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Medical Comorbidities and Functional Dependent Living Are Independent Risk Factors for Short-Term Complications Following Osteotomy Procedures about the Knee

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Abstract

Objective. To characterize rates and risk factors for adverse events following distal femoral osteotomy (DFO), high tibial osteotomy (HTO), and tibial tubercle osteotomy (TTO) procedures. *Design*. Patients undergoing DFO, HTO, or TTO procedures during 2005 to 2016 were identified in the American College of Surgeons National Surgical Quality Improvement Program. Rates of adverse events were characterized for each procedure. Demographic, comorbidity, and procedural factors were tested for association with occurrence of any adverse events. *Results*. A total of 1,083 patients were identified. Of these, 305 (28%) underwent DFO, 273 (25%) underwent HTO, and 505 (47%) underwent TTO. Mean ages for patients undergoing each procedure were the following: DFO, 51 $\pm$ 23 years; HTO, 40 $\pm$ 13 years; and TTO, 31 $\pm$ 11 years. The most common comorbidities for DFO were hypertension (34%) and smoking (17%); for HTO, hypertension (22%) and smoking (21%); and for TTO, smoking (20%) and hypertension (11%). Independent risk factors for occurrence of any adverse event were age $\geqslant$45 years for DFO (odds ratio [OR] = 3.1, $P < 0.001$) and HTO (OR = 2.3, $P = 0.029$), and body mass index $>$30 for HTO (OR = 2.5, 95% confidence interval = 1.1-5.7, $P = 0.031$). When all osteotomy procedures were analyzed collectively, additional variables including diabetes mellitus (OR = 2.2, $P = 0.017$), chronic obstructive pulmonary disease (OR = 5.5, $P = 0.003$), and dependent functional status (OR = 3.0, $P = 0.004$) were associated with adverse events. *Conclusions*. The total rate of adverse events was not independently associated with the type of osteotomy procedure. In addition, patients with age $>$45, diabetes mellitus, chronic obstructive pulmonary disease, and dependent functional status have greater odds for adverse events and should be counseled and monitored accordingly.

Keywords

osteotomy, procedures, high tibial osteotomy, distal femoral osteotomy, tibial tubercle osteotomy

Introduction

Knee osteotomy procedures are performed to redistribute forces about the knee joint in an attempt to mechanically offload diseased compartments, thus avoiding or delaying arthroplasty procedures.[1,2] Appropriate indications include young patients with unicompartmental osteoarthritis, as a concomitant procedure to joint restoration surgery and to address ligament instability, all of which have been shown to benefit from osteotomies about the knee.[2-6] Numerous osteotomy techniques have been described for treatment of specific pathology about the knee including distal femoral osteotomy (DFO) and high tibial osteotomy (HTO) to address coronal and sagittal malalignment, and tibial tubercle osteotomy (TTO) for patellofemoral maltracking, instability, arthritis, or chondral defects.[2,3,7] HTO is an option for treating patients with a tibial sided deformity,

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such as proximal tibia vara associated with isolated medial compartment arthritis.[5,8] Similarly, DFO has been reported as a technique for correcting femoral sided deformities, the most common being valgus malalignment with isolated lateral compartment arthritis.[6,9] Both HTO and DFO serve to unload the medial and lateral tibiofemoral compartments and frequently are performed in conjunction with articular cartilage or meniscal restoration procedures.[5,7-10] Furthermore, tibial based osteotomies may be used to adjust the tibial slope to address anterior cruciate ligament or posterior cruciate ligament deficiency, as well as address collateral ligament laxity by altering the coronal plane alignment. Many variations of TTO procedures have been described (e.g., anteriorization, anteromedialization, medialization); however, the premise of each technique is to offload a patellar facet that has sustained trauma or degenerative changes and improve patellar tracking.[7,8,11]

