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Original Research

Sex Disparities Affecting Postoperative Outcomes After Total Elbow Arthroplasty

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Purpose: To investigate sex disparities in 30-day postoperative outcomes of total elbow arthroplasty.
Methods: The American College of Surgeons-National Surgical Quality Improvement Program files were queried for all patients who underwent a total elbow arthroplasty (TEA) between 2006 and 2020. Sex disparities in preoperative variables were studied using Fisher exact tests. Multivariate logistic regression models were used to determine the adjusted odds ratios (aOR) of postoperative outcomes for women in comparison with men.
Results: A total of 788 patients underwent a TEA in the period of 2006–2020. Of those, 180 were men, and 608 were women. We found an increase in TEAs performed each year with a predominance in females compared to males. Additionally, our work demonstrated increased statistically significant odds of a major adverse cardiac event ($P < .0001$), transfusions required ($P < .0001$), and return to the operating room ($P < .0001$) as postoperative outcomes in females compared to males following TEA. Finally, we found no statistically significant difference in mortality between the groups ($P = 1$).
Conclusions: Following a TEA, women had higher adjusted postoperative odds of experiencing a major adverse cardiac event, requiring transfusion, and return to the operating room. No significant differences were found in wound outcomes, pulmonary outcomes, venous thromboembolic outcomes, sepsis, and length of stay. Overall mortality rates were similar between the two groups. Our study warrants further evaluation of the root cause of sex disparities in TEA outcomes and methods to improve care delivery to reduce those disparities.
Type of study/level of evidence: Prognostic 2b.

The number of total elbow arthroplasty (TEA) procedures performed in the United States has been on the rise and is expected to continue to increase with the expanding availability of trained hand surgeons.[1] TEA is used for inflammatory arthropathies, post-traumatic osteoarthritis, some acute fractures, and osteoarthritis of the elbow.[1–4] Although the annual procedure numbers are relatively modest, complications range from 20% to 45%.[5] The increasing annual trend warrants an examination of risk factors, both modifiable and unmodifiable.

Several studies in the literature have described an increased prevalence of TEA in females, yet even less is known about the impact of sex on TEA outcomes.[1–3] Women undergoing TEA have been found to have lower mortality rates and length of stay; however, few studies exist further investigating perioperative morbidity and mortality differences.[6]

To date, no study exists that extensively evaluates sex disparities in TEA operative outcomes. Given the observed disparities in surgical outcomes outside of TEA, it is imperative to present a multifaceted evaluation of postoperative outcomes that disproportionately affect particular sexes to improve perioperative care and optimization. Our

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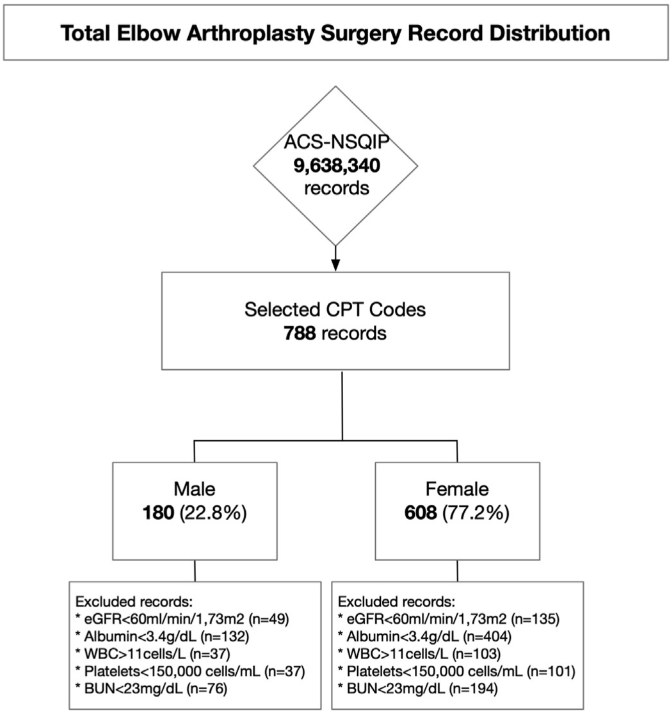

Figure 1. Selection of 788 records from the American College of Surgeons-National Surgical Quality Improvement Program public use files from 2006 to 2020 for the Current Procedural Terminology code 24363. The term "missing" refers to the number of instances where data records are absent for each preoperative variable within an individual sex.

