Effect of Body Mass Index on Blood Transfusion in Total Hip and Knee Arthroplasty

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abstract

Perioperative blood management remains a challenge during total hip arthroplasty (THA) and total knee arthroplasty (TKA). The purpose of this study was to systematically examine the relationship between body mass index (BMI) and perioperative blood transfusion during THA and TKA while attempting to resolve conflicting results in previously published studies. The authors retrospectively evaluated 2399 patients, 896 of whom underwent THA and 1503 of whom underwent TKA. Various outcome variables were assessed for their relationship to BMI, which was stratified using the World Health Organization classification scheme (normal, <25 kg/m^2; overweight, 25-30 kg/m^2; obese, >30 kg/m^2). Among patients undergoing THA, transfusion rates were 34.8%, 27.6%, and 21.9% for normal, overweight, and obese patients, respectively (P=.002). Among patients undergoing TKA, transfusion rates were 17.3%, 11.4%, and 8.3% for normal, overweight, and obese patients, respectively (P=.002). Patients with an elevated BMI have decreased rates of blood transfusion following both THA and TKA. This same cohort also loses a significantly decreased percentage of estimated blood volume. No trends were identified for a relationship between BMI and deep venous thrombosis, pulmonary embolism, myocardial infarction, discharge location, length of stay, 30-day readmission rate, and preoperative hemoglobin level. Elevated BMI was significantly associated with increased estimated blood loss in patients undergoing THA and those undergoing TKA. There was a statistically significant trend toward increased deep surgical-site infection in patients undergoing THA (P=.043). Patients with increased BMI have lower rates of blood transfusion and lose a significantly smaller percentage of estimated blood volume following THA and TKA. [*Orthopedics.* 2016; 39(5):e844-e849.]

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are associated with substantial blood loss, ranging from 300 to 2400 mL per operation.[1-5] Due to this significant blood loss, the risk of requiring perioperative transfusions during TKA and THA is high, ranging from 3% to 67% and 4% to 68%, respectively.[6-10] Blood transfusions are associated with risk of infectious disease transmission, transfusion-related immune reactions, potential for bacterial-induced sepsis, and other minor injection-related effects such as fever or urticaria.[6] Furthermore, transfusions have been associated with increased morbidity and increased hospital resource use, particularly associated with increased hospital

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stays, increased intensive care unit (ICU) admissions, and increased risk of surgical-site infections.[2,5,11] Minimization of these risks begins with identifying factors that place patients at a higher likelihood of blood transfusion during the postoperative period. Previous work by Frisch et al[12] identified a number of criteria that are associated with increased risk of blood transfusion following THA and TKA. One factor that was found to be protective of transfusion risk was increased body mass index (BMI).

Perioperative blood management strategies have become an integral component of total joint replacement surgery. Despite advances in blood transfusion protocols, 20% of transfusions are associated with some type of adverse effect.[13] In an attempt to decrease these risks, various blood management techniques have been developed, such as autologous blood pre-donation, red cell salvage, preoperative hemodilution, anesthetic hypotension, human recombinant erythropoietin treatment, tranexamic acid use, and intra- and postoperative blood recovery.[6,14-16] However, each of these techniques is associated with its own unique challenges. For example, autologous transfusion is more costly than allogeneic transfusion in terms of screening, cross-matching, and storage on a per-unit basis. In addition, 38% to 44% of autologous donated blood is not used and is ultimately wasted.[7] Furthermore, autologous pre-donation is associated with an increased risk of requiring a transfusion perioperatively.[1,5] Given the number of challenges associated with the aforementioned strategies, recent studies have focused on identifying predictors of transfusion to enhance perioperative optimization and decrease overall rates of blood transfusions.

It has been estimated that more than 502 million people are classified as obese (BMI ≥30 kg/m^2) worldwide.[17] Obese patients are at much greater risk of developing osteoarthritis of the knee and hip.[18] Therefore, the number of obese patients requiring THA and TKA is likely to increase.[18-20] As such, there has been an increasing body of literature studying the effect of BMI on total joint replacement surgery.