Early reports of osteotomies about the knee demonstrated high rates of complications in some reports surpassing 50%.[3,12,13] Historically, many reports of outcomes following these procedures reported significant rates of symptomatic hardware, cortical breaches, hardware failure, undercorrection, or overcorrection.[3,10,14-18] However, a better understanding of indications, advances in techniques, instrumentation, fixation, and rehabilitation protocols in recent decades have led to improving outcomes, faster recovery times, and shorter durations of immobilization in part to try lower the rates of complications. The literature to date has not distinctly separated short-term versus long-term complications after osteotomy procedures about the knee. Most reports comment on short-term complications including intraoperative fracture, neurovascular injury, hospital readmission, cardiopulmonary events, undercorrection/overcorrection, and infection.[3,7,19] Longer-term complications that have been frequently reported include hardware failures, delayed or nonunion, symptomatic hardware, late infection, and development of complex regional pain syndromes. As Vena *et al*.[3] noted in their 2013 article regarding complications of HTO and DFO, "complications can occur at any stage of treatment." Understanding short-term complications is important for surgeons to understand to guide patient selection and medical optimization both before and after surgery.

To date, there is a paucity of literature that has evaluated patient demographic and morbidity factors associated with adverse events following osteotomy procedures about the knee. The purpose of this study was to characterize rates and risk factors for short-term adverse events following DFO, HTO, and TTO procedures using a large national database. The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database is a national database that has previously been used to report on short-term outcomes regarding many orthopedic interventions.[20-22] The authors hypothesized that medical comorbidities including diabetes, smoking, and older age would be associated with higher rates of short term adverse events following an osteotomy about the knee.

Materials and Methods

This study was exempted from institutional review board approval due to the utilization of the deidentified patient data from ACS-NSQIP. This database has been well described and published previously.[22] In brief, ACS-NSQIP is a national database of civilian health care centers who voluntarily enter data into the program prospectively that are age >18 years and monitors them during the first 30 postoperative days for adverse events. The ACS-NSQIP compiles data from a growing network of 687 participating hospitals. Requirements in participation include staffing surgical clinical reviewers with medical backgrounds that collect data prospectively on over 270 variables from medical records, and random interrater reliability audits for quality assurance. ACS-NSQIP was queried by Current Procedural Terminal (CPT) code for all patients who underwent DFO (CPT 27450), HTO (CPT 27455), and TTO (CPT 27418) from 2005 to 2016.

Demographic data including age, sex, body mass index (BMI), medical comorbidities, and dependent functional status were obtained. In addition, incidence of adverse events were extracted, including mortality, wound dehiscence, sepsis, pulmonary embolism and deep vein thrombosis, myocardial infarction, urinary tract infection, anemia requiring a blood transfusion, pneumonia, surgical site infection, unplanned intubation, and readmission. These adverse events were deemed most relevant to osteotomy procedures by the authors and are part of a standard set of adverse event variables provided by ACS-NSQIP. Other adverse event variables include failed wean off of a ventilator, progressive renal insufficiency, stroke, coma, graft/prosthesis failure, sepsis, and septic shock. Demographic, comorbidity, and procedural factors were tested for association with occurrence of any adverse events, extended length of stay (LOS), and readmission. Extended length of stay was defined as greater than one standard deviation from mean length of stay.

Statistical Analysis

Stata 13.1 (College Station, TX) was utilized for statistical analysis. Analysis of variance with post hoc pairwise comparison was used to determine significant differences between age and BMI. Significant differences in gender, functional status, smoking status, and comorbidities between procedures was determined using a Fischer exact test in pairwise fashion. Multivariate logistical stepwise regression was performed to determine the influence of

Table 1. Demographics, Comorbidity Characteristics, and Concomitant Procedures for Patients Undergoing Osteotomy Procedures.

