which may not capture patients who presented to the hospital after that time period. It is possible our study was underpowered given the inequality of patients per group and the number of group comparisons as sample size and variability are 2 important factors that conceptually should influence the power. As such, small sample sizes and high variability could be more likely to lead to conclusions of nonequivalence and predispose to a type 1 error. Despite these limitations, this is the first study to evaluate anemia severity and the relationship to postoperative complications after TEA.

Conclusion

Preoperative anemia is a modifiable risk factor for medical and surgical complications within 30 days of TEA. Patients with moderate-to-severe anemia in comparison with those with mild and no anemia were at an increased risk for an extended LOS and major complications after TEA. Medical optimization and transfusion prior to surgical intervention may improve outcomes in patients undergoing TEA.

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