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Prearthroplasty glenohumeral pathoanatomy and its relationship to patient's sex, age, diagnosis, and self-assessed shoulder comfort and function

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Background: There is great current interest in characterizing the prearthroplasty glenohumeral pathoanatomy because of its role in guiding surgical technique and its possible effects on arthroplasty outcome.
Methods: We examined 544 patients within 6 weeks before arthroplasty with the goals of characterizing the following: demographic and radiographic characteristics; relationships of the radiographic pathoanatomy to the patient's age, sex, and diagnosis; inter-relationships among glenoid type, glenoid version, and amount of decentering of the humeral head on the glenoid; and relationships of the pathoanatomy to the patient's self-assessed comfort and function.
Results: Male patients had a higher frequency of B2 glenoids and a lower frequency of A2 glenoids. The arthritic shoulders of men were more retroverted and had greater amounts of posterior decentering. Patients with types A1 and C glenoids were younger than those with other glenoid types. Shoulders with osteoarthritis were more likely to be type B2 and to be retroverted. Types B2 and C had the greatest degree of retroversion, whereas types B1 and B2 had the greatest amounts of posterior decentering. Shoulders with glenoid types B1 and B2 and those with more decentering did not have worse self-assessed shoulder comfort and function.
Conclusions: Glenohumeral pathoanatomy was found to have previously unreported relationships to the patient's sex, age, and diagnosis. Contrary to what might have been expected, more advanced glenohumeral pathoanatomy (ie, type B glenoids, greater retroversion, greater decentering) was not associated with worse self-assessed shoulder comfort and function.
Level of evidence: Level III; Cross-Sectional Design; Epidemiology Study

Keywords: Axillary radiograph; glenohumeral pathoanatomy; retroversion; glenoid type; decentering; shoulder arthritis

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This study was approved by the Institutional Review Board of the University of Washington (#38897).

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The radiographic appearance of arthritic shoulders is commonly used to define the pathoanatomy before anatomic shoulder arthroplasty. Technical standardization of an axillary radiograph taken with the arm elevated in the scapular plane can enable characterization of the preoperative glenoid type, glenoid version, and amount of decentering of the humeral head on the face of the glenoid.[15,16,20,25,39,43,44,46,52] The relationships of these preoperative radiographic findings to the patient's age, sex, diagnosis, and self-assessed comfort and function have not been previously analyzed in detail.

We studied 544 shoulders within 6 weeks before arthroplasty with the goal of answering 4 questions:

- What are the typical demographic and radiographic characteristics of patients having elective anatomic shoulder arthroplasty?
- How does the pathoanatomy seen on standardized axillary radiographs correlate with the patient's age, sex, and diagnosis?
- What are the inter-relationships among glenoid type, glenoid version, and amount of decentering of the humeral head on the glenoid?
- How does the pathoanatomy seen on preoperative standardized axillary radiographs correlate with the patient's self-assessed comfort and function?

We tested the hypotheses that the radiographic characteristics of arthritic shoulders before arthroplasty are interrelated and that these radiographic characteristics are associated with the patient's age, sex, and diagnosis.

Materials and methods

Patients having shoulder arthroplasty were invited to enroll in a longitudinally maintained database that was searched to identify all shoulders having elective primary anatomic shoulder arthroplasty between August 2010 and August 2016. This study included only those patients enrolled in the database; for each of these patients, we documented the demographics, shoulder side, and whether the shoulder problem was related to the patient's work, insurance, body mass index, marital status, race, alcohol use, tobacco use, narcotics use, and prior surgery. The diagnoses were characterized as primary osteoarthritis, capsulorrhaphy arthropathy (arthritis after a prior instability repair), secondary degenerative joint disease (degenerative arthritis related to a prior procedure other than instability repair), post-traumatic arthritis (arthritis after a major injury), chondrolysis (arthritis resulting from the intra-articular infusion of local anesthetics through a pain pump), avascular necrosis, confirmed rheumatoid arthritis, or other. Each patient completed the Simple Shoulder Test (SST) within 6 weeks before the elective arthroplasty.[17]

Because preoperative radiographs were taken while the patient was in our clinic, we were able to control their quality and return the patient for repeated imaging if the films were inadequate for making the desired measurements. Of the patients enrolled in the database, 544 (99%) had standardized axillary radiographs taken within the 6 weeks before surgery that met the inclusion criterion of clearly showing the spinoglenoid notch. Six patients had been excluded because of inadequate radiographs; inadequate radiographs were the only exclusion criterion.