				P Values		
	DFO	HTO	TTO	DFO versus HTO	DFO versus TTO	HTO versus TTO
Patients, *n* (%)	305 (28)	273 (25)	505 (47)			
Age (years), mean ± SD	51 ± 23	40 ± 13	31 ± 11	<0.001	<0.001	<0.001
BMI (kg/m^2), mean ± SD	28 ± 10	30+7	30 ± 8	0.002	0.015	0.302
Female sex	60%	38%	67%	<0.001	0.082	<0.001
Dependent functional status	10%	1%	0%	<0.001	<0.001	0.192
Diabetes mellitus	10%	6%	2%	0.098	<0.001	0.003
Dyspnea on exertion	5%	1%	1%	0.003	<0.001	1
Hypertension	34%	22%	11%	0.001	<0.001	<0.001
COPD	4%	1%	0%	0.014	<0.001	0.283
Current smoker	17%	21%	20%	0.340	0.406	0.851
Operative time, mean ± SD	146 ± 72	149 ± 73	105 ± 54	0.550	<0.001	<0.001
Concomitant procedures						
Chondroplasty, *n* (%)	7 (2.3)	2 (7.7)	64 (12.7)	0.003	<0.001	0.040
Microfracture, *n* (%)	4 (1.3)	13 (4.8)	18 (3.6)	0.024	0.073	0.445
OCA, *n* (%)	5 (1.6)	12 (4.4)	8 (1.6)	0.081	1.000	0.030
ACI, *n* (%)	2 (0.7)	3 (1.1)	5 (1.0)	0.671	0.716	1.000
MPFL, *n* (%)	7 (2.3)	6 (2.2)	95 (18.8)	1.000	<0.001	<0.001
ACL, *n* (%)	2 (0.7)	8 (2.9)	3 (0.6)	0.052	1.000	0.020
Meniscectomy, *n* (%)	9 (3.0)	22 (8.1)	16 (3.2)	0.009	1.000	0.005
Meniscus repair, *n* (%)	3 (1.0)	12 (4.4)	4 (0.8)	0.016	1.000	0.002
MAT, *n* (%)	1 (0.3)	0 (0.0)	1 (0.2)	1.000	1.000	1.000

DFO = distal femoral osteotomy; HTO = high tibial osteotomy; TTO = tibial tubercle osteotomy; BMI = body mass index; COPD = chronic obstructive pulmonary disease; OCA = osteochondral allograft/autograft transplantation; ACI = autologous chondrocyte implantation; MPFL = medial patellofemoral ligament reconstruction; ACL = anterior cruciate ligament reconstruction; MAT = meniscal allograft transplantation.

demographics and comorbidities on adverse events, extended length of stay, and readmission. Significance was considered as $P < 0.05$.

Results

A total of 1,083 patients were identified. Of these, 305 (28%) underwent DFO, 273 (25%) underwent HTO, and 505 (47%) underwent TTO. Patients who underwent DFO were significantly older on average (51 ± 23 years) than patients who underwent HTO (40 ± 13 years) and TTO (30 ± 8 years). In addition, a significantly higher number of patients who underwent DFO (60%) or TTO (67%) were female compared with HTO (38%). The most common concomitant procedure for DFO (3%) and HTO (8.1%) was meniscectomy. Concomitant medial patellofemoral ligament reconstruction was commonly performed with TTO (18.8%) as was chondroplasty (12.7%). A complete profile of demographic and comorbidity characteristics for each osteotomy and comparative analysis are reported in **Table 1**.

Adverse Events

The total rate of adverse events was 10.9%. The rates of adverse events varied widely between the type of osteotomy with DFO having the highest rate at 22.3%, HTO having an adverse event incidence of 9.9%, and TTO the lowest incidence at 4.6%. Overall, the most common adverse events were anemia requiring transfusion ($N = 50$; 4.6%), readmission ($N = 33$; 3.1%), and surgical site infection ($N = 27$; 2.5%). For DFO, the most common adverse event was anemia requiring transfusion ($N = 43$; 14.1%). In patients who underwent a HTO, surgical site infection ($N = 14$; 5.1%) was the most common adverse event. Readmission ($N = 11$; 2.2%) was the most common adverse event in patients who underwent TTO. A complete analysis adverse events are reported in **Table 2**.

