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Gender bias in glenosphere size selection in reverse total shoulder arthroplasty: Glenoid size correlates with height and weight, not just gender

Brendan M. Patterson, MD, MPH[a,*], Joseph W. Galvin, DO[a], Maria F. Bozoghlian, MD[a], Natalie Glass, PhD[a], Melissa Wright, MD[b]

[a]Department of Orthopedics & Rehabilitation, University of Iowa, Iowa City, IA, USA
[b]Department of Orthopedic Surgery, Washington University School of Medicine, St. Louis, MO, USA

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Background: Optimal glenosphere selection is critical for successful outcomes following reverse total shoulder arthroplasty (rTSA). This study primarily aimed to determine patient-specific variables associated with dimensions of native glenoid anatomy. Secondarily, we aimed to determine the distribution of glenosphere sizes selected in male and female patients with similar-sized glenoids.
Methods: Computed tomography scans from patients undergoing rTSA with a diagnosis of cuff arthropathy or irreparable cuff tears were included for analysis. Variables collected included the following: age, gender, height, weight, and glenosphere size. Glenoid dimensions were measured, and interobserver reliability was calculated. Correlation coefficients were calculated for all variables. Multivariate predictive regression models were utilized to determine correlations between patient variables and glenoid width and height.
Results: One hundred and eighteen patients (46% male, 54% female) were included for analysis. Taller and male patients were significantly associated with increased glenoid height ($P = .0096$ and $P = .0003$, respectively). Females, shorter patients, and patients with decreased body weight were significantly associated with decreased glenoid width ($P = .01$, $P < .0001$, and $P = .01$, respectively). Through stepwise selection, patient height was most strongly associated with glenoid width ($P < .0001$). For glenoid widths between 25 and 30 mm, there was a significant variation in selected glenosphere sizes based on gender ($P < .0001$).
Discussion: Patient gender and height are significantly associated with glenoid height and width. There remains a strong tendency towards gender bias when selecting glenosphere sizes for patients undergoing rTSA with similar-sized glenoids. This data highlights the importance of considering patient height as well as gender when considering glenoid component size in the setting of rTSA.

In recent years, the expanding indications for reverse total shoulder arthroplasty (rTSA) have led to a dramatic growth in rTSA procedures in the United States.[2,20] Many factors can influence outcomes and complication rates following rTSA. Patient factors such as demographics and medical comorbidities have been shown to impact complications and patient-reported outcomes.[6,17,19] The specifics of the shoulder pathology being addressed, including rotator cuff integrity and glenoid and humeral bone loss, can also impact surgical outcomes.[21,22] Finally, the selection of the implants themselves has notable impact on the outcome of reverse shoulder arthroplasty.[3,5,1,14] Component selection in rTSA is often multifactorial for many surgeons. Factors that can influence component selection in rTSA include patient size, patient gender, rotator cuff integrity, analysis of preoperative computed tomography (CT) scan with virtual planning tools, and intraoperative assessment of range of motion and stability.[18]

One important aspect of component selection in rTSA is glenosphere size. Increased glenosphere size has been associated with increased external rotation range of motion in prior studies; however, the relationship between glenosphere size and functional outcome is not fully understood.[10,11] Increased glenosphere size has

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*Corresponding author: Brendan M. Patterson, MD, MPH, Department of Orthopaedics and Rehabilitation, University of Iowa Health Care, 200 Hawkins Drive, 01071 JPP, Iowa City, IA 52242, USA.

E-mail address: brendan-patterson@uiowa.edu (B.M. Patterson).

