Original Research Article

Geriatric Orthopaedic Surgery & Rehabilitation
Volume 15: 1–8

DOI: 10.1177/21514593241260097
journals.sagepub.com/home/gos
Sage

Total Elbow Arthroplasty Versus Open Reduction and Internal Fixation for Distal Humerus Fractures: A Propensity Score Matched Analysis of 30-Day Postoperative Complications

Luke A. Sandoval, BA[1], Charles R. Reiter, BS[1], Phillip B. Wyatt, DPT[1], James R. Satalich, MD[1], Brady S. Ernst, MD[1], Conor N. O'Neill, MD[2], and Jennifer L. Vanderbeck, MD[1]

Abstract

Introduction: Open reduction and internal fixation (ORIF) is an established surgical procedure for distal humeral fractures; however, total elbow arthroplasty (TEA) has become an increasingly popular alternative for elderly patients with these injuries. Using a large sample of recent patient data, this study compares the rates of short-term complications between ORIF and TEA and evaluates complication risk factors. **Methods:** Patients who underwent primary TEA or ORIF from 2012 to 2021 were identified by Current Procedural Terminology codes in the American College of Surgeons National Surgical Quality Improvement Program database. Propensity score matching controlled for demographic and comorbid differences. The rates of 30-day postoperative complications were compared. **Results:** A total of 1539 patients were identified, with 1365 (88.7%) and 174 (11.3%) undergoing ORIF and TEA, respectively. Patients undergoing TEA were older on average (ORIF: 56.2 ± 19.8 years, TEA: 74.3 ± 11.0 years, $P < .001$). 348 patients were included in the matched analysis, with 174 patients in each group. TEA was associated with an increased risk for postoperative transfusion (OR = 6.808, 95% CI = 1.355 – 34.199, $P = .020$). There were no significant differences in any adverse event (AAE) between procedures ($P = .259$). A multivariate analysis indicated age was the only independent risk factor for the development of AAE across both groups (OR = 1.068, 95% CI = 1.011 – 1.128, $P = .018$). **Conclusion:** The risk of short-term complications within 30-days of ORIF or TEA procedures are similar when patient characteristics are controlled. TEA, however, was found to increase the risk of postoperative transfusions. Risks associated with increasing patient age should be considered prior to either procedure. These findings suggest that long-term functional outcomes can be prioritized in the management of distal humerus fractures.

Keywords

geriatric trauma, sports medicine, upper extremity surgery, total elbow arthroplasty, distal humerus fracture

Submitted 6 October 2023. Revised 25 March 2024. Accepted 15 May 2024

[1]Department of Orthopaedic Surgery, Virginia Commonwealth University Health System, Richmond, VA, USA
[2]Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

Corresponding Author:
Luke A. Sandoval, Department of Orthopaedic Surgery, Virginia Commonwealth University Health System, Richmond, 1200 E. Broad St, VA 23298-0153, USA.
Email: sandovalla@vcu.edu

Introduction

Total elbow arthroplasty (TEA) has risen in popularity as an alternative to the traditional open reduction and internal fixation (ORIF) surgery for distal humeral fractures in elderly patients.[1] The increased prevalence of TEAs in traumatic elbow injuries began in the early 2000s as survival and outcome rates improved significantly as compared to previous decades.[2-4] During this same time period, one study found that trauma had overtaken inflammatory arthritis as the most common indication for TEA.[5] Some studies have suggested that TEA produces better long-term functional outcomes than ORIF, especially in complex distal humeral fractures, which account for the vast majority of cases.[3,6,7] However, two systematic reviews have shown mixed data as to whether one is superior based on functional outcome scores and range of motion.[8,9]

There have been many studies analyzing survivorship and performance in elderly patients after undergoing TEA for both traumatic and atraumatic elbow conditions; the findings of these studies have consistently shown long-term outcomes similar to that of ORIF and high implant survival rates (81% at 10 years).[4,8-12] A previous analysis of 30-day postoperative complications from 2007 to 2013 utilized the National Surgical Quality Improvement Program (NSQIP) database to demonstrate that TEA and ORIF have similar short-term complication rates in patients over 65 years.[13] However, patients undergoing TEA were found to have significantly longer operative times and hospital length of stay (LOS). Additionally, insulin-dependent diabetes and functional status were significant risk factors for postoperative adverse events.