Risk Factors for Occurrence of Adverse Events in All Osteotomy Patients

Independent risk factors for occurrence of any adverse event were age ⩾45 years (odds ratio [OR] = 4.1, 95% confidence interval [CI] = 2.7-6.2, $P < 0.001$), diabetes mellitus (OR = 2.2, 95% CI = 1.1-4.2, $P = 0.017$), chronic obstructive pulmonary disease (OR = 5.5, 95% CI = 1.8-16.7, $P = 0.003$), and dependent functional status (OR = 3.0, 95% CI = 1.4-6.5, $P = 0.004$). A complete analysis of risk factors for adverse events for all osteotomy patients can be seen in **Table 3**.

Table 2. Incidence of Adverse Events for Patients Undergoing Osteotomy Procedures.

	DFO		HTO		TTO		Overall	
	n	Rate	*n*	Rate	*n*	Rate	*n*	Rate
Any adverse event	68	22.3%	27	9.9%	23	4.6%	118	10.9%
Mortality	2	0.7%	0	0.0%	0	0.0%	2	0.2%
Wound dehiscence	2	0.7%	3	1.1%	1	0.2%	6	0.6%
Sepsis	7	2.3%	0	0.0%	1	0.2%	8	0.7%
Pulmonary embolism	1	0.3%	0	0.0%	0	0.0%	1	0.1%
Myocardial infarction	1	0.3%	0	0.0%	0	0.0%	1	0.1%
Anemia requiring transfusion	43	14.1%	7	2.6%	0	0.0%	50	4.6%
Deep vein thrombosis	7	2.3%	4	1.5%	5	1.0%	16	1.5%
Urinary tract infection	12	3.9%	1	0.4%	1	0.2%	14	1.3%
Pneumonia	2	0.7%	0	0.0%	1	0.2%	3	0.3%
Unplanned intubation	0	0.0%	0	0.0%	1	0.2%	1	0.1%
Surgical site infection	7	2.3%	14	5.1%	6	1.2%	27	2.5%
Fracture	0	0%	0	0%	0	0%	0	0%
Readmission	12	4.0%	10	3.7%	11	2.2%	33	3.1%
Reoperation	11	3.6%	10	3.7%	7	1.4%	28	2.6%

DFO = distal femoral osteotomy; HTO = high tibial osteotomy; TTO = tibial tubercle osteotomy.

Table 3. Multivariate Analysis for Risk Factor Influence on Adverse Event, Extended Length of Stay, and Readmission Following DFO, HTO, and TTO.

	AAE		Extended LOS		Readmission	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age >45 years	**4.1 (2.7-6.2)**	**<0.001**	**4.1 (2.8-6.1)**	**<0.001**	**2.1 (1.0-4.2)**	**0.039**
Female sex	n.s.	0.652	**1.5 (1.0-2.2)**	**0.032**	n.s.	0.777
BMI >30	n.s.	0.331	n.s.	0.456	n.s.	0.254
Functionally dependent	**3.0 (1.4-6.5)**	**0.004**	**7.7 (3.6-16.5)**	**<0.001**	n.s.	n/a
Diabetes mellitus	**2.2 (1.1-4.2)**	**0.017**	**2.1 (1.1-3.9)**	**0.018**	n.s.	0.237
Dyspnea	n.s.	0.076	n.s.	0.486	n.s.	0.811
Hypertension	n.s.	0.615	**1.7 (1.1-2.7)**	**0.012**	n.s.	0.190
COPD	**5.5 (1.8-16.7)**	**0.003**	n.s.	0.445	n.s.	0.728
Smoker	n.s.	0.288	n.s.	0.388	n.s.	0.798

DFO = distal femoral osteotomy; HTO = high tibial osteotomy; TTO = tibial tubercle osteotomy; AAE = any adverse event; extended LOS = length of stay in hospital over 4 days; OR = odds ratio; CI = confidence interval; BMI = body mass index; COPD = chronic obstructive pulmonary disease; n.s. = nonsignificant and variable was dropped from multivariate regression model.
Bold values indicate statistical significance.

