Research Article

Factors Associated With Perioperative Transfusion in Lower Extremity Revision Arthroplasty Under a Restrictive Blood Management Protocol

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ABSTRACT

Introduction: Approximately 37% of patients undergoing lower extremity revision total joint arthroplasty (TJA) receive allogeneic blood transfusions (ABTs), which are associated with increased risk of morbidity and death. It is important to identify patient factors associated with needing ABT because the health of higher-risk patients can be optimized preoperatively and their need for ABT can be minimized. Our goal was to identify the patient and surgical factors independently associated with perioperative ABT in revision TJA.

Methods: We included all 251 lower extremity revision TJA cases performed at our academic tertiary care center from January 1, 2016, to December 31, 2018. We assessed the following factors for associations with perioperative ABT: patient age, sex, race, body mass index, preoperative hemoglobin level, and infection status (ie, infection as indication for revision TJA); use of vasopressors, tranexamic acid (TXA), surgical drains, tourniquets, and intraoperative cell salvage; and procedure type (hip versus knee), procedure complexity (according to the number of components revised), and surgical time. Multivariable regression was used to identify factors independently associated with perioperative ABT.

Results: The following characteristics were independently associated with greater odds of perioperative ABT: preoperative hemoglobin level (odds ratio [OR], 1.8; 95% confidence interval [CI], 1.5 to 2.2), infectious indication for revision (OR, 3.6; 95% CI, 1.3 to 9.7), and procedure complexity. TXA use was a negative predictor of ABT (OR, 0.47; 95% CI, 0.23 to 0.98). Compared with polyethylene liner exchanges, single-component revisions (OR, 14; 95% CI, 3.6 to 56) and dual-component revisions (OR, 7.8; 95% CI, 2.3 to 26) were associated with greater odds of ABT.

Discussion: Patients with preoperative anemia, those undergoing revision TJA because of infection, those who did not receive TXA, and

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those undergoing more complex TJA procedures may have greater odds of requiring ABT. We recommend preoperative optimization of the health of these patients to reduce the need for ABT.

Level of Evidence: Level III, prognostic study

Among patients undergoing primary lower extremity total joint arthroplasty (TJA), approximately 3% to 9% receive allogeneic blood transfusion (ABT).[1,2] Transfusions are associated with infection, wound complications, higher treatment costs, longer hospital stays, and death[3-7]; therefore, reducing ABT rates is vital. Patients undergoing revision TJA are at higher risk of needing ABT than those undergoing primary TJA.[2,8] Despite decreasing rates of ABT in revision TJA, transfusion rates remain at 15% to 76%, depending on institutional blood management protocols.[8-11] An understanding of the patient- and treatment-related factors associated with ABT may help surgeons develop strategies to reduce the need for ABT in revision TJA, particularly as institutions implement more restrictive transfusion policies, such as lower transfusion thresholds and use of antifibrinolytic agents.[12,13]

Certain patient characteristics and comorbidities are associated with higher rates of transfusion.[14-17] ABT rates are higher in revision hip arthroplasty than in revision knee arthroplasty and in dual-component revision than in single-component revision.[8,9] Blood conservation strategies, including the use of tranexamic acid (TXA),[18-21] tourniquets in knee revisions,[22,23] and intraoperative cell salvage,[24] have shown some success in reducing the need for ABT in arthroplasty procedures. However, little is known about the association between perioperative variables and the need for ABT in revision TJA, particularly in the setting of restrictive blood management protocols. In addition, many studies have used large databases, which provide limited detail in their data sets. Our aim was to identify the patient and surgical factors that are independently associated with perioperative ABT in revision TJA in the setting of a restrictive transfusion threshold.