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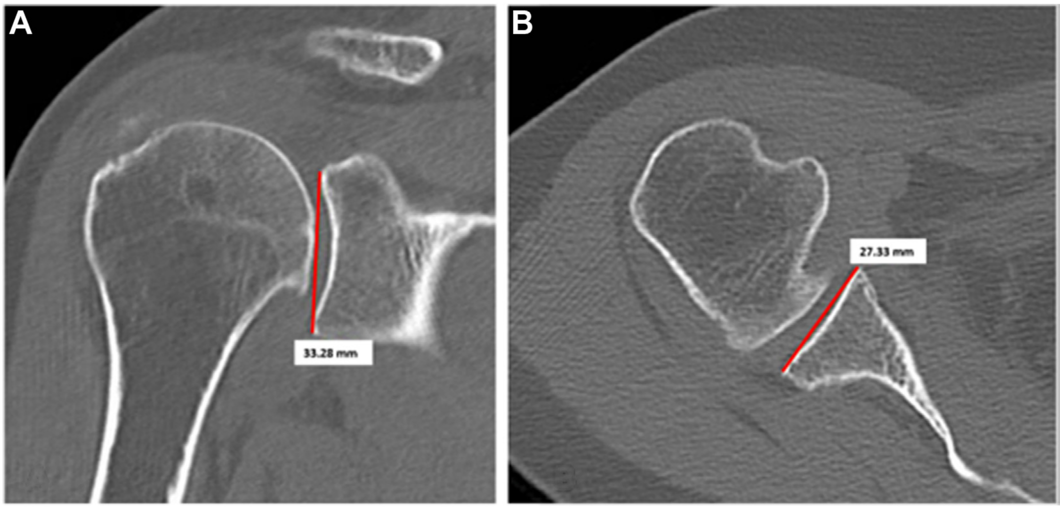

Figure 1 (**A**): Measurement of glenoid height in the midcoronal plane. (**B**): Measurement of glenoid width in the midaxial plane.

also been associated with decreased revision rates in population-based studies; however, these revision rates are variable for male and female patients with similar-sized glenospheres.[14] Exactly how to select the correct glenosphere size for an individual patient remains controversial. Even with the advent of preoperative planning software and improved accuracy in assessing glenoid size and morphology, patient gender remains a strong predictor of glenosphere size selection for many surgeons.[10,18] There is a paucity of literature defining the correlation between patient gender, height, weight, and glenoid size for patients undergoing reverse shoulder arthroplasty. Early anatomical studies on this topic have demonstrated correlations between patient gender and glenoid size, with male patients having increased glenoid size compared to female patients.[4] More recent literature suggests that patient gender is the strongest predictor of glenoid size; however, factors such as patient height and weight may also lead to significant variations in glenoid size within patients of the same gender.[16]

Given the increased recognition of the importance of glenosphere size on outcomes following rTSA, it is imperative that shoulder arthroplasty surgeons have an accurate understanding of the factors associated with patient glenoid size that may be relevant for guiding optimal glenosphere selection. This study, therefore, primarily aimed to determine patient-specific variables that are significantly associated with the size and dimensions of native glenoid anatomy in patients undergoing rTSA. Secondarily, we aimed to determine the distribution of rTSA glenosphere sizes selected in male and female patients with similar glenoid widths.

Materials and methods

This study was approved by our internal institutional review board (#202402464). This was a retrospective review of consecutive patients undergoing reverse shoulder arthroplasty by a single surgeon at an academic medical center. Patients were included for analysis if they had undergone primary rTSA between 2020 and 2023, had a preoperative CT scan performed for their operative shoulder, and had a primary diagnosis of rotator cuff arthropathy or irreparable rotator cuff tear. Patients with a diagnosis of primary glenohumeral osteoarthritis, those undergoing rTSA for proximal humerus fracture, and patients undergoing revision shoulder arthroplasty were excluded. Patients with glenohumeral osteoarthritis were excluded because the glenoid in these patients commonly is altered due to significant osteophytes, and the width can be difficult to accurately assess in patients with B2 glenoids and a significant neo-glenoid. One hundred and eighteen patients met inclusion criteria and were included for analysis.

Variables collected from the electronic medical record included the following: patient age at time of surgery, gender, height, and weight. Height and weight values collected included measurements performed closest to the surgical date. Operative notes were reviewed to determine the rTSA glenosphere size that was implanted.