Subanalysis for Risk Factors Associated with Adverse Events Based on Specific Type of Osteotomy

One-way ANOVA with post hoc analysis revealed that patients who underwent DFO had significantly more adverse events when compared with HTO ($P < 0.001$) and TTO ($P < 0.001$). However, no significant difference existed between HTO and TTO. Subanalysis demonstrated that patients age >45 years have greater odds of an adverse event for DFO (OR = 3.1, 95% CI = 1.8-5.5, $P < 0.001$) and HTO (OR = 2.3, 95% CI = 1.1-4.7, $P = 0.029$). There were no patient variables found to increase the odds of an adverse event in patients who undergo TTO. Complete subanalysis can be found in **Table 4**.

Discussion

The significant findings from this study demonstrate complications rates of TTO and HTO that are consistent with recently published literature, but comparatively higher for DFO. Patients who undergo DFO have significantly greater odds of an adverse event as compared with HTO and TTO ($P < 0.001$ for each). Several patient specific variables including age >45 years had greater odds of having any adverse event in both DFO (OR = 3.1; $P < 0.001$) and HTO (OR = 2.3; $P = 0.029$).

Table 4. Multivariate Analysis for Risk Factor Influence on Adverse Event Following DFO, HTO, and TTO Analyzed Individually.

	DFO		HTO		TTO	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age >45 years	**3.1 (1.8-5.5)**	**<0.001**	**2.3 (1.1-4.7)**	**0.029**	n.s.	0.152
Dyspnea	**2.2 (1.4-3.4)**	**<0.001**	n.s.	0.678	n.s.	n/a
BMI >30	n.s.	0.833	**2.5 (1.1-5.7)**	**0.031**	n.s.	n/a
Functionally dependent	n.s.	0.074	n.s.	0.385	n.s.	n/a
Diabetes mellitus	n.s.	0.092	n.s.	0.780	n.s.	n/a
Hypertension	n.s.	0.571	n.s.	0.464	n.s.	0.813
COPD	n.s.	0.454	**11.9 (5.8-24.4)**	**<0.001**	n.s.	n/a
Smoker	n.s.	0.113	n.s.	0.388	n.s.	n/a
Gender	n.s.	0.384	n.s.	0.135		

DFO = distal femoral osteotomy; HTO = high tibial osteotomy; TTO = tibial tubercle osteotomy; OR = odds ratio; CI = confidence interval; BMI = body mass index; COPD = chronic obstructive pulmonary disease; n.s. = nonsignificant and variable was dropped from multivariate regression model. Bold values indicate statistical significance.

When all osteotomy patients were analyzed collectively, patients who were diabetics or had a dependent functional status preoperatively had significantly greater odds of having any adverse event (diabetes: OR = 2.2; $P = 0.017$; dependent functional status: OR = 3.0; $P = 0.004$) and an extended LOS (diabetes: OR = 2.1; $P = 0.018$; dependent functional status: OR = 7.7; $P < 0.001$). While not all short-term complications such as the need for a blood transfusion will have detrimental impact on long-term outcome of the osteotomy procedure, these events are important in guiding patient selection and can be used by surgeons to counsel and monitor patients who may be candidates for an osteotomy about the knee accordingly.

Many different techniques for performing osteotomies about the knee, particularly for HTO, have been described in recent years. A meta-analysis of randomized controlled trials and comparative studies between opening-wedge and closing-wedge HTO from 2017, which included 22 studies and 2,582 knees, demonstrated no significant difference in duration of hospitalization, visual analog pain (VAS) score postoperatively, and numerous patient reported outcome measures (PROs).[23] While adverse events were not a primary focus of this meta-analysis, these data suggest that when adequately powered, the differences in clinical outcomes including some adverse event measures such as LOS and VAS pain score are not significantly affected by technique.

