Biological sex impacts perioperative complications after reverse shoulder arthroplasty for proximal humeral fracture

Chimere O. Ezuma, BS, Rashed L. Kosber, BA, David Kovacevic, MD*

Department of Orthopedic Surgery, Columbia University Medical Center, New York, NY, USA

Background: The purpose of this study was to determine the difference in complication rates between males and females undergoing reverse shoulder arthroplasty for proximal humerus fractures. We hypothesized that (1) females were more likely to undergo reverse shoulder arthroplasty for fracture, and (2) males were more likely to sustain a perioperative complication.

Methods: The National Surgical Quality Improvement Program database was queried to identify patients who underwent reverse shoulder arthroplasty for proximal humerus fracture between 2011 and 2018. Patients were stratified based on biological sex. Patient demographics, comorbidities, and 30-day perioperative complication rates were collected. Univariate analyses and multiple variable logistic regression modeling were performed.

Results: About 905 patients were included in the analysis—175 (19.3%) were male and 730 (80.7%) were female. Males were more likely to sustain perioperative complications (26.3% vs. 14.1%; $P < .001$)—pneumonia (2.9% vs. 0.5%; $P = .016$), unplanned intubation (2.3% vs. 0.4%; $P = .029$), and unplanned reoperation (9.1% vs. 1.1%; $P < .001$). On multivariate analysis, males were at a 2.4-fold increase risk of developing any complication (OR = 2.38 [95% CI 1.55-3.65]; $P < .001$) and a 10-fold increase risk of returning to the operating room for an unplanned reoperation (OR = 10.59 [95% CI 4.23-27.49]; $P < .001$) compared with females.

Conclusion: Females were more likely to undergo reverse shoulder arthroplasty for proximal humerus fracture, but males were at increased risk of sustaining short-term complications. This study provides useful information for clinicians to consider when counseling their patients during the perioperative period.

Proximal humerus fractures (PHFx) are debilitating musculoskeletal injuries that cause substantial pain, loss of function, impaired quality of life, and an inability to perform activities of daily living.[16,24,38] PHFx are the third most common fracture in the elderly after hip and distal radial fractures[4] and represent 10% of all fractures.[26] The incidence of these fractures is expected to increase in the United States, tracking with an aging population, and will lead to an increase in health care—associated costs. The management and treatment strategy require stratification based on a variety of clinical criteria including anatomical location of the fracture in accordance with either the AO or Neer classification systems, known associated risk factors such as frequent falls, female sex, age, and low bone density.[11,12,28]

Management of displaced, comminuted three- and four-part PHFx is focused on operative management, and there exists a variety of surgical options, each with associated benefits and risks.[21,33] Open reduction and internal fixation (ORIF) provides anatomic reconstruction with bone preservation and without concern for prosthetic glenoid wear or loosening. However, major complications include arthrofibrosis, fracture displacement, humeral head osteonecrosis (4% to 55%), and screw cutout (16% to 67%).[8,9,34,37,38] Although hemiarthroplasty (HA) avoids displacement and humeral head osteonecrosis, it can be complicated by tuberosity malunion/ nonunion and postoperative loss of function.[1,5,8,9,36] Recently, reverse total shoulder arthroplasty (RSA) has emerged as a preferred treatment of comminuted three- and

four-part proximal humeral fractures[18] because of the functional superiority of RSA compared with ORIF and HA.[8,9,32,40] However, there remains a paucity of literature analyzing complication rates by gender and age, which could impact patient counseling and education in the perioperative period given the increase in incidence of proximal humerus fractures in older adults.[25]

The present study used the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database to analyze data for all patients who underwent RSA for PHFx between 2011 and 2018 and stratify them based on biological sex. The purpose of this study was to examine the difference in complication rates between females and males undergoing RSA for PHFx. A retrospective, population-based analysis found the incidence of PHFx in females to be more than twice the incidence in men,[27] whereas the Nordic Arthroplasty Register Association, showed that male sex was an independent risk factor for revision after primary RSA for cuff tear arthropathy and osteoarthritis.[29] We hypothesized that (1) females were more likely to undergo RSA for fracture, and (2) males were more likely to sustain an initial perioperative complication after surgery.