The purpose of this study was to leverage the NSQIP database to compare 30-day complications between TEA and ORIF for distal humerus fractures across a large, nationalized sample of contemporary patient data. In addition, this study sought to identify independent risk factors for short-term post-operative complications following both procedures.

Methods

This is a retrospective cohort study of prospectively collected data as part of the ACS NSQIP database. This registry contains demographics, comorbidities, and laboratory values with corresponding readmission and complication rates within 30 days of the indexed procedure. Patients are identified through Current Procedural Terminology (CPT) and International Classification of Diseases Ninth and 10th Revision codes.[14] NSQIP hospitals each employ trained nurse surgical clinical reviewers to oversee data collection adding an additional quality measure. All patients are monitored for 30 days postoperatively for any adverse events (AAEs), readmissions, and reoperations. No outcome differences exist between institutions participating in the NSQIP program with non-participants.[15] The ACS NSQIP database is comprised of a network of hospitals which are required to employ surgical clinical reviewers to collect 274 variables from surgical procedures. The database implements several quality assurance measures, such as biweekly random internal audits, which have reported <1.8% inter-rater disagreement.[16,17]

Adult patients who had undergone TEA or ORIF for a distal humerus fracture were identified. Inclusion criteria were age of 18 years or older, CPT for TEA (24 363) or ORIF (24 546, 24 579, 24 586), procedure diagnosis of distal humerus fracture (ICD-9812.4, ICD-10 S42.4), and procedure occurred from years 2012 through 2021. Patients less than 18 years of age or with a diagnosis other than distal humerus fracture (using the aforementioned ICD codes) and entries with incomplete or missing data were excluded from analysis. Limiting our study from 2012 to 2022 takes into account the most recent trends in distal humeral fractures available within the dataset while still gathering a large and representative sample size. Patient demographics, including age, smoking status, body mass index (BMI), sex, and American Society of Anesthesiologists (ASA) physical status classification score was collected along with complication data for each. Incomplete patient entries were removed from consideration. Patients in each group underwent a 1:1 propensity match for age, sex, BMI, ASA status, diabetes mellitus (DM), hypertension requiring medication, congestive heart failure, chronic obstructive pulmonary disease (COPD), smoking status, dialysis use, dependent functional status, ascites, bleeding disorders, prior transfusions, and steroid use. Dependent functional status was defined as requiring assistance with activities of daily living (ADLs). This propensity matching protocol was utilized to control for as many patient characteristics as possible within the confines of the NSQIP database.

For each patient, operative time, length of stay (LOS), unplanned readmission rate, and 30-day complications were collected. Complications that were recorded included the following: both superficial and deep surgical site infections (SSI), wound dehiscence, pneumonia, unplanned intubation, pulmonary embolism, postoperative renal insufficiency or failure, urinary tract infection, cerebrovascular accident, cardiac arrest, myocardial infarction (MI), transfusions, deep vein thrombosis (DVT), sepsis, and return to the operative room. Any adverse event (AAE) was defined as experiencing any of the above complications. LOS was defined as the number of days from

procedure to postoperative discharge. Extended LOS was defined as greater than the 75% quartile LOS (>3 d) for the entire sample.

Statistical Analysis

Propensity score matching, univariate, bivariate, and multivariable logistic regression analyses were performed using R-Studio software version 2023.06.0 + 421 (R Foundation for Statistical Computing, Vienna, Austria). Propensity score matching was conducted using the nearest neighbor method in order to reduce treatment assignment bias and simulate randomization between the ORIF and TEA cohorts. Patient demographics, comorbidities, and complications were compared between the two cohorts using the student's 2-tailed *t* test for continuous variables and chi-squared analysis for categorical variables. The variable(s) with a *P*-value of less than 0.2 from the bivariate comparisons were used in the multivariable logistic regression analysis.[18] This controlled for all baseline patient characteristics and medical comorbidities. Lastly, multivariable logistic regression with robust error variance identified independent risk factors for any adverse event after both procedures. Statistical significance was set a priori at $P < .05$ for all analyses.

Results

A total of 1539 patients were identified, with 1365 (88.7%) undergoing ORIF and 174 (11.3%) undergoing TEA (Table 1). Following propensity score matching, 348 patients were included in the matched sample, with each cohort consisting of 174 patients. The mean age for the ORIF and TEA groups after propensity matching were 74.9 ± 10.8 and 74.3 ± 11.0, respectively. The mean BMI for the groups were 29.6 ± 8.6 and 29.0 ± 6.4, respectively. In both groups, 10.9% (n = 19) of patients were male.