Two fellowship-trained shoulder and elbow surgeons manually measured maximal glenoid height and width, through previously validated methods for glenoid measurement.[16] Measurements were made on two-dimensional CT scans at the midcoronal and midaxial cut to capture the maximal glenoid height and width, respectively (Fig. 1, *A* and *B*). Glenoid version was also recorded with use of automated three-dimensional (3D) preoperative planning software. Glenoid version was extracted from the Blueprint (version 4.0.2; Stryker, Kalamazoo, MI, USA) measurements of each patient's CT scan.

Intraclass correlation coefficients were used to describe intrarater and interrater reliability and were calculated using 2-way mixed or random effects models, respectively. Descriptive statistics were performed. Continuous variables were evaluated for skew and kurtosis and tested for normality using Shapiro-Wilk tests. Those without severe departures from normality were described using means ± standard deviations (SDs) and compared between gender and race groups using independent t-tests. Continuous variables with skewed or nonnormal distributions were described using medians and interquartile ranges and compared between groups using Wilcoxon Rank-Sum tests. Categorical variables were presented as frequencies (percentages) and compared between gender and race groups using Chi-square tests.

Relationships among patient factors and glenoid height and width

Generalized linear regression was used to model the bivariate relationships between glenoid size (height and width) and patient factors. Patient factors with P values ≤ 0.2 from bivariate model in the previous step were evaluated for inclusion in multivariable models predicting glenoid height and glenoid width using stepwise selection. Models with the lowest Akaike's information criterion were selected and r^2 values were reported. Analyses were completed using SAS statistical software (version 9.4; SAS Institute, Cary, NC, USA).

Table I
Baseline characteristics of the study cohort.

Variable	Min	Max	Mean ± SD or median (IQR)
Age (y)	50.0	86.0	68.8 ± 7.9
BMI (kg/m^2)	18.5	54.0	30.8 ± 6.8
Sex (n, % female)	64 (54%)		
Race			
Black	3 (2.54%)		
Hispanic	2 (1.69%)		
Multiracial	1 (0.85%)		
White	112 (94.92%)		
Height (inches)	54.0	75.0	66.1 ± 4.3
Weight (pounds)	94.0	338.0	191.3 ± 49.3
Glenoid version (degrees)	−25.0	35.0	8.0 (4-12)
Glenoid version Direction (n, % originally negative)	101 (86%)		
Glenoid height (mm)	26.7	45.9	35.2 ± 3.6
Glenoid width (mm)	21.0	38.7	28.6 ± 3.6

BMI, body mass index; *IQR*, interquartile range; *SD*, standard deviation.

Results

One hundred and eighteen patients were included for analysis. There were 54 male patients (46%) and 64 female patients (54%). The mean age of the cohort was 68.8 years (SD 7.9). The mean patient weight, height, and body mass index were 191.3 lbs (SD 49.3), 66.1 inches (SD 4.3), and 30.8 (SD 6.8). Glenoid version had a median value of 8 degrees of retroversion (IQR 4-12). For the entire cohort, the mean glenoid height was 35.2 mm (SD 3.6), and the mean glenoid width was 28.6 mm (SD 3.6). Interrater reliability between measurements for both glenoid width and glenoid height was substantial. The intraclass correlation coefficient for interrater reliability for glenoid height was 0.85 (confidence interval 0.473-0.937, P < .0001) and for glenoid width was 0.87 (confidence interval 0.569-0.942, P < .001). When glenoid size was analyzed according to gender, mean glenoid height in females was 33.2 mm (SD 2.6), and 37.6 mm in males (SD 3.2) (P < .0001). Mean glenoid width was 26.4 mm in females (SD 2.5), and 31.1 mm in males (SD 3.0) (P < .0001). Glenoid retroversion did not significantly differ between males and females (8 degrees and 7.5 degrees, respectively, P = .877). Descriptive characteristics of the cohort are provided in Table I and comparison between females and males in Table II.