Materials and methods

Database

Data were collected using the ACS-NSQIP database which was queried to identify all patients undergoing a reverse total shoulder arthroplasty between 2011 and 2018. This study used the ACS-NSQIP database because it is a nationally represented surgical database that prospectively collects a multitude of preoperative and postoperative patient variables as well as complication rates, readmission information, and unplanned surgeries within 30 days of the original procedure. There are over 700 participating private and academic hospitals across the United States that submit deidentified patient data in the form of 274 measurable variables for each surgical procedure.[35] The information is collected and examined by trained clinical reviewers and the cases are selected based on the Health Insurance and Portability Accountability Act with a documented interobserver disagreement rate of less than 1.8%.[14,23,35]

Patient selection criteria

Patients undergoing RSA were identified through ACS-NSQIP between 2011 and 2018 using the Current Procedural Terminology code (23472). Subsequently, patients with a diagnosis of a closed proximal humerus fracture were further identified using *International Classification of Diseases, Ninth Revision* and *International Classification of Diseases, Tenth Revision* codes (812.00, 812.01, 812.03, 812.09, 812.11, 812.20, 812.21, S42.201A, S42.202A, S42.202K, S42.202P, S42.242A, S42.252A, S42.291A, S42.292A).[30] If a patient had the CPT code and either one of these ICD-9/10 codes, they were deemed to have undergone an RSA. Patients were then stratified into two groups based on biological sex (male or female). Patient demographics, including race, anesthesia type, American Society of Anesthesiologists (ASA) classification score, diabetes mellitus status, smoking status, dyspnea status, preoperative functional status, age, body mass index (BMI), mean operation time, and mean postoperative length of stay were collected. Medical comorbidity data, including chronic obstructive pulmonary disease, congestive heart failure, hypertension, renal failure, requirement of dialysis, steroid use, > 10% weight loss in the last 6 months, preoperative blood transfusion and disseminated cancer were also collected and included in the analysis.

Thirty-day postoperative complications in the analysis included superficial surgical site infections, deep surgical site infections,

organ/space infections, wound dehiscence, pneumonia, unplanned intubations, pulmonary embolisms, failure to wean off ventilator for greater than 48 hours, renal insufficiency, urinary tract infections, cardiac arrest, myocardial infarctions, bleeding transfusions, deep vein thrombosis, and sepsis. Postoperative outcomes that were also measured were unplanned returns to the operating room and any stroke or cerebrovascular accident.

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS version 26; IBM, Armonk, NY, USA). Pearson's chi-squared test, Fisher exact test, and one-way analysis of variance were used to perform univariate analyses on demographic data, comorbidities, and postoperative complications. Multiple variable binomial logistic regression was used to calculate the adjusted odds ratios with 95% confidence intervals for postoperative complications between the two cohorts. The independent variables included in this model were the demographic characteristics and comorbidities that were shown to be statistically different between males and females (Table I and Table II). Statistical significance for all tests was achieved with a P value < .05.

Results

Patient demographics and comorbidities

About 905 patients underwent RSA, of which 175 (19.3%) were male and 730 (80.7%) were female. There were statistically significant differences between males and females in ASA classification ($P = .036$), diabetes mellitus status ($P = .025$), smoking status ($P = .001$), functional status ($P = .016$), mean age (70.50 ± 11.67 vs. 72.94 ± 8.95; $P = .002$), and BMI ($P = .045$) (Table I). A higher percentage of males were nondiabetic, nonobese, or overweight as characterized by BMI and functionally independent. Males also were younger, tended to smoke more and had a higher ASA classification status than females. There were no statistically significant differences between the groups in race ($P = .796$), anesthesia type ($P = .697$), dyspnea status ($P = .248$), mean operation time (130.63 ± 50.91 vs. 125.73 ± 51.35; $P = .257$), or mean postoperative length of stay (2.90 ± 8.8 vs. 3.05 ± 2.7; $P = .699$) (Table I).