Prior to matching, there were statistically significant differences in age, sex, LOS, outpatient status, ASA status, morbidity probability, mortality probability, congestive heart failure, steroid, use, hypertension, bleeding disorder, diabetes, COPD (Table 1). After propensity score matching, only outpatient status and morbidity probability maintained statistical significance between groups; a higher percentage of ORIF operations were performed in the outpatient setting, whereas morbidity probability was higher in patients undergoing TEA.

The rate of 30-day postoperative adverse events of the combined propensity-matched group was 8.91% (Table 2). Prior to matching, there was a lower rate of postoperative adverse events in ORIF patients as compared to TEA patients. This was reversed after matching, as there was no significant difference in AAE. There was a significant difference in the rates of wound dehiscence (1.72% TEA vs .22% ORIF) and transfusions (6.32% TEA vs 1.68% ORIF) in the unmatched population. After matching, only postoperative blood transfusions differed between the cohorts: transfusions occurred in 1.15% of ORIF patients vs 6.32% of TEA patients ($P = .024$).

Across both groups, 105 (30.17%) patients had an extended LOS and 21 (6.03%) patients were readmitted to the hospital (Table 2). Prior to matching, the TEA group had a significantly higher rate of extended LOS (29.89% TEA vs 16.12% ORIF, $P < .001$); however, this no statistically significant difference was observed after matching.

A multivariate analysis that controlled for patient demographics and comorbidities revealed that patients undergoing TEA were significantly more likely to require a postoperative transfusion (odds ratio [OR]: 6.808, 95% confidence interval [CI]: 1.355-34.199, $P = .020$) compared to patients undergoing ORIF (Table 3). A multivariate analysis accounting for patient demographics, comorbidities, and procedure determined that patient age (OR: 1.068, 95% CI: 1.011-1.128, $P = .018$) was the only independent risk factor for any adverse event (Table 4).

Discussion

The objective of this study was to compare 30-day complications and adverse event risk factors between TEA and ORIF for distal humerus fractures across a large, nationalized patient database. Using the NSQIP database from 2012-2021, 1539 patients required surgery for distal humerus fractures, with 1365 (88.7%) ORIF cases and 174 (11.3%) TEA cases. Despite similar rates of any adverse event, postoperative transfusions, specifically, were more common among TEA patients vs matched ORIF patients ($P = .024$); a subsequent multivariate analysis established that TEA carried an increased risk of this complication compared to ORIF. When all other factors were controlled, age emerged as the sole independent risk factor contributing to the onset of any adverse event in both groups. Balancing the postoperative complications with best long-term outcomes in patients with distal humerus fractures is a critical factor in selecting the surgical approach in repairing these injuries in elderly patients.

A prior analysis of NSQIP >65 year old patients from 2007 to 2013 highlighted that TEA and ORIF yielded similar outcomes and short-term complication rates.[13] Lovy et al found no discernible differences in age, comorbidities, or functional status between the two groups;

Table 1. Demographic & Comorbidity Characteristics for patients Undergoing ORIF and TEA.