The complication rate for DFO was the highest of the 3 types of osteotomy procedures analyzed about the knee (22.3%). A systematic review by Wylie *et al*.[6] that included 16 studies reporting on 372 DFOs demonstrated 34 complications (9.1%), which is less than half of the 22.3% adverse event rate in the present study. The most commonly reported complications were loss of correction ($N = 11$; 3.0%) and fracture ($N = 6$; 1.6%). The authors did not conduct subanalysis to identify patient-specific and operative variables associated with fracture. Much of this difference might be attributed to the inclusion of anemia requiring transfusion in this study ($N = 43$; 14.1%) that does not appear have been recorded and analyzed in the study by Wylie *et al*.[6] but is nevertheless an important event to consider given that blood transfusion has inherent risks to the recipient.

The incidence of surgical site infection was highest in patients who underwent HTO (5.1%). Anagnostakos *et al*.[24] summated the literature on infection after HTO and noted rates ranging from 1% to 9% for superficial infection and from 0.5% to 4.7% for deep infection. The results of the present study validate these findings using a large, population database. Smith and colleagues[25] conducted a meta-analysis of 12 studies to see what role, if any, the type of HTO had on infection rate. The authors noted no significant differences between closing and opening wedge HTO.[25] The overall adverse event rate for HTO in the present study was 9.9%, which is in stark contrast to the complication rate of 31% reported in a recent retrospective single center study of 115 patients who underwent opening wedge HTO from the United Kingdom. In this study, Woodacre *et al*.[19] noted a minor wound infection rate of 9.6% and a major wound infection rate of 3.5%, vastly higher than the present study. While patients in their study had similar BMIs to the present study (29 vs. 30 kg/m^2 in the present study) their cohort was on average 7 years older (47 years vs. 40 years). As the current study demonstrates, increasing age, specifically >45 years, has significantly greater odds of adverse events.

A recent study by Martin *et al*.[10] evaluated adverse events following medial opening wedge HTO in a large series of 323 consecutive patients with a mean follow-up of 39.5 months. The authors *a priori* classified adverse events into 1 of 3 categories based on if the events required no additional treatment (class 1), nonoperative treatment (class 2), or events that required additional or revision surgery

and/or long-term medical care (class 3). The authors reported nondisplaced lateral cortical breaches (20%) as the most common class 1 complication, delayed union (12%) and cellulitis (10%) as the most common class 2 complications, and aseptic nonunion (3%) and deep infection (2%) as the most common class 3 complications.[10] Their patient population is comparable to the present study with regard to male predominance, mean BMI, and mean patient age >40 years. While the current study was unable to stratify in a similar manner due to the short-term follow-up of the database utilized, our study demonstrated similar rates of readmission (4%) compared with 3.7% in this study as well as similar rates of additional surgery (2.7% vs. 3.7%). Further comparisons are challenging as the results from Martin *et al*.[10] were not confined to the immediate 30-day postoperative period but rather over several years.

Authors of a systematic review of over 1,000 knees that underwent TTO procedures from 21 studies reported a total of 79 complications (8%), which is nearly twice the rate reported in the present study (4.6%).[2] Patient age and BMI are unlikely to account for this difference as the mean age of the study by Saltzman *et al*.[2] was 27.68 years and mean BMI was 27kg/m^2, which is commensurate with the present study findings of mean age of 30 years and mean BMI of 30 kg/m^2. The most commonly reported complications from the systematic review were proximal tibia fractures (N = 19; 1.8%), recurrent patellar dislocations (N = 17; 1.9%), and 14 tibial tubercle fractures (N = 14; 1.3%) with no mention of readmission.[2] Their findings are in stark contrast to the current study that found no incidence of fracture about the knee intraoperative or in the 30-day period postoperatively. This difference may in part be accounted for by the relatively short postoperative time frame (30 days compared with 60 or 90 day) in which patients were followed for adverse events.