About 645 patients (71.2%) had comorbidities. This number included 112 males (64%) and 557 (73%) females. A lower percentage of males had hypertension (58.3% vs. 70.5%; $P = .002$; OR = 0.583 [95% CI 0.42-0.82]) (Table II). There were no statistically significant differences between the groups with severe chronic obstructive pulmonary disease (8.6% vs. 7.0%; $P = .517$; OR = 1.25 [95% CI 0.68-2.28]), congestive heart failure (2.3% vs. 1.0%; $P = .238$; OR = 2.416 [95% CI 0.702-8.35]), acute renal failure (0% vs. 0.4%; $P = .907$; OR = 0.996 [95% CI 0.991-1.001]), dialysis-dependent (1.7% vs. 0.5%; $P = .271$; OR = 3.166 [95% CI 0.702-14.28]), chronic steroid use (4.0% vs. 4.5%; $P = .923$; OR = 0.88 [95% CI 0.383-2.024]), > 10% loss of body weight in the past 6 months (1.1% vs. 0.1%; $P = .178$; OR = 8.43 [95% CI 0.76-93.48]), transfusion ≥ 1 unit PRBCs 72 hours before surgery (1.7% vs. 2.1%; $P = .768$; OR = 0.831 [95% CI 0.238-2.904]), and disseminated cancer (0.6% vs. 0.4%; $P = .577$; OR = 1.393 [95% CI 0.144-13.47]).

Perioperative and postoperative complications

About 149 patients (16.46%) had either postoperative or perioperative complications. Males had a significantly higher complication rate than females (26.3% vs. 14.1%; $P < .001$). A higher percentage of males had pneumonia (2.9% vs. 0.5%; $P = .016$), unplanned intubation (2.3% vs. 0.4%; $P = .029$), and returned to the OR for an unplanned reoperation (9.1% vs. 1.1%; $P < .001$) (Table III). There were no statistically significant differences between the two

Table I

Demographic and clinical characteristics of males and females undergoing reverse total shoulder arthroplasty for proximal humeral fracture.

Characteristics	Male		Female		P value
	175		730		
	N	%	N	%	Male vs. female
Race					.796
White	157	89.7%	661	90.5%	
Black or African American	4	2.3%	18	2.5%	
Asian	3	1.7%	6	0.8%	
Other	11	6.3%	45	6.2%	
Anesthesia type					.697
General	171	97.7%	707	96.8%	
Regional	3	1.7%	11	1.5%	
MAC/IV sedation	1	0.6%	8	1.1%	
Spinal	0	0.0%	3	0.4%	
Epidural	0	0.0%	1	0.1%	
ASA classification					**.036**
1	4	2.3%	6	0.8%	
2	45	25.7%	246	33.7%	
3	109	62.3%	434	59.5%	
4	17	9.7%	44	6.0%	
Diabetes mellitus status					**.025**
No DM	145	82.9%	537	73.6%	
NIDDM	18	10.3%	121	16.6%	
IDDM	12	6.9%	72	9.9%	
Smoking status (within 1 yr)					**.001**
No	141	80.6%	654	89.6%	
Yes	34	19.4%	76	10.4%	
Dyspnea status					.248
No dyspnea	163	93.1%	681	93.3%	
Moderate	12	6.9%	43	5.9%	
At rest	0	0.0%	6	0.8%	
Functional status pre-op					**.016**
Independent	166	94.9%	682	93.4%	
Partially dependent	7	4.0%	42	6.6%	
Totally dependent	2	1.1%	0	0.0%	
Body mass index (kg/m2)					**.045**
Underweight (BMI < 18.5)	2	1.1%	19	2.6%	
Nonobese (BMI 18.5-25)	40	22.9%	150	20.5%	
Overweight (BMI 25-30)	63	36.0%	202	27.7%	
Obese I (BMI 30-35)	42	24.0%	178	24.4%	
Obese II (BMI > 35)	28	16.0%	181	24.8%	
Mean operation time (min)	130.63 (SD: 50.91)		125.73 (SD: 51.35)		.257
Mean post-op LOS (d)	2.90 (SD: 8.8)		3.05 (SD: 2.7)		.699
Mean age (yr)	70.50 (SD: 11.67)		72.94 (SD: 8.95		**.002**