	ORIF	TEA		ORIF	TEA	
	Unmatched (%)	Unmatched (%)	*P*-Value	Matched (%)	Matched (%)	*P*-Value
Patients, N (%)	1365 (88.7)	174 (11.3)	NA	174 (50.0)	174 (50.0)	NA
Age (y)	56.2 ± 19.8	74.3 ± 11.0	<.001[a]	74.9 ± 10.8	74.3 ± 11.0	.644
BMI (kg/m2)	29.5 ± 7.6	29.0 ± 6.4	.289	29.6 ± 8.6	29.0 ± 6.4	.484
Male sex	412 (30.2)	19 (10.9)	<.001[a]	19 (10.9)	19 (10.9)	1
Operative time (mins)	157.2 ± 79.4	157.1 ± 61.8	.98	149.2 ± 72.3	157.1 ± 61.8	.278
Length of stay	2.02 ± 4.12	3.09 ± 2.96	<.001[a]	2.83 ± 3.03	3.09 ± 2.96	.421
Outpatient status	751 (55)	55 (31.6)	<.001[a]	76 (43.7)	55 (31.6)	.027[a]
ASA status	2.3 ± 0.8	2.7 ± 0.6	<.001[a]	2.7 ± 0.6	2.7 ± 0.6	.563
1 (no disturbance)	209 (15.3)	4 (2.3)	NA	6 (3.4)	4 (2.3)	NA
2 (mild disturbance)	616 (45.1)	58 (33.3)	NA	58 (33.3)	58 (33.3)	NA
3 (severe disturbance)	492 (36.0)	98 (56.3)	NA	99 (56.9)	98 (56.3)	NA
4 (life-threatening disturbance)	48 (3.5)	14 (8.0)	NA	11 (6.3)	14 (8)	NA
5 (moribund)	0 (0)	0 (0)	NA	0 (0)	0 (0)	NA
Race						
White	1007 (73.8)	146 (83.9)	NA	131 (75.3)	146 (83.9)	NA
Black	67 (4.9)	1 (.6)	NA	9 (5.2)	1 (.6)	NA
Asian	51 (3.7)	3 (1.7)	NA	7 (4.0)	3 (1.7)	NA
Other	240 (17.6)	24 (13.8)	NA	27 (15.5)	24 (13.8)	NA
Morbidity probability	.026 ± .021	.051 ± .032	<.001[a]	.037 ± .023	.051 ± .032	<.001[a]
Mortality probability	.003 ± .012	.007 ± .010	<.001[a]	.007 ± .010	.007 ± .010	.973
Dependent functional status (partial or total)	52 (3.8)	10 (5.7)	.308	9 (5.2)	10 (5.7)	1
Comorbidities, n (%)						
Current smoker	217 (15.9)	19 (10.9)	.109	15 (8.6)	19 (10.9)	.588
Congestive heart failure	6 (.4)	4 (2.3)	.018[a]	3 (1.7)	4 (2.3)	1
Dialysis	9 (.7)	0 (0)	.585	0 (0)	0 (0)	NA
Steroid use	45 (3.3)	14 (8.0)	.004[a]	13 (7.5)	14 (8.0)	1
Hypertension	527 (38.6)	121 (69.5)	<.001[a]	113 (64.9)	121 (69.5)	.424
Bleeding disorder	47 (3.4)	17 (9.8)	<.001[a]	17 (9.8)	17 (9.8)	1
Ascites	2 (.1)	0 (0)	1	0 (0)	0 (0)	NA
Pre-operative transfusion	9 (.7)	1 (.6)	1	0 (0)	1 (.6)	1
Diabetes	199 (14.6)	46 (26.4)	<.001[a]	38 (21.8)	46 (26.4)	.381
IDDM	79 (5.8)	19 (10.9)	NA	17 (9.8)	19 (10.9)	NA
NIDDM	120 (8.8)	27 (15.5)	NA	21 (12.1)	27 (15.5)	NA
COPD	45 (3.3)	12 (6.9)	.031[a]	10 (5.7)	12 (6.9)	.826

BMI: body mass index; ASA: American Society of Anesthesiologists; COPD: chronic obstructive pulmonary disease; Hypertension: hypertension requiring medication; IDDM: insulin-dependent diabetes mellitus; NIDDM: non-insulin-dependent diabetes mellitus; ORIF: open reduction internal fixation; TEA: total elbow arthoplasty.
[a]denotes statistical significance.

however, those undergoing TEA had significantly prolonged operative times and hospital lengths of stay (LOS). Moreover, the authors identified insulin-dependent diabetes and functional status as significant risk factors for postoperative adverse events. A similar study on TEA and ORIF short-term complications in >65 year old patients in the NSQIP database showed no significant difference in cohort age, comorbidities, risk factors, or postoperative complications.[19] Our study found that there were significant differences in patient demographics and comorbidities prior to propensity matching; however, this was likely due to the older average age of TEA patients. It is important to note that we did not exclude patients under 65 years, but as a result of the matching process we still identified an elderly cohort (ORIF: 74.9 ± 10 vs TEA: 74.3 ± 11.0). Notably, our study paralleled Lovy et al in finding that LOS was significantly longer in TEA patients; however, this difference was not significant after matching. In addition, we did not find a significant difference in operative time between groups. These differences may be due to developments in surgical techniques used in TEA over the past several decades.[2,6,20]

Table 2. Incidence of Adverse Events for patients Undergoing ORIF vs TEA.