Results of bivariate analyses showed patient gender, height, and weight were significantly associated with both glenoid height and width (Fig. 2). Glenoid version was significantly associated with glenoid height (P = .02) but was not associated with glenoid width (P = .369). Results of multivariable regression analyses revealed that taller patients and male patients were significantly associated with increased glenoid height (P = .0096 and P = .0003, respectively). For glenoid width, female patients, shorter patients, and patients with lower weight were significantly associated with decreased glenoid width (P = .01, P < .0001, and P = .01, respectively). In our generalized linear model, through stepwise selection we found that patient height had a stronger association with glenoid width, compared to the association between glenoid width and gender (r^2 0.59 vs. 0.56). When analyzing glenoid height, we found that patient gender had a slightly stronger association with glenoid height, compared to the association between patient height and glenoid height (r^2 0.41 vs. 0.37).

For patients within a range of glenoid widths of 25-30mm, there was a significant variation of selected glenosphere sizes based on patient gender (P < .0001). For male patients, 16/21 patients (76%) received a size 39mm sphere at the time of surgery, and only one patient (5%) received a 36 mm glenosphere. For female patients, 38/42 (90%) patients received a size 36 mm sphere, 3/42 (7%) patients received a 33mm sphere, while none of these female patients received a 39 mm or 42 mm sphere (Fig. 3). Radiographic examples of variations in glenopshere sizes for female patients with similar stature are shown in Fig. 4.

Discussion

This study adds to the understanding of predictors of native glenoid height and width in patients undergoing rTSA. This study identified that patient gender and height are significantly associated with glenoid height and width in patients with rotator cuff arthropathy and irreparable rotator cuff tears undergoing rTSA. Taller and male patients had increased glenoid heights, whereas shorter and female patients had smaller glenoid widths. Most notably, we found that increased patient height, more than patient gender, was most strongly associated with increased glenoid width. This study also found that gender played a large role in glenosphere size decisions, regardless of the actual size of the glenoid—a finding which has not been reported previously.

Our data have some similarities to prior literature investigating the relationships between patient gender and glenoid size. Piponov et al reviewed the CT scans of 96 patients to determine relationships between glenoid size and patient gender.[16] In their study population, patient gender was the strongest predictor of both glenoid height and width. Merrill et al evaluated 363 human scapular bone specimens and found significant differences in glenoid height and width based on gender, as well as gender based differences in overall glenoid shape.[9] The current study also found that patient gender was most strongly correlated with glenoid height, with male patients having larger glenoid height compared to female patients. However, data from this present study highlight important differences from previous work, as we found, through multivariate analysis, that for glenoid width, patient height, rather than gender, was most strongly correlated. This data suggests that while patient gender does have good correlation with glenoid size, patient height should also be taken into consideration when predicting accurate glenoid width for most patients. This relationship between patient height and glenoid width has not yet been fully described in the literature and has important implications when considering glenoid component selection for patients undergoing reverse shoulder arthroplasty.

Previous studies correlating glenoid size to gender were based on normal shoulders.[9,16] Our study, however, assessed the pathologic shoulder, specifically individuals with rotator cuff arthropathy. Understanding what impacts the size of the glenoid in the pathologic shoulder is of more relevance to the surgeon who will be implanting the rTSA in such a shoulder. Glenoid size and morphology change in the setting of pathology due to progressive wear and bone loss. When choosing implants in rTSA, it is critical to have a firm understanding of the pathologic glenoid state, and which implants will have adequate coverage and seating for the pathologic glenoid.

Implant selection is important for optimizing outcomes after shoulder arthroplasty. Implants that are undersized for an individual may lead to instability or poor function due to inadequate muscle tension.[8,11,13,15] Oversized or undersized implants, however, can cause stiffness and pain, limiting patients' functional outcome.[7,13] It is, thus, critical to understand which patient factors are related to glenoid size so that planning can take these factors into account and optimize the glenosphere size for each individual patient. While preoperative planning with 3D CT scans has become increasingly common in shoulder arthroplasty, it still requires decision making by the surgeon regarding what size glenosphere is most appropriate for the patient. There is wide variability in how

Table II
Patient characteristics by gender.