Although many studies have examined the use of preoperative hemoglobin values to predict the need for a blood transfusion in THA and TKA, studies using BMI in a similar fashion are less common.[7,17,21,22] The data that are currently available regarding the relationship between BMI and perioperative transfusion are conflicting and often of insignificant power. Several studies have noted a correlation between increased BMI, increased perioperative blood loss, and decreased risk of requiring a blood transfusion following THA and TKA.[1,6,7,15,23-26] However, other studies have reported no statistically significant relationship between BMI, blood loss, and transfusion risk.[3-5,13,14,16,22,27,28]

The goal of the current study was to systematically examine the relationship between BMI, perioperative blood transfusion, and complication rates following TKA and THA in hopes of clarifying conflicting data in the literature. The authors aimed to answer 3 primary questions: (1) whether BMI can be used to effectively predict perioperative blood loss and the risk of transfusion in THA and TKA, (2) whether this effect is limited to a distinct set of BMI values as defined by the World Health Organization (WHO) classification scheme, and (3) whether elevated BMI is associated with selected perioperative complications. The authors hypothesized that there would be a protective effect of increasing BMI on the requirement of perioperative transfusion and that increased BMI would be associated with an increased rate of complications.

Materials and Methods

After institutional review board approval, a retrospective chart review of clinical records from 2399 patients who underwent THA or TKA at the authors' institutions between January 1, 2011, and November 1, 2013, was performed. Data were collected from 6 fellowship-trained surgeons (C.D.S.) at 2 academically affiliated hospitals. All THAs were performed using a standard posterior (Southern) approach, and all TKAs were performed using the medial parapatellar approach. Five independent reviewers (N.F., N.M.W., B.C., A.G.) collected all data and performed extensive chart reviews. After excluding patients who underwent a bilateral procedure, partial arthroplasty, or revision surgery, a total of 2399 patients were ultimately included in the statistical analysis, 1503 (62.7%) of whom underwent TKA and 896 (37.3%) of whom underwent THA.

Primary outcome variables included blood transfusion, number of units transfused, deep venous thrombosis (DVT), pulmonary embolism (PE), myocardial infarction (MI) and deep surgical-site infection (DSSI). Secondary outcome variables included superficial surgical-site infection (SSSI), estimated blood loss (EBL), and percentage of estimated blood volume (EBV) lost.

Estimated blood volume lost was calculated using the equation *EBV=weight (kg) × 'Z' mL/kg*, where Z=65 mL/kg for females and 75 mL/kg for males.[29] Superficial and deep surgical-site infections were evaluated and categorized according to the guidelines published by the Healthcare Infection Control Practices Advisory Committee of the Centers for Disease Control and Prevention.[30] Nonsurgical-site infections (NSSI) included occurrences such as perioperative urinary tract infections and pneumonia.

Body mass index was categorized into 3 standardized groups consistent with the current World Health Organization (WHO) classification system: normal (<25 kg/m^2), overweight (25-29.9 kg/m^2), and obese (>30 kg/m^2). Among the 2399 patients, only 12 were considered underweight (BMI <18.5 kg/m^2); for purposes of statistical analysis, these individuals were included in the normal weight group.

All patients were started on enoxaparin or rivaroxaban on postoperative day 1,

Table 1

Transfusion Rate in THA and TKA as It Relates to BMI

	Transfusion Rate (No./Total No.)				
Procedure	**Normal BMI**	**Overweight BMI**	**Obese BMI**	***P***	**Trend *P***
THA	34.8% (62/178)	27.6% (87/315)	21.9% (95/433)	.002	.001
TKA	17.3% (24/139)	11.4% (46/403)	8.3% (77/931)	.002	.001

Abbreviations: BMI, body mass index; THA, total hip arthroplasty; TKA, total knee arthroplasty.