	ORIF		TEA			ORIF		TEA			Total	
	Unmatched		Unmatched			Matched		Matched			Matched	
	N	Rate (%)	N	Rate (%)	*P*-Value	N	Rate (%)	N	Rate (%)	*P*-Value	N	Rate (%)
Any adverse event	57	4.18	19	10.92	<.001[a]	12	6.90	19	10.92	.259	31	8.91
Death	6	.44	1	.57	1.000	2	1.15	1	.57	1.000	3	.86
Wound dehiscence	3	.22	3	1.72	.019[a]	1	.57	3	1.72	.615	4	1.15
Sepsis	2	.15	0	.00	1.000	0	.00	0	.00	NA	0	.00
Pulmonary embolism	5	.37	0	.00	.926	3	1.72	0	.00	.246	3	.86
Renal complication	0	.00	0	.00	NA	0	.00	0	.00	NA	0	.00
Myocardial infarction	2	.15	1	.57	.769	0	.00	1	.57	1.000	1	.29
Cardiac arrest	0	.00	0	.00	NA	0	.00	0	.00	NA	0	.00
Stroke	1	.07	1	.57	.541	0	.00	1	.57	1.000	1	.29
Transfusion	23	1.68	11	6.32	<.001[a]	2	1.15	11	6.32	.024[a]	13	3.74
DVT	6	.44	1	.57	1.000	3	1.72	1	.57	.615	4	1.15
UTI	7	.51	2	1.15	.611	4	2.30	2	1.15	.680	6	1.72
Pneumonia	2	.15	1	.57	.769	1	.57	1	.57	1.000	2	.57
Intubation issues	2	.15	0	.00	1.000	1	.57	0	.00	1.000	1	.29
SSI	17	1.25	2	1.15	1.000	4	2.30	2	1.15	.680	6	1.72
Return to the OR	27	1.98	4	2.30	1.000	4	2.30	4	2.30	1.000	8	2.30
Extended LOS	220	16.12	52	29.89	<.001[a]	53	30.46	52	29.89	1.000	105	30.17
Readmission	45	3.30	11	6.32	.073	10	5.75	11	6.32	1.000	21	6.03

Any adverse event (AAE): superficial and deep surgical site infection, organ space infection, renal failure or insufficiency, intubation (fail to wean or reintubation), post-operative transfusion, pneumonia, DVT, PE, UTI, stroke, cardiac arrest, MI, return to the OR; DVT: deep vein thrombosis; UTI: urinary tract infection; SSI: surgical site infection; LOS: Length of stay (extended: >3 days); OR: operating room; Intubation issues: re-intubation or failure to wean from intubation; Renal complication: progressive renal insufficiency or renal failure.
[a]denotes statistical significance.

Table 3. Odds of Specific postoperative complication Development as Related to patient Demographics and Comorbidities When Comparing TEA to ORIF.

TEA to ORIF	OR	95% CI	*P*-Value
Postoperative transfusion	6.808	1.355 – 34.199	.020[a]

OR: Odds Ratio; 95% CI: 95% confidence interval.
[a]denotes statistical significance.

Our findings showed an overall AAE rate of 8.91%, with no significant difference between matched ORIF and TEA groups (6.90% vs 10.92%, $P = .259$). Lovy et al found similar adverse event rates with no significant difference between groups (8.4% vs 12.1%, $P = .51$) and no increased probability of serious adverse events following TEA.[13] Two recent systematic reviews further substantiated this apparent lack of significant difference in AAE between groups.[8,9] In the context of other common arthroplasties, the complication rates we reported for TEA are higher than that of total knee arthroplasty (5.07%), yet lower than that of total hip arthroplasty (35.4%).[21,22] In addition, the complication rates following TEA in our study are not unexpected when taken in context of current literature, where complication rates ranging between 14% and 80% have been reported following TEA.[23-25] It is important to note that the data presented in this study is an aggregate of 10 years' worth of surgeries, and therefore any temporal patterns were not reflected. Specifically, the surgical techniques and instrumentation used in TEA have evolved in recent years, which has likely contributed to a decline in complications and the rise in popularity of the procedure.[2,23,26]

Age was identified as an independent risk factor for AAE after both procedures. This explains the higher rate of AAE in the TEA group prior to matching, as the TEA patients were, on average, over 18 years older than ORIF patients. After propensity matching the ORIF cohort with the TEA cohort, average patient age was not statistically different and no significant difference in AAE was observed. Older patients are more frequently affected by distal humeral fractures, in addition to being at higher risk for more complex fractures and nonunion after fixation.[20,27,28] Several studies have concluded that these predispositions likely explain the superior or non-inferior functional score outcomes in elderly patients after TEA, as compared to ORIF.[6,8,9,29] In contrast, ORIF has remained the "gold-standard" approach for younger patients, where

Table 4. Odds of Developing any Adverse Event During Surgery as Related to patient Demographics, Comorbidities, and Procedure.