Bold values are statistically significant.

groups in superficial surgical site infections ($P = .192$), deep surgical site infections ($P = .192$), organ/space infections ($P = 1.000$), wound dehiscence ($P = .347$), pulmonary embolism ($P = .357$), ventilator usage > 48 hours ($P = .246$), renal insufficiency ($P = 1.000$), urinary tract infections ($P = 1.000$), cardiac arrest ($P = .347$), myocardial infarctions ($P = .246$), p perioperative transfusion requirement ($P = .148$), deep vein thrombosis ($P = 1.000$), sepsis ($P = .574$), or cerebrovascular accidents ($P = .192$) (Table III).

Multivariate modeling and analysis determined that male sex was an independent risk factor for any complication (OR = 2.38 [95% CI 1.55-3.65]; $P < .001$). Separating patients returning to the operating room for an unplanned reoperation from total complications, male sex was still found to be an independent risk factor (OR = 1.73 [95% CI 1.10-2.71]; $P = .02$). Independently examining patients returning to the operating room for an unplanned reoperation, male sex was found to be an even stronger independent risk factor (OR = 10.59 [95% CI 4.23-27.49]; $P < .001$) (Table IV). Age and preoperative functional status were also found to be

independent risk factors for any complication and any complication excluding unplanned reoperation, whereas functional status alone was found to be an independent risk factor for unplanned reoperation.

Discussion

Utilizing the NSQIP database, it was observed that females were more likely to suffer from proximal humeral fractures than males (80.7% vs. 19.3%) which is in line with the published literature examining associated risk factors.[11,12,27,28] By contrast, males were more likely to sustain perioperative complications after surgery than females (26.3% vs. 14.1%; $P < .001$). Male sex was found to be an independent risk factor for any complication controlling for differences in demographic information and comorbidities between the cohorts (OR = 2.38 [95% CI 1.55-3.65]; $P < .001$). Examining individual complications, males were more likely to suffer from postoperative pneumonia (2.9% vs. 0.5%; $P = .016$), perioperative unplanned intubation (2.3% vs. 0.4%; $P = .029$), and an unplanned reoperation that required a return to the operating room (9.1% vs. 1.1%; $P < .001$).

Those patients who sustained a postoperative pneumonia and unplanned intubation, all were found to have received general anesthesia for their proximal humerus fracture surgery. Contemporary literature for primary shoulder arthroplasty suggests a reduction in perioperative complications for patients receiving regional anesthesia as opposed to general anesthesia.[3,6,19] Herrick et al analyzed 30-day mortality and complication rates for patients undergoing primary shoulder arthroplasty who received general anesthesia (GA), general and regional anesthesia (RA), or RA alone. They observed that patients who received GA alone (compared with GA and RA) had a 16% increase in all-cause infectious complications and were 2.6 times more likely to develop pulmonary complications.[22] GA alone was also associated with substantial increases in likelihood of ICU transfers, blood transfusions, and prolonged length of stay compared with RA alone.[22] Prior literature as well as our present study findings suggests that collaboration and communication between the anesthesia and orthopedic surgery teams are critical to determine the optimal mode of anesthetic administration to minimize perioperative complications.