Table 1
Preoperative Variables by Sex

Preoperative variable*	Sex		Fisher *P* Value‡
	F (n = 608)	M (n = 180)	
	Count (%)†	Count (%)†	
DM	103 (16.94)	25 (13.90)	.3588
Smoker	78 (12.83)	30 (16.67)	.2173
Dyspnea	32 (5.26)	10 (5.56)	.8517
Functional status	39 (6.41)	13 (7.22)	.3871
COPD	43 (7.07)	5 (2.78)	**.0332**
CHF	8 (1.32)	1 (0.56)	.6925
Hypertension	345 (56.74)	93 (51.67)	.2317
Kidney injury	0 (0)	0 (0)	0
Dialysis	2 (0.33)	0 (0)	1.00
Presepsis	5 (0.82)	0 (0)	.594
Disseminated cancer	7 (1.15)	1 (0.56)	.690
Wound infection	9 (1.48)	5 (2.78)	.3309
Steroid use	122 (20.07)	21 (11.67)	**.0111**
Weigh loss (>10%)	3 (0.49)	0 (0)	1.00
Bleeding disorder	25 (4.11)	7 (3.89)	1.00
BMI (>30 kg/m^2) (n = 778)	242 (39.80)	64 (35.56)	.3806
eGFR (<60 mL/min) (n = 604)	154 (32.56)	22 (16.79)	**<.001**
Albumin (<3.4 g/dL) (n = 252)	34 (16.67)	6 (12.50)	.5167
WBC (>11 cells/L) (n = 648)	49 (9.70)	15 (10.49)	.8742
Platelets (<150,000 cells/mL) (n = 650)	29 (5.72)	14 (9.79)	**.1259**
BUN (>23 mg/dL) (n = 518)	73 (17.68)	16 (15.38)	.6628
ASA Class (4/5) (n = 788)	32 (5.26)	6 (3.33)	.3290

ASA, American Society of Anesthesiologists; BMI, body mass index; BUN, blood urea nitrogen; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; WBC, white blood cell.

* Each of these variables was categorical, depending on whether the criteria specified was met (True) or not (False). The variables from DM through bleeding disorder had no missing values for the cohorts of women (608) and men (180) patients. For the percentages of patients meeting the cutoff criteria for the variables from BMI through ASA Class, we used the total count of values per sex that were present for that variable (as specified by each of the variables).

† Number of patients (% of total patients of each sex) are shown.

‡ Bolded *P* values indicate significant differences in preoperative variables among sexes in univariate analysis.

study investigates the disparities in 30-day postoperative TEA morbidity and mortality outcomes between females and males.

Materials and Methods

The American College of Surgeons-National Surgical Quality Improvement Program public use files from 2006 to 2020 were queried for Current Procedural Terminology code 24363 to identify all patients who underwent a TEA (Fig. 1). Additionally, the American College of Surgeons-National Surgical Quality Improvement Program database was deemed exempt from institutional review board approval by our institution.

Sex disparities in preoperative variables were first identified (Table 1). Sex was defined as male or female by the ACS-NCQIP and is collected from a retrospective chart review. Preoperative variables studied include but are not limited to age, body mass index, smoker status, diabetes mellitus, comorbid cardiopulmonary disorders, medication history, functional status, and preoperative laboratory values.

Sex disparities in postoperative outcomes were then studied (Table 2). Outcomes were grouped for wound, pulmonary, venous thromboembolism, major adverse cardiopulmonary (MACE), and renal events. Other outcomes of interest included 30-day mortality, extended length of stay (LOS) defined as greater than 3 days, sepsis, urinary tract infection, bleeding requiring transfusion, and return to operating room (ROR).

Statistical methods

Fisher exact test was used to examine univariable associations of sex with preoperative variables and outcomes. Multivariate logistic regression was then created to examine the association of sex with each postoperative outcome after adjusting for confounding preoperative variables. A Fisher $P < .20$ was required for stepwise selection of preoperative variables into our regression models. Female sex was compared to male sex for increased or decreased adjusted odds of postoperative events. A $P < .05$ for regression modeling was considered significant. Blank values were originally coded as −99, and they were converted to not available for R statistics, left blank for analysis using SAS, and ignored for multivariate logistic regression. In the logistic models, for each outcome, we adjusted the female odds ratio using the men as our reference group (Table 3).