Risk Factor	OR	95% CI	*P*-value
TEA	1.675	.750 – 3.744	.208
Age	1.068	1.011 – 1.128	.018[a]
BMI	.951	.881 – 1.026	.193
Male sex	2.24	.743 – 6.749	.152
ASA	1.175	.565 – 2.445	.666
IDDM	2.292	.943 – 5.572	.067
Hypertension	.646	.265 – 1.577	.337
Congestive heart failure	0	0 – ∞	.994
COPD	3.347	.809 – 13.854	.096
Current Smoker	.677	.119 – 3.856	.660
Dependent functional status	.934	.184 – 4.749	.934
Bleeding disorder	.884	.238 – 3.281	.854
Pre-operative transfusion	4.17 E+08	0 – ∞	.998
Steroid use	0	0 – ∞	.989

OR: Odds Ratio; 95% CI: 95% Confidence Interval; TEA: total elbow arthoplasty; BMI: body mass index; ASA: American Society of Anesthesiologists; IDDM: insulin-dependent diabetes mellitus; COPD: chronic obstructive pulmonary disease; Hypertension: considered as hypertension requiring medication.
[a]denotes statistical significance.

there are stronger considerations for implant lifespan and loading limitations.[10,28]

Postoperative transfusion rates were significantly different between groups (ORIF: 1.15 vs TEA: 6.32, $P = .024$), and TEA was found to increase the risk of postoperative transfusion. Although Lovy et al did not report data on postoperative transfusions, Medvedev et al found that it did not differ significantly between groups.[13,19] It is unlikely that this is due to differences in duration of the procedures, as operative time was not significantly different between TEA and ORIF groups (ORIF: 149.2 ± 72.3 vs TEA: 157.1 ± 61.8, $P = .278$). Previous studies have found postoperative transfusion rates between 1.08% - 17.58% in TEA patients, with preoperative hemoglobin level and older age serving as risk factors for this adverse event.[30,31] Therefore, it is possible that differences in preoperative hemoglobin contributed to the disparate rates and likelihood of postoperative transfusion seen in our study.[30-32] It is unlikely, however, that age contributed to this disparity, as our analysis controlled for age. Ostensibly, frequency and duration of hemoglobin monitoring presents a possible confounding factor for transfusion risk. Patients with increased LOS or discharge to a rehabilitation center likely would have had a longer duration of lab monitoring and would thus be more likely to meet the indications for transfusions that patients without regular hemoglobin monitoring otherwise would not. We cannot directly account for these potential differences in the frequency of patient lab samples. Future studies on the impact of increased monitoring on transfusion rates would be beneficial to contextualize our findings.

This study has several limitations. The most salient limitation is the NSQIP database itself, which may be vulnerable to errors.[16,33,34] The database also does not report on subjective variables of a surgery, such as surgeon preferences or surgical center information, and does not report on specific orthopaedic variables, such as patient-reported outcomes, functional/performance outcomes, or radiographic data on the injuries.[15] Without the added context from these variables, it is difficult to stratify patients by fracture severity or draw comparisons on the complexity of the surgery. However, operative time can serve as a rough approximation for the surgical complexity, which was found to not differ significantly between groups. The use of the NSQIP database also limits our analysis to the 30-day postoperative follow-up data gathered from participating institutions; future studies with longer monitoring periods are necessary to better contextualize the implications of our findings. Additionally, the data in this study does not account for any potential longitudinal trends or changes in the complication rates. Lastly, non-significant findings should be interpreted with caution, as a power analysis was not performed for each complication and the samples sizes were dictated by the data that was available in the database. Given this, our findings are further limited to the effectiveness of our matching protocol, which, despite controlling for a wide array of patient factors, may still lead to disparities between paired subjects.