Methods

Study Design, Setting, and Sample

We retrospectively reviewed all 276 lower extremity revision TJA cases performed in patients aged 18 years or older at our tertiary care, academic medical center from January 1, 2016, to December 31, 2018. We excluded cases for which revision was performed to treat acute periprosthetic fracture (n = 25), resulting in 251 cases (125 hip and 126 knee revisions) in 208 patients for analysis. The mean (±SD) patient age was 65 ± 11 years. Forty-seven percent of patients were men. Mean preoperative hemoglobin level was 12 ± 2.0 g/dL. Eighty-one cases (32%) involved transfusion of at least 1 unit of allogeneic blood (1 unit in 27 cases; 2 units in 34 cases; 3 units in 8 cases; 4 units in 7 cases; 5 units in 2 cases; 6 units in 2 cases, and 7 units in 1 case). Eighteen cases (7.2%) involved intraoperative ABT only, 46 (18%) involved postoperative ABT only, and 17 (6.8%) had both intraoperative and postoperative ABT.

Patient and Surgical Characteristics

The following patient characteristics were recorded: sex, age, race, body mass index (BMI), and preoperative hemoglobin level. The following surgical characteristics were recorded: procedure type (hip or knee); infection as indication for surgery (irrigation and débridement with modular component exchange, explantation/removal of components with placement of an antibiotic spacer, antibiotic spacer removal and prosthesis reimplantation, or antibiotic spacer exchange); use of TXA, vasopressors, tourniquets in knee cases, intraoperative cell salvage, and surgical drains; procedure complexity; and total operative time. Procedure complexity was categorized according to components exchanged in the procedure (polyethylene liner exchange [least complex], single-component revision, or dual-component revision [most complex]). The following were considered dual-component revisions: infected instrumentation removal and articulating antibiotic spacer placement, articulating antibiotic spacer removal and prosthesis reimplantation, and articulating antibiotic spacer exchange. To determine which patients had received perioperative ABT, we reviewed the data on intraoperative and postoperative ABT (within the first three days) from the "blood product history" section of each patient's medical record. The blood management protocol at our institution is consistent with the clinical practice guideline for blood management from the American Association of Blood Banks,[25] which recommends a restrictive transfusion threshold of 7 g/dL of hemoglobin for asymptomatic patients or 8 g/dL for symptomatic patients or asymptomatic patients with cardiac disease. Decisions regarding ABT administration were made by the anesthesiologist intraoperatively and the attending surgeon postoperatively.

Table 1. **Preoperative Characteristics of Patients Who Underwent 251 Revision Total Joint Arthroplasties, 2016 to 2018**

	N (%)			
Variable	All Patients	Nontransfused (n = 170)	Transfused (n = 81)	*P* Value
Sex				0.77
Male	118 (47)	81 (48)	37 (46)	
Female	133 (53)	89 (52)	44 (54)	
Age, yrs		64 ± 11[a]	66 ± 12[a]	0.81
Race/ethnicity				0.31
White	179 (71)	125 (74)	54 (67)	
Black	58 (23)	36 (21)	22 (27)	
Hispanic	5 (2.0)	4 (2.4)	1 (1.2)	
Asian	2 (0.80)	0 (0)	2 (2.5)	
Other	7 (2.8)	5 (2.9)	2 (2.5)	
BMI, kg/m^2		32 ± 6.6[a]	30 ± 5.4[a]	0.02
Preoperative hemoglobin level, g/dL		13 ± 1.7[a]	11 ± 2.0[a]	<0.01
Men		13 ± 1.8	11 ± 2.0	<0.01
Women		12 ± 1.6	10 ± 2.0	<0.01

BMI = body mass index
[a]Data presented as mean ± SD.

Statistical Analysis

Distributions of preoperative patient characteristics and preoperative and intraoperative clinical characteristics are described using mean and SD for continuous variables and frequency for categorical variables. Unadjusted associations between these characteristics and ABT status were assessed for all revisions using two-sample Student *t*-tests (or analysis of variance) for continuous variables and Pearson chi-squared tests for categorical variables. All patient characteristics and intraoperative variables with *P* values < 0.1 were included in the multivariable analysis to identify independent predictors of transfusion. These model-adjusted results are reported as odds ratios (ORs) and 95% confidence intervals (CIs). *P* values < 0.05 were considered significant. All analyses were performed using JMP statistical software (SAS Institute).