Table 2

Percent of Estimated Blood Volume Lost in THA and TKA as It Relates to BMI

	Estimated Blood Volume Loss				
Procedure	**Normal BMI**	**Overweight BMI**	**Obese BMI**	***P***	**Trend *P***
THA	6.12%±8.12%	4.92%±3.05%	4.50%±3.25%	.001	.001
TKA	2.05%±4.00%	1.55%±2.73%	1.26%±1.01%	.001	.001

Abbreviations: BMI, body mass index; THA, total hip arthroplasty; TKA, total knee arthroplasty.

Table 3

Percent of Estimated Blood Volume Lost in THA and TKA Among Patients Who Did and Did Not Receive Blood Transfusions

	Estimated Blood Volume Lost		
Procedure	**Transfusion**	**No Transfusion**	***P***
THA	7.12%±7.50%	4.19%±2.49%	.001
TKA	2.08%±2.41%	1.34%±1.99%	.001

Abbreviations: THA, total hip arthroplasty; TKA, total knee arthroplasty.

and lower extremity sequential compression devices were used in the immediate postoperative period for venous thromboembolism prophylaxis.[31] A standardized postoperative total joint replacement protocol was instituted for all patients on postoperative day 1. At the authors' institutions, patients are routinely transfused at a hemoglobin level of less than 8 g/dL with the presence of symptoms and less than 7 g/dL without symptoms.

Chi-square tests were used to assess nominal data, and the Cochran-Armitage test was used to evaluate for trends in outcome variables as they relate to categories of BMI. Continuous variables were analyzed using the Kruskal-Wallis test. Trends among continuous variables were examined using the nonparametric Jonckheere-Terpstra test. A priori criteria for statistical significance (type I error) was set at alpha=0.05.

Results

Among THA patients, transfusion rates were 34.8%, 27.6%, and 21.9% for normal, overweight, and obese patients, respectively (*P*=.002). Among TKA patients, transfusion rates were 17.3%, 11.4%, and 8.3% for normal, overweight, and obese patients, respectively (*P*=.002) (**Table 1**). The trend toward a reduced rate of transfusion in patients with elevated BMI was significant (*P*=.001). Estimated blood loss increased significantly with elevated BMI in both the THA and TKA groups (*P*=.001). Average EBL was 268.2±313.9 mL, 282.0±208.7 mL, and 330.5±302.4 mL among normal, overweight, and obese patients, respectively, undergoing THA (*P*=.001) and 85.7±153.8 mL, 90.5±164.6 mL, and 89.4±72.4 mL among normal, overweight, and obese patients, respectively, undergoing TKA (*P*=.001).

Patients with increased BMI lost a significantly lower percentage of EBV in both THA and TKA. Among patients undergoing THA, average percentage of EBV lost was 6.12%±8.12%, 4.92%±3.05%, and 4.50%±3.25% in the normal, overweight, and obese populations, respectively (*P*=.001). Patients undergoing TKA lost an average 2.05%±4.00%, 1.55%±2.73%, and 1.26%±1.01% of their EBV in the normal, overweight, and obese populations, respectively (*P*=.001) (**Table 2**). **Table 3** shows a significantly greater loss of EBV in patients who required blood transfusion in both the THA and TKA groups. Transfused patients undergoing THA lost an average 7.12%±7.50% of EBV, whereas those who did not receive a blood transfusion lost an average 4.19%±2.49% (*P*=.001). Similarly, transfused patients undergoing TKA lost an average 2.08%±2.41% of EBV, whereas nontransfused patients lost an average 1.34%±1.99% (*P*=.001).

In normal, overweight, and obese patients, the rate of DVT was 0.6%, 0.3%, and 0.9% in patients undergoing THA (*P*=.587) and 1.4%, 3.0%, and 1.6% in patients undergoing TKA (*P*=.229), respectively. In normal, overweight, and obese patients, PE occurred at a rate of 1.7%, 0.6%, and 0.5% in patients undergoing THA (*P*=.271) and 2.2%, 0.5%, and 1.0% in patients undergoing TKA (*P*=.219), respectively. In normal, overweight and obese patients, the rate of MI was 1.7%, 1.0%, and 1.2% in patients undergoing THA (*P*=.768) and 1.4%, 0.5%, and 1.0% in patients undergoing TKA (*P*=.534), respectively. These results are summarized in **Table 4**.