Starting with the onset of the study, the radiographic characteristics were assessed by an orthopedic surgeon blinded to the identities of the patients as well as their demographics and SST scores. This surgeon was one of the observers in a previous study of the interobserver variability in the analysis of standardized axillary views in 344 patients.[25] In that study, there was excellent correlation between observers: 0.81 for glenoid retroversion and 0.92 for the contact position ratio. The weighted κ statistic for glenoid type was 0.859. In that previous study and in this one, the glenoid type was determined using the following definitions based on the original description of Walch et al[46]: A1, humeral head centered in the glenoid with minimal wear (Fig. 1, *left*); A2, humeral head centered in the glenoid with central wear (Fig. 1, *right*); B1, humeral head posteriorly displaced on the glenoid with a loss of joint space but no or minimal biconcavity (Fig. 2); B2, humeral head posteriorly displaced on the glenoid with a double concavity on the glenoid surface (biconcavity; Fig. 3); and C, dysplastic. For each shoulder, we determined the degree of retroversion (90°minus the angle between the plane of the face of the glenoid and the plane of the body of the scapula)[46] and the humeral contact position ratio (the ratio of the distance between the anterior lip of the glenoid and the center point of contact between the humeral head and the glenoid divided by the distance between the anterior and posterior lips of the glenoid; Fig. 4).[25]

We then sought to determine the relationship of these pathoanatomic characteristics to the patient's age, sex, and diagnosis; the inter-relationship among glenoid type, glenoid version, and amount of decentering of the humeral head on the glenoid; and the preoperative relationship of the pathoanatomy to the patient's self-assessed comfort and function.

Statistical methods

Continuous variables were described by mean and standard deviations and categorical variables by count and percentage. Standard errors (SEs) for means of continuous variables accompany comparisons of means. Associations of sex and diagnoses with retroversion and with decentering were tested using 1-way analysis of variance (ANOVA) and Kruskal-Wallis test. Associations of sex and diagnoses with glenoid type were tested using Fisher exact test. Associations of age with retroversion and with decentering were quantified and tested using Spearman correlation. Associations of age with glenoid type were tested using 1-way ANOVA and Kruskal-Wallis test. The unadjusted and adjusted effects of retroversion, decentering, and glenoid type on preoperative SST score were quantified and tested using linear regression. To avoid omitting cases with missing risk factors, linear regression was carried out on multiple imputed data sets. The imputation was implemented using the random forest method.[37,40,42] A second sensitivity analysis using an alternative imputation technique (predictive mean matching[42]) found no material differences from the primary analysis. The adjustment variables were selected from candidate covariates (demographic variables and prior shoulder surgery) using backward elimination with the Akaike information criterion goodness-of-fit statistic.[37] All calculations were carried out in R (R Foundation for Statistical Computing, Austria, Vienna), version