For those patients who required a return to the operating room, the most common unplanned operations for males were revision RSA, closed treatment of a shoulder dislocation and open treatment of an acute shoulder dislocation. The most common unplanned operations for females were revision RSA and open treatment of an acute shoulder dislocation. Previous literature has shown that the most common complication of RSA is dislocation, with rates ranging from 1.5% to 31%.[8,10,17,39,41] Factors that contribute to reported postoperative instability include soft-tissue tension, glenosphere diameter, constraint on the humeral socket, mechanical impingement, and axillary/deltoid nerve dysfunction. The present study demonstrates dislocation is also the most common complication in both males and females, with a higher incidence for males. As male sex has been shown to be an independent risk factor for periprosthetic instability after RSA,[7,8,15,17] future work should focus on understanding how prosthetic design may impact prosthetic stability based on biological sex.

Our findings suggest that males are more susceptible than females for developing complications after orthopedic surgical procedures, which has been previously observed in the literature.[20,29,31] Basques et al demonstrated in their analysis of 20,383 patients that male sex is associated with an increased risk of adverse events after anterior cervical discectomy and fusion.[2] In particular, they noticed a higher incidence of pneumonia and unplanned intubation in males which is similar to our study findings.

Table II
Comorbidities for males and females undergoing reverse total shoulder arthroplasty for proximal humeral fracture.

Comorbidities	Male		Female		P value	OR (95% CI)
	175		730			
	N	%	N	%	Male vs. female	Male vs. female
COPD	15	8.6%	51	7.0%	.517	1.25 (0.68-2.28)
CHF	4	2.3%	7	1.0%	.238	2.416 (0.70-8.35)
Hypertension	102	58.3%	515	70.5%	**.002**	**0.583 (0.42-0.82)**
Renal failure	0	0.0%	3	0.4%	.907	0.996 (0.991-1.001)
Dialysis	3	1.7%	4	0.5%	.271	3.166 (0.702-14.28)
Steroid use	7	4.0%	33	4.5%	.923	0.88 (0.383-2.024)
Weight loss	2	1.1%	1	0.1%	.178	8.43 (0.76-93.48)
Pre-op transfusion	3	1.7%	15	2.1%	.768	0.831 (0.238-2.904)
Disseminated cancer	1	0.6%	3	0.4%	.577	1.393 (0.144-13.47)

CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.
Bold values are statistically significant.

Cvetanovich et al queried NSQIP to determine the rates, risk factors, and reasons of hospital readmission after primary TSA. They identified male sex as one of the most prominent independent risk factors for readmission (RR = 1.6; P = .025) and pneumonia (16.7%) and dislocation (8.3%) as the two most common reasons for readmission.[13] Our study findings are similar to previously published work demonstrating male sex as an independent risk factor for readmission after an orthopedic surgical procedure.

This study has several limitations that should be considered when interpreting the results. The NSQIP database, while encompassing data from multiple centers, relies primarily on a proper and standardized method of data collection and documentation. Because NSQIP collects data from a variety of surgical procedures, the variables included in the database are broad which hinders complete evaluation of individual surgical procedures. Furthermore, the data collected are deidentified. As a result, it does not include granular information that could influence complication rates such as surgeon's surgical experience, technique, mechanism of injury, prosthetic device used, discharge disposition, perioperative protocols, or case severity. There exists the possibility that one of these unreported variables can be a confounder and lead to the interaction observed in our data.