Results

From 2006 through 2020, a total of 788 patients had an elbow arthroplasty (22.8% men, 77.2% women) (Table 1). There is an overall uptrend of TEAs, with an average annual procedure volume of 53. Most TEAs were completed in 2016 (n=94), followed by 2017 (n = 87) and 2014 (n = 86) (Fig. 2). In terms of distribution, females had between two and five times as many procedures completed in any given year.

Sex cohorts differed on a number of preoperative variables (Table 1). Significant differences among males and females were identified for cardiopulmonary obstructive disease ($P = .033$), steroid use ($P = .011$), chronic kidney disease ($P \leq .001$), and platelet count ($P = .13$), all of which were predominant in females. No statistically significant preoperative differences were found in the other variables we studied.

Table 2
Thirty-day Postoperative Outcomes by Sex

Postoperative variable	Sex		Fisher *P* Value†
	F (n = 608)	M (n = 180)	
	Count (%)*	Count (%)*	
Wound outcomes	9 (1.48)	3 (1.67)	.7356
SSI (n = 651)	0 (0)	0 (0)	
Deep wound (n = 651)	0 (0)	1 (0.15)	.2231
Organ space infection (n = 651)	1 (0.15)	0 (0)	1
Dehiscence (n = 788)	8 (1.01)	2 (0.25)	1
Pulmonary outcomes	3 (0.49)	2 (1.11)	.3089
Pneumonia (n = 788)	0 (0)	1 (0.13)	.2227
Prolonged intubation (n = 788)	0 (0)	0 (0)	
Reintubation (n = 788)	3 (0.38)	1 (0.13)	1
Venous thromboembolic outcome	2 (0.33)	6 (3.33)	**.0024**
Pulmonary embolism (n = 788)	2 (0.25)	3 (0.38)	.0817
DVT (n = 788)	0 (0)	3 (0.38)	**.0118**
Major adverse cardiac event	4 (0.49)	2 (1.67)	.6245
Cardiac arrest (n = 788)	2 (0.25)	0 (0)	1
Myocardial infarction (n = 788)	1 (0.13)	1 (0.13)	.4053
Stroke (n = 788)	1 (0.13)	1 (0.13)	.4053
Renal outcomes	0 (0)	0 (0)	
Acute kidney injury (n = 788)	0 (0)	0 (0)	
30-day in-hospital mortality (n = 788)	3 (0.38)	1 (0.13)	1
Sepsis (n = 651)	2 (0.31)	2 (0.31)	.226
UTI (n = 651)	4 (0.61)	0 (0)	.5791
Transfusion required (n = 788)	3 (0.38)	1 (0.13)	1
ROR (n = 651)	19 (2.92)	12 (1.84)	**.0466**
LOS ≥ 3 days (n = 788)	222 (28.2)	57 (7.23)	.2491

DVT, deep vein thrombosis; UTI, urinary tract infection.
* Number of patients (% of total patients of each sex) are shown.
† Bolded *P* values indicate significant differences in postoperative variables among sexes in univariate analysis.

Table 3
Adjusted OR for Postoperative Outcomes by Sex

Postoperative Variable*	Adjusted OR	Lower 95% CI	Upper 95% CI	*P* Value†
Wound outcomes	1.821	0.329	10.066	.9567
Pulmonary outcomes	3.135	0.268	36.601	.9497
Venous thromboembolic Outcome	0.703	0.133	3.725	.6789
Major adverse cardiac event	2.300	0.379	13.954	**<.0001**
Renal outcomes	0	0	0	
Sepsis	10.607	0.849	132.528	.9510
UTI	<0.001	<0.001	>999.999	.9596
Transfusion required	1.381	0.127	15.002	**<.0001**
ROR	2.384	0.992	5.728	**<.0001**
LOS ≥ 3 days	0.954	0.625	1.457	.1585
Still in-hospital	11.590	0.411	326.667	.9605

UTI, urinary tract infection.
* Missing values were ignored. Men were used as a reference group.
† Bolded *P* values indicate significant OR after adjusting for preoperative variables (significant in Table 1).