Variable	Female (n = 64)			Male (n = 54)			P value
	Min	Max	Mean ± SD or median (IQR)	Min	Max	Mean ± SD or median (IQR)	
Age (y)	51	86	67.4 ± 7.7	50	86	70.5 ± 7.9	.0304
BMI (kg/m^2)	19	54	31.4 ± 7.8	18.5	45.9	30 ± 5.4	.2825
Height (inches)	54	70.5	63.2 ± 3.2	63	75	69.6 ± 2.5	<.0001
Weight (pounds)	94	307	177.5 ± 50.7	125	338	207.8 ± 42.5	.0007
Glenoid version (degrees)	−25	30	8 (5-11)	−7	35	7.5 (3-12)	.9461
Glenoid version direction (n, % neg)	57 (89%)			44 (82%)			.2427
Glenoid height (mm)	27.5	40.3	33.2 ± 2.6	26.7	45.9	37.6 ± 3.2	<.0001
Glenoid width (mm)	21	35.2	26.4 ± 2.5	26.4	38.7	31.1 ± 3.0	<.0001

BMI, body mass index; *IQR*, interquartile range; *SD*, standard deviation.

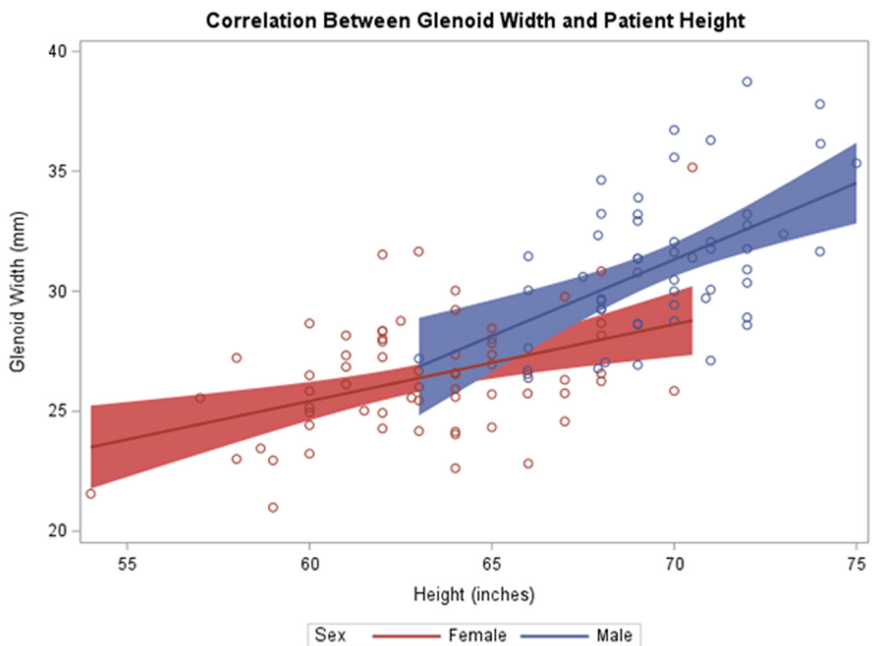

Figure 2 Correlation between patient height and glenoid width in male and female patients.

surgeons select glenosphere size, and what size they select for a given individual. Having a 3D picture of the glenoid does not ensure optimal sizing of the glenoid implant. In fact, utilizing CT scans and patient-specific instrumentation has not shown a proven benefit in terms of reducing the risk of complications or implant loosening.[12] More knowledge about what factors impact glenoid size, and what factors are currently guiding surgeon decision making about glenosphere size, is important as we work to understand how best to plan shoulder arthroplasty cases and what implants to select to optimize results.