There were 0 DSSIs among normal BMI patients and rates of 0.3% and 1.4% among overweight and obese patient populations undergoing THA, respectively (*P*=.108; trend *P*=.043). In patients undergoing TKA, DSSI occurred at rates of 0%, 0%, and 0.4% in normal, overweight and obese patients, respectively (*P*=.311; trend *P*=.165) (**Table 4**).

No trends were identified for a relationship between BMI and DVT, PE, MI, SSSI, discharge location, length of stay, 30-day readmission rate, and preoperative hemoglobin level. Elevated BMI was significantly associated with decreased age, increased hemoglobin A1c, increased baseline creatinine, increased operating room time, increased American Society of Anesthesiologists scores, and increased EBL. Average age in each group decreased as BMI increased: in normal, overweight, and obese patients, average age was 69.0±12.9 years, 66.4±11.9 years, and 62.2±11.0 years in the THA group, respectively (*P*=.001), and 71.0±11.3 years, 70.0±9.2 years, and 65.1±9.1 years in the TKA group, respectively (*P*=.001). Total operative time increased as BMI increased (THA group, *P*=.049; TKA group, *P*=.001).

Table 4

Complication Rates Among Patients With a Normal, Overweight, and Obese BMI in THA and TKA

	Complication Rate (No./Total No.)				
Complication	**Normal BMI**	**Overweight BMI**	**Obese BMI**	***P***	**Trend *P***
DVT					
THA	0.6% (1/178)	0.3% (1/315)	0.9% (4/433)	.587	.470
TKA	1.4% (2/139)	3.0% (12/403)	1.6% (15/931)	.229	.462
MI					
THA	1.7% (3/178)	1.0% (3/315)	1.2% (5/433)	.768	.683
TKA	1.4% (2/139)	0.5% (2/403)	1.0% (9/931)	.533	.999
PE					
THA	1.7% (3/178)	0.6% (2/315)	0.5% (2/433)	.271	.146
TKA	2.2% (3/139)	0.5% (2/403)	1.0% (9/931)	.219	.535
SSSI					
THA	0.6% (1/178)	0.6% (2/315)	0.7% (3/433)	.983	.852
TKA	1.4% (2/139)	0.5% (1/315)	0.5% (5/931)	.419	.352
DSSI					
THA	0.0% (0/178)	0.3% (1/315)	1.4% (6/433)	.108	.043
TKA	0.0% (0/139)	0.0% (0/403)	0.4% (4/931)	.311	.162

Abbreviations: BMI, body mass index; DSSI, deep surgical-site infection; DVT, deep venous thrombosis; MI, myocardial infarction; PE, pulmonary embolism; SSSI, superficial surgical-site infection; THA, total hip arthroplasty; TKA, total knee arthroplasty.

Discussion

Although several studies report a correlation between increased BMI, increased perioperative blood loss, and decreased risk of blood transfusion requirements in THA and TKA,[1,6,7,15,23-26] other studies have reported no statistically significant relationship between BMI, blood loss, and transfusion risk.[3-5,13,14,16,22,27,28] Prasad et al[13] reported no relationship between total perioperative blood loss and BMI and no significant difference in postoperative hemoglobin drop. A number of studies support a positive correlation between BMI and transfusion risk but do not stratify patient groups using the BMI classification system set forth by the WHO and instead use a variety of stratification methods.[25,26,32,33] Therefore, an accurate correlation between BMI and blood transfusion following THA and TKA remains largely inconclusive to date.