Results

Variables Associated With Perioperative Allogeneic Blood Transfusion

The transfused and nontransfused cases were similar in sex, age, and race/ethnicity, but the mean (±SD) BMI of the transfused group (30 ± 5.4 kg/m^2) was lower than that of the nontransfused group (32 ± 6.6 kg/m^2) (P = 0.02) (Table 1). The mean preoperative hemoglobin level was lower in the transfused group (11 ± 2.0 g/dL) than that in the nontransfused group (13 ± 1.7 g/dL) ($P < 0.01$). After stratification by sex, the mean preoperative hemoglobin level was lower in the transfused group than that in the nontransfused group for both men (11 ± 2.0 g/dL versus 13 ± 1.8 g/dL) and women (10 ± 2.0 g/dL versus 12 ± 1.6 g/dL) ($P < 0.01$).

The following surgical characteristics were associated with ABT: infection as indication for revision ($P < 0.01$), lack of TXA use ($P < 0.01$), hip (versus knee) revision (P = 0.04), and greater procedure complexity (P = 0.02) (Table 2). No associations were found between ABT and total surgical time or use of vasopressors, tourniquets (in knee revisions), intraoperative cell salvage, or drains (all, $P > 0.05$).

Independent Predictors of Perioperative Allogeneic Blood Transfusion

Each 1-g/dL decrease in preoperative hemoglobin level was associated with nearly double the odds of perioperative ABT administration (OR, 1.8; 95% CI, 1.5 to 2.2) (Table 3). Single-component (OR, 14; 95% CI, 3.6 to 56) and dual-component procedures (OR, 7.8; 95% CI, 2.3 to 26) were associated with higher odds of ABT than were polyethylene liner exchange procedures; however, dual-component procedures did not differ substantially from single-component procedures

Table 2. Intraoperative Characteristics of 251 Cases of Revision Total Joint Arthroplasty

Variable	Total N	N (%) Nontransfused (n = 170)	N (%) Transfused (n = 81)	*P* Value
Vasopressor use				
Yes	180	117 (69)	63 (78)	0.14
No	71	53 (31)	18 (22)	
TXA				
Yes	170	129 (76)	41 (51)	<0.01
No	81	41 (24)	40 (49)	
Tourniquet use[a]				
Yes	87	67 (72)	20 (61)	0.22
No	39	26 (28)	13 (39)	
Intraoperative cell salvage				
Yes	98	73 (43)	25 (31)	0.07
No	153	97 (57)	56 (69)	
Surgical time, min		202 ± 80[b]	209 ± 100[b]	0.59
Infection as indication				
Yes	112	60 (35)	52 (64)	<0.01
No	139	110 (65)	29 (36)	
Procedure type				
Hip revision	125	77 (45)	48 (59)	0.04
Knee revision	126	93 (55)	33 (41)	
Procedure complexity				
Polyethylene liner exchange	41	35 (21)	6 (7.4)	0.02
Single-component revision	80	55 (32)	25 (31)	
Dual-component revision	130	80 (47)	50 (62)	
Surgical drain use				
Yes	126	82 (48)	44 (54)	0.37
No	125	88 (52)	37 (46)	

TXA = tranexamic acid
[a]Only used in knee revisions (n = 126), of which 93 were nontransfused and 33 were transfused.
[b]Data presented as mean ± SD.

regarding the odds of ABT (*P* = 0.23). Infection was associated with substantially higher odds of ABT (OR, 3.6; 95% CI, 1.3 to 9.7), and TXA use was associated with lower odds of ABT (OR, 0.47; 95% CI, 0.23 to 0.98). BMI (*P* = 0.27), procedure type (*P* = 0.19), and intraoperative cell salvage (*P* = 0.78) were not independently associated with ABT.