Conclusion

This study demonstrated that the risk of experiencing an adverse event within 30 days of TEA or ORIF for distal humerus fractures was broadly similar. Although the

overall adverse event rate was higher in TEA patients prior to matching, TEA tended to be performed in much older patients on average. Propensity score-matching and independent risk factor analyses suggested that age was likely the reason for this difference. However, TEA was still found to increase the risk of postoperative transfusions vs ORIF despite controlling for patient demographics and medical comorbidities. While the risk profiles for these procedures may continue to evolve, our findings suggest that surgical decision making for distal humerus fractures can prioritize longer-term functional outcomes, of which prior studies have suggested TEA to be superior in older patients.

Author Contributions

Luke A. Sandoval: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Charles R. Reiter:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – review & editing. **Philip B. Wyatt:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – review & editing. **James Satalich:** Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing. **Brady S. Ernst:** Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing. **Conor N. O'Neill:** Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing. **Jennifer L. Vanderbeck:** Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing.

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.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical Statement

Ethical Approval

This retrospective research study involved the analysis of anonymized and aggregated patient data obtained from a national database, and, as such, institutional review board (IRB) approval.

ORCID iD

Luke A. Sandoval https://orcid.org/0000-0002-6283-5578

References

1. Rajaee SS, Lin CA, Moon CN. Primary total elbow arthroplasty for distal humeral fractures in elderly patients: a nationwide analysis. *J Shoulder Elbow Surg*. 2016;25:1854-1860.
2. Prkić A, van Bergen CJ, The B, Eygendaal D. Total elbow arthroplasty is moving forward: review on past, present and future. *WJO*. 2016;7:44-49.
3. Athwal GS, Goetz TJ, Pollock JW, Faber KJ. Prosthetic replacement for distal humerus fractures. *Orthop Clin North Am*. 2008;39:201-212.
4. Kwak J-M, Koh K-H, Jeon I-H. Total elbow arthroplasty: clinical outcomes, complications, and revision surgery. *Clin Orthop Surg*. 2019;11:369-379.
5. Gay DM, Lyman S, Do H, Hotchkiss RN, Marx RG, Daluiski A. Indications and reoperation rates for total elbow arthroplasty: an analysis of trends in New York state. *J Bone Joint Surg Am*. 2012;94:110-117.
6. McKee MD, Veillette CJH, Hall JA, et al. A multicenter, prospective, randomized, controlled trial of open reduction—internal fixation versus total elbow arthroplasty for displaced intra-articular distal humeral fractures in elderly patients. *J Shoulder Elbow Surg*. 2009;18:3-12.
7. Jupiter JB, Mehne DK. Fractures of the distal humerus. *Orthopedics*. 1992;15:825-833.
8. Githens M, Yao J, Sox AHS, Bishop J. Open reduction and internal fixation versus total elbow arthroplasty for the treatment of geriatric distal humerus fractures: a systematic review and meta-analysis. *J Orthop Trauma*. 2014;28:481-488.
9. Seok H-G, Park J-J, Park S-G. Comparison of the complications, Reoperations, and clinical outcomes between open reduction and internal fixation and total elbow arthroplasty for distal humeral fractures in the elderly: a systematic review and Meta-analysis. *JCM*. 2022;11:5775.
10. Plaschke HC, Thillemann TM, Brorson S, Olsen BS. Implant survival after total elbow arthroplasty: a retrospective study of 324 procedures performed from 1980 to 2008. *J Shoulder Elbow Surg*. 2014;23:829-836.
11. Prasad N, Dent C. Outcome of total elbow replacement for distal humeral fractures in the elderly: a comparison of primary surgery and surgery after failed internal fixation or conservative treatment. *J Bone Joint Surg Br*. 2008;90:343-348.
12. Krukhaug Y, Hallan G, Dybvik E, Lie SA, Furnes ON. A survivorship study of 838 total elbow replacements: a report from the Norwegian Arthroplasty Register 1994-2016. *J Shoulder Elbow Surg*. 2018;27:260-269.
13. Lovy AJ, Keswani A, Koehler SM, Kim J, Hausman M. Short-term complications of distal humerus fractures in elderly patients: open reduction internal fixation versus total elbow arthroplasty. *Geriatr Orthop Surg Rehabil*. 2016;7:39-44.
14. Khuri SF. The NSQIP: a new frontier in surgery. *Surgery*. 2005;138:837-843.