There was no analysis in their study regarding patient demographic and comorbidity variables that may influence the incidence of adverse events making it challenging to translate the findings of Saltzman *et al*.[2] into patient selection and counseling for those who may be candidates for a TTO. The present study adds valuable information in this regard as no variables were found to increase the odds of an adverse event. In a separate systematic review from 2015, Payne *et al*.[26] included 19 studies and 787 total procedures noting a complication rate of 4.6%, similar to the present study. In their study, the authors reported a risk of tibial fracture of 1.0%, wound complications of 0.8%, and risk of infection of 1.0%. While the specific technique of TTO is unable to be reported in the present, Payne *et al*.[26] noted that the risk of complications was higher when the tibial tubercle was completely detached (10.7%) providing insight into how technique might affect adverse events.

In a recent systematic review and meta-analysis, Hoorntje *et al*.[27] reported good clinical outcomes for osteotomies about the knee, specifically a return-to-work rate of 82% and return-to-sport rate of 80% in studies with a low risk of bias. Their study was isolated to patients who underwent either HTO or DFO but overall demonstrates the clinical utility and efficacy of these procedures in returning a significant portion of patients back to functional status. Others have corroborated these findings noting significant pain relief and functional improvement after HTO[28,29] and DFO[30] with 5-year survival rates between 87% and 99% for HTO[31-33] and between 74% and 90% for DFO.[9,34] Similarly, Saltzman *et al*.[2] reported significant improvements in VAS, Lysholm, and Kujala scores from preoperative values with the majority of patients reporting good (37.9%) or excellent (39.2%) results at minimum 2-year follow-up after TTO.

Strengths of this study include the utilization of a nationwide, large patient database that continues to increase in the number of surgeons and participating hospitals each year making these findings more likely to be generalizable to practices across the United States.[22] In addition to being a nationwide database, data in the ACS-NSQIP database undergoes continuous routine auditing that has demonstrated a high degree of reliability.[35]

There are several limitations of this study. First, while the data in the ACS-NSQIP database have been shown to be of high quality and reliable, information of adverse events is only recorded 30 days following the procedure, thus negating any longer-term quantification of adverse events. In addition, participation in ACS-NSQIP is voluntary and is a sample of patients per month, which may allow for geographic and sampling bias. Regarding transfusion protocols for postoperative anemia, there is no information provided through ACS-NSQIP detailing hospital protocol for transfusion. There is likely variation between medical centers but we are unable to comment further on indications. In addition, this database only includes patients at least 18 years of age; therefore, findings may not be generalizable to pediatric populations treated with HTO, DFO, or TTO. There are no PROs, pain scores, or satisfaction scores recorded as part of routine data collection, which may be useful in correlating the effects of adverse events on the subjective patient experience in the immediate postoperative setting. Although many authors have described varying techniques, fixation methods, rehabilitation protocols, and indications for DFO, HTO, and TTO, specific details regarding the diagnostic workup, operative indications, and surgical techniques are not recorded as part of this database, thereby restricting more detailed analysis regarding how these factors might influence adverse events. In this context, these findings should serve to stimulate future prospective investigation into short-term adverse events of osteotomy procedures about the knee with a focus on surgical technique and fixation.

Conclusion

The present study highlights a high rate of adverse events in the first 30 days following DFO but comparable rates of adverse events for TTO and HTO with previously published studies. The total rate of adverse events was not independently associated with the type of osteotomy procedure. In addition, patients with age >45, diabetes mellitus, chronic obstructive pulmonary disease, and dependent functional status have greater odds for adverse events and should be counseled and monitored accordingly.

Authors' Note

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

Ethical approval was not sought for the present study because of the utilization of the deidentified patient data from ACS-NSQIP.

Informed Consent

Informed consent was not sought for the present study because this study utilizes deidentified patient data from a large, nationwide database (ACS-NSQIP).

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