Despite variations in glenoid height and glenoid width among both men and women, there remains a strong tendency towards gender bias when selecting glenosphere sizes for patients undergoing rTSA with similar-sized glenoids. This study found that for patients in the same range of average width glenoids, there was a strong tendency to place larger glenospheres in male patients and smaller glenospheres in females. Even while using a 3D CT scan to plan the cases, this bias was noted. Because there is no standardized way to select glenosphere size for a patient, decision making is left to surgeon discretion. Based on our findings, this discretion may be impacted substantially by patient gender, not just the size and morphology of the glenoid. This has potential significant implications for patient outcomes following reverse shoulder arthroplasty. Schoch et al similarly found that both patient height and patient sex were highly correlated with surgeons' glenosphere size choice. However, they could not find any significant interaction between patient height and glenosphere size that correlated with improvements in motion or patient-reported outcomes.[18] The optimal parameters for determining glenosphere size for an individual patient have yet to be determined. There is, however, literature demonstrating the impact of glenopshere size on outcomes overall. Larger glenospheres have been associated with improved active forward elevation, active external rotation, and abduction strength.[10,11] The impact of glenosphere size on functional outcomes may be impacted by gender as well, with larger glenospheres in female patients associated with improved functional outcomes.[10] Our data builds on previous literature and highlights the importance of considering both patient and glenoid size as well as gender when considering appropriate glenoid component size in the setting of rTSA.

This study does have limitations. Measurements were made based on two-dimensional CT scan and there is the potential for error in measurements, although interrater reliability was high. This is a single surgeon study and as such the results related to glenosphere selection may not be generalizable to all surgeons. This study did not assess outcomes and so the impact of the bias in glenosphere size on outcomes cannot be determined. Finally, we excluded rTSA patients with glenohumeral osteoarthritis due to the common significant alteration of the glenoid anatomy and height