15. Molina CS, Thakore RV, Blumer A, Obremskey WT, Sethi MK. Use of the national surgical quality Improvement program in orthopaedic surgery. *Clin Orthop Relat Res*. 2015;473:1574-1581.
16. Davis CL, Pierce JR, Henderson W, et al. Assessment of the reliability of data collected for the department of veterans affairs national surgical quality improvement program. *J Am Coll Surg*. 2007;204:550-560.
17. Trickey AW, Wright JM, Donovan J, et al. Interrater reliability of hospital readmission evaluations for surgical patients. *Am J Med Qual*. 2017;32:201-207.
18. Basques BA, Gardner EC, Varthi AG, et al. Risk factors for short-term adverse events and readmission after arthroscopic meniscectomy: does age matter? *Am J Sports Med*. 2015;43: 169-175.
19. Medvedev G, Wang C, Amdur R, Neviaser R, Neviaser A. Operative distal humerus fractures in older patients: Predictors for early complications based on a national database. *HSS Jrnl*. 2017;13:212-216.
20. Amir S, Jannis S, Daniel R. Distal humerus fractures: a review of current therapy concepts. *Curr Rev Musculoskelet Med*. 2016;9:199-206.
21. O'Neill CN, Gowd AK, Waterman BR, Kates SL, Patel NK. Significant reduction in short-term complications following Unicompartmental versus total knee arthroplasty: a propensity score matched analysis. *J Arthroplasty.* 2022;37:2014-2019.
22. Haynes MS, Ondeck NT, Ottesen TD, Malpani R, Rubin LE, Grauer JN. Perioperative outcomes of hemiarthroplasty versus total hip arthroplasty for geriatric hip fracture: the importance of studying matched populations. *J Arthroplasty.* 2020;35:3188-3194.
23. Little CP, Graham AJ, Carr AJ. Total elbow arthroplasty: a systematic review of the literature in the english language until the end of 2003. *J Bone Joint Surg Br.* 2005;87:437-444.
24. Voloshin I, Schippert DW, Kakar S, Kaye EK, Morrey BF. Complications of total elbow replacement: a systematic review. *J Shoulder Elbow Surg*. 2011;20:158-168.
25. Obert L, Ferrier M, Jacquot A, et al. Distal humerus fractures in patients over 65: complications. *Orthop Traumatol Surg Res*. 2013;99:909-913.
26. Dachs RP, Fleming MA, Chivers DA, et al. Total elbow arthroplasty: outcomes after triceps-detaching and triceps-sparing approaches. *J Shoulder Elbow Surg*. 2015;24:339-347.
27. Korner J, Lill H, Müller LP, Rommens PM, Schneider E, Linke B. The LCP-concept in the operative treatment of distal humerus fractures – biological, biomechanical and surgical aspects. *Injury.* 2003;34 Suppl 2:20-30.
28. Ellwein A, Lill H, Voigt C, Wirtz P, Jensen G, Katthagen JC. Arthroplasty compared to internal fixation by locking plate osteosynthesis in comminuted fractures of the distal humerus. *Int Orthop*. 2015;39:747-754.
29. Frankle MA, Herscovici D, DiPasquale TG, Vasey MB, Sanders RW. A comparison of open reduction and internal fixation and primary total elbow arthroplasty in the treatment of Intraarticular distal humerus fractures in Women older than age 65. *J Orthop Trauma*. 2003;17:473-480.
30. Duncan SFM, Sperling JW, Morrey BF. Incidence and risk factors for blood transfusion in total elbow arthroplasty. *J Shoulder Elbow Surg*. 2008;17:961-962.
31. Gordon AM, Ashraf AM, Sheth BK, Magruder ML, Conway CA, Choueka J. Anemia severity and the risks of postoperative complications and extended length of stay following primary total elbow arthroplasty. *Hand (New York, N,Y)*. 2023;18:1019-1026.
32. Gupta P, Quan T, Manzi JE, Zimmer ZR. Thirty-day morbidity and mortality following primary total elbow arthroplasty in octogenarians. *Shoulder Elbow.* 2022;14:562-567.
33. Basta M, Rao V, Paiva M, et al. Evaluating the inaccuracy of the NSQIP surgical risk calculator in predicting 30-day complications in plastic surgery. *Plastic and Reconstructive Surgery - Global Open*. 2021;9:89-90.
34. Rolston JD, Han SJ, Chang EF. Systemic inaccuracies in the National Surgical quality improvement program database: implications for accuracy and validity for neurosurgery outcomes research. *J Clin Neurosci*. 2017;37:44-47.