In the examination of 30-day postoperative outcomes through univariate analysis (Table 2), statistically significant sex disparities were found for venous thromboembolism ($P = .0024$), deep vein thrombosis ($P = .01$), and ROR ($P = .047$). No significant univariate differences were found in wound, pulmonary, MACE, renal events, 30-day in-hospital mortality, sepsis, urinary tract infections, transfusions, or extended LOS. Several variables did not have any patients that would have had a specific postoperative outcome, including surgical site infection, renal outcomes, and acute kidney injury.

After adjusting for preoperative characteristics with a univariate $P < .20$, females had higher adjusted odds than males of experiencing a MACE (adjusted odds ratio [aOR]: 2.30, 95% confidence interval [CI]: 0.38–13.95, $P < .0001$), requiring transfusion (aOR: 1.38, 95% CI: 0.13–15.00, $P < .0001$), and ROR (aOR: 2.38, 95% CI: 0.99–5.73, $P < .0001$) (Table 3). In the remaining eight examined postoperative variables, no statistically significant adjusted odds were observed between the two groups.

Discussion

Our study used the American College of Surgeons-National Surgical Quality Improvement Program database to examine sex disparities in TEA postoperative morbidity and mortality. With increased odds in several areas of outcomes for females compared to males, perioperative care must be directed to ensure a reduction in female complications. To our knowledge, only one study exists assessing immediate sex-based outcomes following TEA. Singh et al[7] demonstrated reduced female LOS ($P = .01$) and mortality ($P = .01$) relative to males.[7] Our study demonstrated no significant difference in mortality rates following TEA. Notably, Singh et al[7] used the Nationwide Inpatient Sample database to study patients from 1998 to 2011, whereas our population is from 2006 to 2020. Given limitations in the Nationwide Inpatient Sample database, logistic regression analysis of Singh et al[7] did not consider the many comorbidity variables we were able to control for. An extensive evaluation of postoperative TEA morbidity and mortality in current literature is absent, requiring further assessment.

We found a greater incidence of TEA among females than males. This finding is supported by the literature.[2,6,7] Over 18 years, Jenkins et al[6] found a 2.9:1 ratio of women to men patients undergoing TEA ($P < .001$). Similarly, University Health Systems Consortium databases were queried for TEA cases demonstrating 64% of those patients being women.[8] We hypothesize that the increased incidence of TEA among females may be attributed to the increased prevalence of inflammatory arthropathies and traumatic fractures secondary to longstanding osteoporosis in females. Gay et al[9] studied trends of TEA isolated to the New York State between 1997 and 2006, and over the 10-year interval, found a 132% increase in TEA utilization for trauma diagnoses.

We found females to have 1.38 higher adjusted odds of needing a transfusion in the 30-day period after a TEA ($P < .0001$). Conversely, Duncan et al[10] found no significant difference in immediate TEA postoperative rates of transfusion between sexes. Unlike our study, the study by Duncan et al[10] was limited to an analysis of a single institution's operative volume and did not control for preoperative bleeding disorder or other comorbidities. The female sex has been shown to increase the odds of transfusion following various general and orthopedic surgeries.[11–16] Transfusion requirements in women are predominant in orthopedics and remain prevalent following TEA.

Females had a 2.38 increased odds of ROR after a TEA ($P < .0001$). The NSQIP data sets do not report the exact indication for a ROR, which is a limitation of our study. ROR in the 30-day period is typically because of acute wound or neurovascular complications. We found only 12 total postoperative wound events, with no significant difference between males and females (Table 2). Females did have significantly higher adjusted odds of requiring a transfusion after surgery which may have warranted a ROR. Future investigations are warranted to identify the exact ROR etiology in females. Other immediate TEA perioperative complications warranting ROR include fracture, hematoma, and seroma.[17,18]

We found females to have a 2.30 increased odds of MACE after a TEA ($P < .0001$). MACE includes cardiac arrest, myocardial infarction, and stroke events. Singh et al[19] found female sex as an independent risk factor for cardiac events 90 days post-total knee and total hip arthroplasty. Numerous other studies have reported