Discussion

We aimed to identify the risk factors associated with perioperative ABT in patients undergoing revision TJA. In the setting of a restrictive transfusion threshold, preoperative hemoglobin level, procedure complexity, and infection as indication for revision were independent predictors of ABT, whereas TXA use was associated with lower odds of ABT. As orthopaedic practices implement more restrictive blood management policies,[12,13] it is important to understand the predictors of ABT, which is associated with higher rates of morbidity and death.[3-7]

Preoperative hemoglobin level and procedure complexity were independent predictors of ABT, which is consistent with previous findings.[8,9,14,17,26,27] However, contrary to the findings of Burnett et al,[8] we found no

Table 3. **Multivariate Odds of Allogeneic Blood Transfusion in Revision Total Joint Arthroplasty**

Variable	OR	95% CI	*P* Value
Single-component revision[a]	14	3.6-56	<0.01
Dual-component revision[a]	7.8	2.3-26	<0.01
Infection as surgical indication	3.6	1.3-9.7	0.01
Preoperative hemoglobin level[b]	1.8	1.5-2.2	<0.01
BMI[c]	1.0	0.98-1.1	0.27
Intraoperative cell salvage use	0.90	0.43-1.9	0.78
Knee (versus hip) revision	0.62	0.30-1.3	0.19
Dual-component (versus single-component) revision	0.55	0.21-1.5	0.23
TXA use	0.47	0.23-0.98	0.04

BMI = body mass index, CI = confidence interval, OR = odds ratio, TXA = tranexamic acid
[a]Versus polyethylene liner exchange.
[b]Per 1-g/dL decrease.
[c]Per 1-kg/m^2 increase.

differences in the risk of ABT in dual-component versus single-component revisions after adjustment for potential confounders. Unadjusted analysis showed a substantial difference in rates of ABT between single-component and dual-component revisions, but after accounting for perioperative factors, this difference disappeared. Burnett et al[8] used Current Procedural Terminology codes to define revision complexity but noted that their database did not differentiate between single-component and polyethylene liner exchange, suggesting that combining these two categories would have contributed to the substantial difference in transfusion rates between single-component and dual-component procedures. We used medical records and surgical notes to confirm procedure complexity, which we think offers a more accurate assessment of the relationship between procedure complexity and ABT rates.

In a study of 626 aseptic or septic hip revisions, George et al[9] reported that when procedure complexity was accounted for, infection was not an independent predictor of transfusion. The authors stratified complexity in the same way we did in the current study. They suggested that the higher transfusion rate was attributable to the greater complexity of infected cases rather than to infection itself. By contrast, we found infection to be a strong predictor of ABT, even after controlling for procedure complexity. Although the transfusion threshold reported by George et al[9] is similar to ours, TXA was not used as commonly during the period of their study (2009 to 2013), and its use may have contributed to the difference in our findings. Consistent with the findings of Samujh et al,[20] we found lower odds of ABT with TXA use. Hines et al[18] reported that TXA use in revision TJA was associated with a >50% reduction in the ABT rate.

Our study has several limitations. First, it was an observational study using a nonconcurrent cohort design. Second, despite the blood management protocols at our institution, the decision to administer an ABT intraoperatively is subject to the clinical judgment of the anesthesiologist, introducing variation based on the provider. Third, this was a single-institution study, and our blood transfusion protocol may differ from those of other institutions. However, we think that our policy is reflective of the increasingly restrictive transfusion practices in orthopaedic practices across the country.[12,13] Finally, our small sample size resulted in wide CIs for the odds of ABT for single- and dual-component revisions compared with polyethylene liner exchanges.

We present several factors associated with higher or lower odds of ABT in patients undergoing lower extremity revision TJA. Preoperative hemoglobin level, procedure complexity, lack of TXA use, and infection as indication for revision independently predicted perioperative ABT. Our study's strengths include the assessment of a wide variety of perioperative factors and the assessment of both intraoperative and postoperative ABT. By using medical records and surgical notes for data collection, we offer a more accurate assessment of procedure complexity than allowed by administrative data. In addition, the shift to more restrictive transfusion policies contributes to the generalizability of our results. We think that our findings can help revision TJA providers counsel patients on how to optimize their health preoperatively and minimize their need for ABT. Preoperative anemia may be treated with hematopoietic agents or iron supplementation.[26,28] For patients who undergo long procedures, receive intraoperative ABT, or experience major decreases in hemoglobin levels after surgery, postoperative intravenous iron administration may be considered.[29] Our results also suggest that TXA should be used when possible.

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