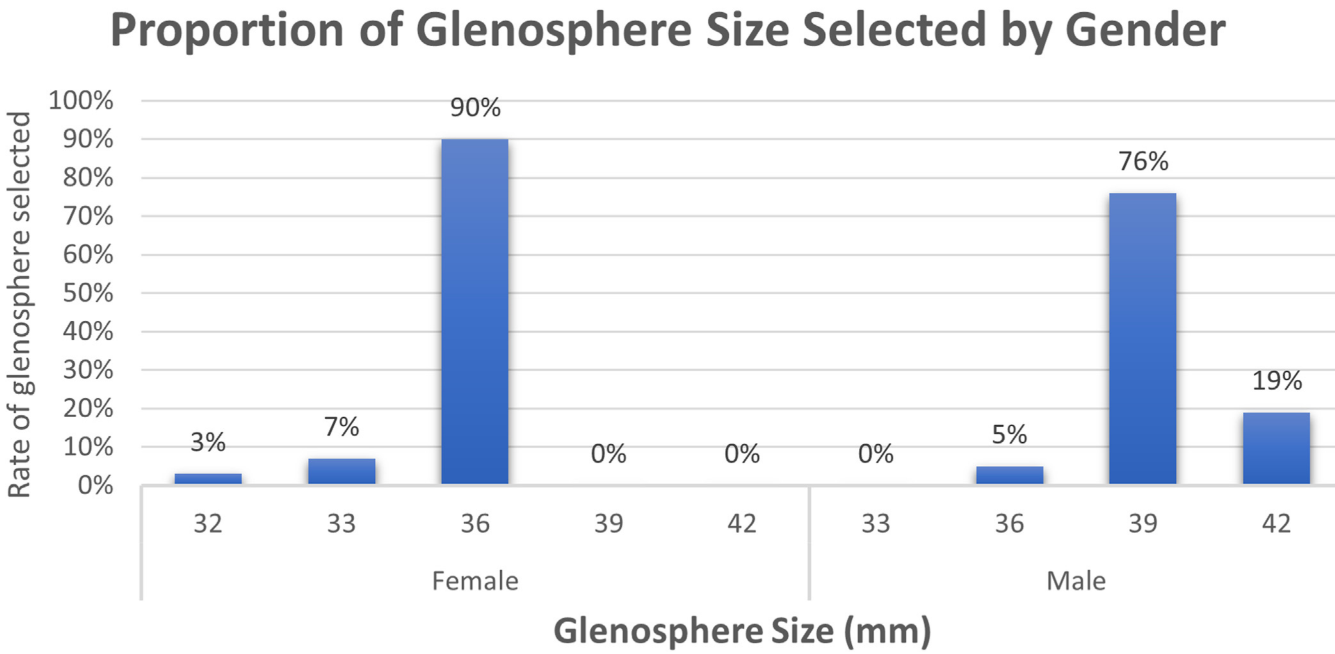

Figure 3 Glenosphere size selected in female and male patients with glenoid widths between 25 and 30 mm.

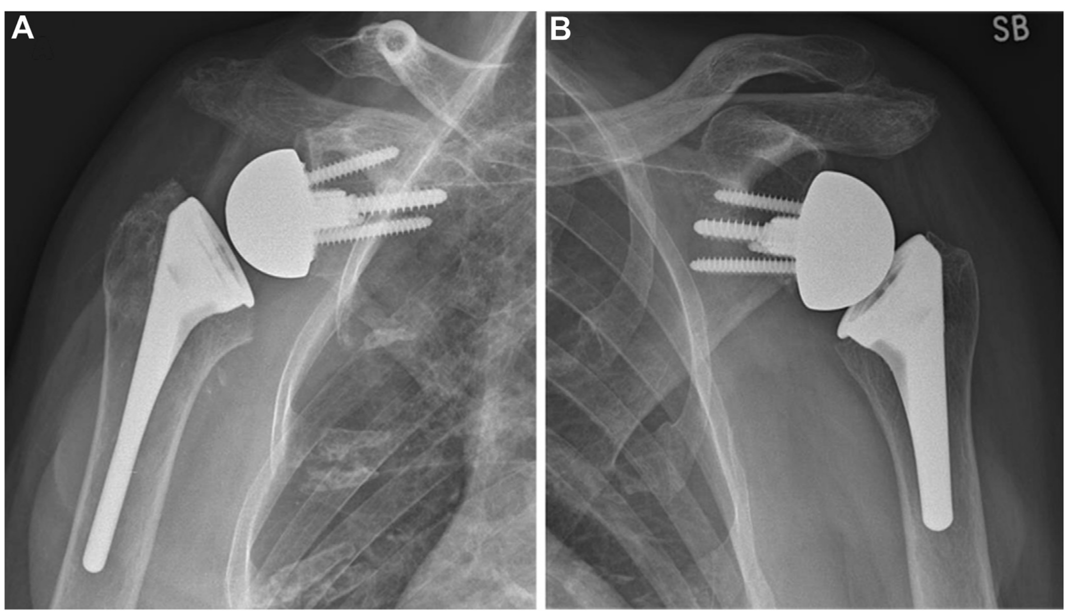

Figure 4 Variations in glenosphere size in female patients of similar stature. (**A**): Female patient with a height of 5′0" who received a 33 mm glenosphere. (**B**): Female patient with a height of 5′1" who received a 36 mm glenosphere.

and width in patients with Walch B2 and B3 glenoids. Therefore, these conclusions don't apply to all patients undergoing rTSA.

Conclusion

Patient gender and height are significantly associated with glenoid height and width in patients with rotator cuff arthropathy and irreparable rotator cuff tears undergoing rTSA. Taller and male patients had increased glenoid heights, whereas shorter and female patients had smaller glenoid widths. Increased patient height is most strongly associated with increased glenoid width. Despite variations in glenoid height and glenoid width, there remains a strong tendency towards gender bias when selecting glenosphere sizes for patients undergoing rTSA with similar-sized glenoids. Our data highlights the importance of considering both patient height as well as gender when considering appropriate glenoid component size in the setting of rTSA.

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