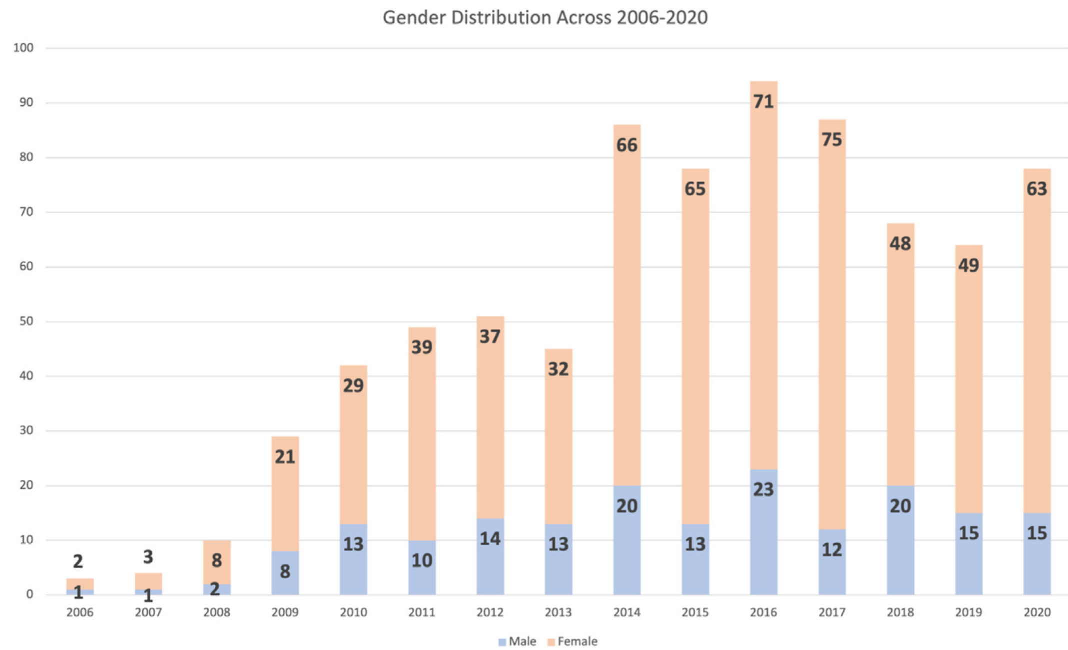

Figure 2. Data from 788 elbow arthroscopy patients over the 2006–2020 timeline separated into female and male sexes. The largest number of procedures was completed in 2016 (94), with 2017 (87) and 2014 (86) trailing very closely behind.

female sex as an independent risk for perioperative stroke in noncardiac and nonvascular surgeries.[20–22]

Our study is subject to limitations. Secondary to patient privacy regulations within the NSQIP database, patient data are limited to 30 days following surgical intervention, diminishing our ability to comprehensively evaluate postoperative issues that might arise after elbow arthroplasty.[23] This ensures patient safety and confidentiality but also reduces our understanding of the long-term complications of TEA. Additionally, the NSQIP and participating hospitals in the database are compliant with the Hospital Participation Agreement (HPA).[24] The HPA deidentifies geographical association of cases and does not allow for the identification of hospitals participating in the NSQIP database.[24] Data provided by the NSQIP data set limit a complete understanding of the rationale behind analogous odds of certain postoperative outcomes between sexes. We are also limited in the preoperative variables available in the data set. Potential confounders that our regression models do not account for include indications for TEA, operative duration, medical screening, and rehabilitation.

In summary, the number of patients undergoing TEA is increasing, as the scope of indications for the procedure extends beyond inflammatory arthropathies. Our work and existing studies in the literature reported an increased prevalence of completed procedures in females compared to males. With growing procedures each year, assessment of postoperative outcomes is warranted and crucial to understanding how sexes respond differently to the surgical intervention. Our work demonstrated increased adjusted TEA postoperative odds of MACE, transfusions, and ROR in females compared to males. Additionally, we found no statistically significant difference in mortality between the sexes. However, our study is limited secondary to patient protection guidelines enforced by HPA. Recognition of our outcomes among women is important for future studies and perioperative decision making.

Conflicts of Interest

No benefits in any form have been received or will be received related directly to this article.

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