Another major limitation is the method of patient selection. As there is currently no individual CPT code for RSA, it was determined that patients with a diagnosis code of a PHFx underwent RSA based on diagnosis codes. In addition, the disparity in sample size between males and females identified could have additionally led to bias and an over exaggeration of observed complication rates. Although the NSQIP database is a random sampling of deidentified patient information from academic and community hospitals across the United States, the racial and demographic breakdown of the patients included in this study (ie, White 90%, Black 2.4%) is not representative of the general US population (ie, White 60.1%, Black 13.4%). Similarly, patients in the NSQIP database who underwent major shoulder surgery (ie, HA, primary/reverse total shoulder arthroplasty, arthroscopic rotator cuff repair, arthroscopic capsulorrhaphy and ORIF proximal humerus fracture) during this same period have a comparable gender and race breakdown to the present study. This sampling bias limits the generalizability of the present study findings and hinders the clinicians' ability to make patient-specific recommendations and draw conclusions about our underrepresented populations most at risk for PHFx (ie, Black, Native American, Asian, and Hispanic and Latino). Finally, with postoperative complications reported within 30 days of the index procedure, it is possible that our analysis is not a true representation of the actual complication rates, especially when examining major complications that occur outside the 30-day postoperative window. With this in mind, the true difference in complication rates between males and females could be theoretically greater than what was reported here.

Table III
Postoperative complications for males and females following reverse total shoulder arthroplasty for proximal humeral fracture.

Complications	Male	Female	P value
	175 (%)	730 (%)	
Any complication	46 (26.3)	103 (14.1)	**<.001**
Superficial surgical site infection	1 (0.6)	0 (0)	.192
Deep surgical site infection	1 (0.6)	0 (0)	.192
Organ/space infection	0 (0)	2 (0.3)	1
Wound dehiscence	1 (0.6)	1 (0.1)	.35
Pneumonia	5 (2.9)	4 (0.5)	**.016**
Unplanned intubation	4 (2.3)	3 (0.4)	**.029**
Pulmonary embolism	0 (0)	7 (1.0)	.357
On ventilator > 48 h	2 (1.1)	2 (0.3)	.17
Renal insufficiency	0 (0)	2 (0.3)	1
Urinary tract infection	2 (1.1)	11 (1.5)	1
Cardiac arrest	1 (0.6)	1 (0.1)	.35
Myocardial infarction	2 (1.1)	3 (0.4)	.249
Bleeding transfusions	26 (14.9)	82 (11.2)	.194
Deep vein thrombosis	1 (0.6)	4 (0.5)	1
Sepsis	1 (0.6)	2 (0.3)	.476
Return to OR	16 (9.1)	8 (1.1)	**<.001**
Cerebrovascular accidents	1 (0.6)	0 (0)	.192

Bold values are statistically significant.

Table IV
Comparison of adjusted odds ratios and 95% confidence intervals for males and females after reverse total shoulder arthroplasty for proximal humeral fracture.

Complications	Multiple variable logistic regression: male vs. female	
	Adjusted OR (95% CI)	P value
Any complication	2.38 (1.55-3.65)	<.001
Return to OR*	10.59 (4.23-27.49)	<.001
Other complications	1.73 (1.10-2.71)	.02

*   Of the 16 males who returned to operating room, 5 underwent a revision of their reverse shoulder arthroplasty, 2 underwent a closed treatment of shoulder dislocation, 2 underwent an open treatment of acute shoulder dislocation, and 2 underwent incision and drainage for a postoperative wound infection. Of the 8 females who return to the operating room, 2 underwent a revision of their reverse shoulder arthroplasty, 2 underwent an open treatment of an acute shoulder dislocation, and 1 female underwent an incision and drainage for treatment of a postoperative wound infection. Two males and 1 female did not have CPT codes associated with their unplanned reoperation.

Conclusions

Female sex is an independent risk factor for fracturing the proximal humerus, whereas male sex is an independent risk factor for developing complications within 30 days of a reverse total shoulder arthroplasty for a proximal humerus fracture. Males are more susceptible to requiring an unplanned intubation and developing postoperative pneumonia. Males are also ten times more likely to return to the operating room for an unplanned reoperation after reverse shoulder arthroplasty for proximal humeral fractures than females. This study provides additional information to consider for the treatment and management of patients undergoing a reverse shoulder arthroplasty for proximal humerus fractures.

Disclaimers:

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