The current study noted a significant decrease in transfusion rates following THA for normal, overweight, and obese patients. Transfusion rates among patients undergoing TKA also decreased significantly for the same BMI categories. In both THA and TKA, there was a statistically significant reduction in transfusion rates as BMI increased. Similar to the current study's results, Walsh et al[1] published data showing a 46% decrease in the risk for transfusion in a subset of patients with elevated BMI who underwent THA. Other studies have also found a correlation between higher rates of blood transfusion and lower body weight.[6,7,15]

In the current study's patient population, there was no identifiable relationship between BMI and DVT, PE, MI, discharge location, length of stay, 30-day readmission rate, and preoperative hemoglobin level. However, there was a statistically significant trend toward increased rates of DSSI with increased BMI in the THA group. Similar to these results, Dewan et al[34] reported a trend toward increased rates of complications and infections with increasing BMI, although this difference was not statistically significant. A large meta-analysis by Kerkhoffs et al[32] evaluated 14 studies encompassing more than 15,000 patients who underwent TKA; they found an increase in the occurrence of infection, both superficial and deep, among patients with a BMI of 30 kg/m^2 or greater.

Within the current study's patient population, elevated BMI was significantly associated with increased EBL. This could be explained by the use of a larger surgical exposure and longer operative time to allow for appropriate visualization, as well as the increased thickness of soft tissue from which additional bleeding can occur during initial dissection. The protective effect of BMI on the risk of transfusion may be related to the overall increase in EBV as BMI increases. Because obese patients have a higher EBV, they have a lower final percentage of EBV lost during a given procedure (**Table 3**). Although a patient with elevated BMI may lose more absolute blood by volume, this represents a relative reduction in the percentage of a patient's total blood volume compared with patient populations with a lower BMI. The authors found that the percentage of EBV lost is more predictive of risk for allogeneic blood transfusion than EBL.

During the study period, all subacute and acute rehabilitation facilities within the authors' geographic region required that patients have a hemoglobin level of 8 g/dL or greater prior to admission to their facility. Patients who failed to meet this requirement were transfused an additional unit of blood to elevate their hemoglobin level to above 8 g/dL. The authors are aware of the potential effect this could have by artificially elevating the number of transfusions. However, the study results showed no difference in discharge location across all BMI categories. This suggests that even in the event of transfusion to facilitate discharge to a rehabilitation center, additional transfusions were distributed uniformly among each BMI group.

There are several limitations to this study. The data are inherently limited by the retrospective nature of the study and the completeness of data collected from patient charts. Second, due to local requirements for discharge to subacute rehabilitation facilities, a subset of patients received blood transfusions to meet discharge criteria regardless of physiologic necessity. Data were not collected to allow for examination of this subset independently; thus, the overall rate of transfusion may be falsely increased. However, there was no correlation between discharge location and BMI, suggesting that those patients requiring transfusion for discharge were evenly distributed among all BMI classifications. In addition, there is new evidence to suggest that percent body fat may be a better indicator of obesity.[35] However, this is a difficult and time-consuming value to collect for the purposes of large study populations.

The strengths of this study include its relatively large sample size collected from both a large, urban hospital and a small, community-based hospital. The dual setting captures subtle differences in patient demographics, operative management, and postoperative health care personnel, making the results more generalizable throughout the orthopedic community. The use of data collected from 6 different fellowship-trained surgeons captures variation in surgical technique and approach. Having extracted data from 6 fellowship-trained surgeons is both a strength and a potential limitation. The strength of this factor stems from the ability to make general conclusions about the data that can be applied to a variable patient population, whereas minute differences in surgical techniques between surgeons may represent a potential confounding factor.

Conclusion

There was a significant decrease in the rate of perioperative blood transfusion following both TKA and THA in patients with increased BMI. This is due to the increase in blood volume in larger patients with a corresponding decrease in the actual percentage of EBV lost in patients with increased BMI. Thus, the presence of increased BMI can effectively predict a decreased risk of postoperative blood transfusion. This trend was consistent among obese, overweight, and normal BMI patients.

Despite prior evidence suggesting that increased BMI is associated with higher rates of postoperative complications, this study found no difference in the rates of DVT, PE, or MI after THA and TKA as they related to variability in BMI. However, there was a significant trend toward increased rates of DSSI with increased BMI in the THA population. Further work is needed to better identify patients at increased risk for perioperative blood transfusion. Prophylactic steps can be taken to help reduce the need for perioperative blood transfusions by minimizing associated risk factors.

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