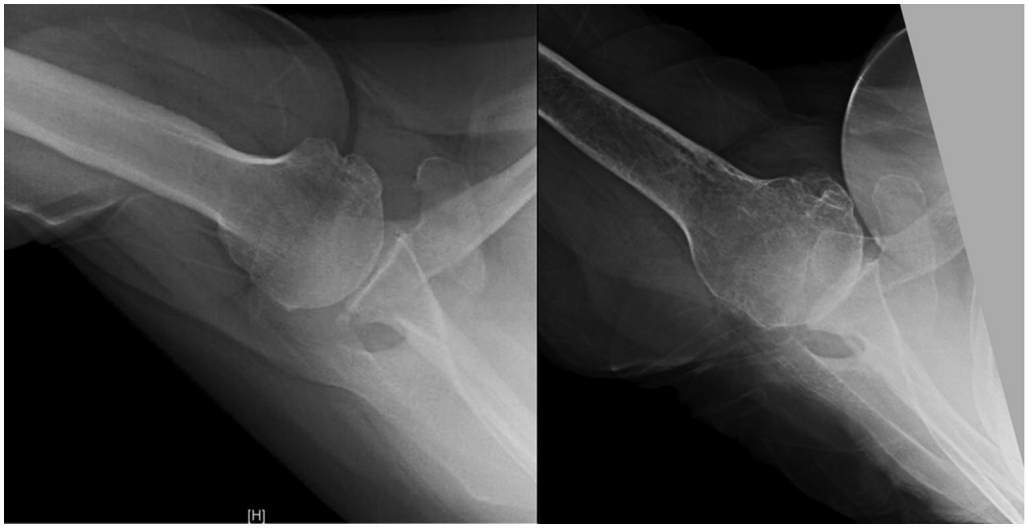

Figure 1 Standardized axillary radiographs of type A glenohumeral pathoanatomy characterized by centering of the humeral head on the glenoid. Type A1 (*left*) has minimal wear and A2 (*right*) has wear of the humeral head into the center of the glenoid.

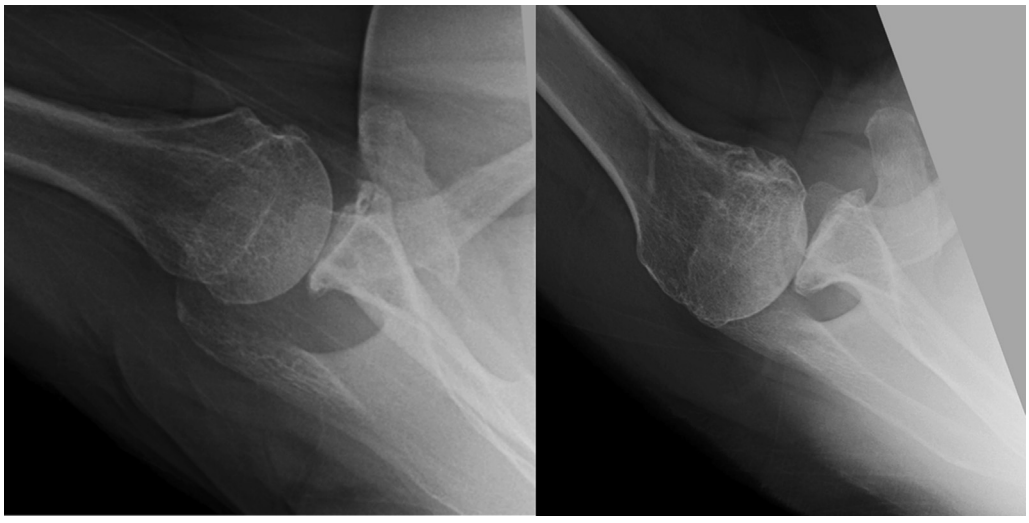

Figure 2 Standardized axillary radiographs of type B1 glenohumeral pathoanatomy characterized by posterior centering of the humeral head on the glenoid. Whereas both meet the definition of B1 pathoanatomy, the shoulder on the *left* has no posterior glenoid wear, whereas the shoulder on the *right* shows early evidence of posterior glenoid wear that may progress to biconcavity (ie, a type B2).

3.5.0, by an experienced statistician (M.B.N.). $P < .05$ was used to denote statistical significance.

Results

These 544 patients had an average age of 63 ± 11 years (range, 24-90 years), were 68.8% male, had commercial (42.1%) or Medicare (41.9%) insurance, and had an average body mass index of 30 ± 6 kg/m^2 (Table I). Typically they were married (74.7%) and white (96%). The primary diagnosis was osteoarthritis in 81.2%; 34.2% had had prior surgery. The average preoperative SST score was 3.9 ± 2.5 (range, 0-11) of 12. The distribution of glenoid types was A1 (2.4%), A2 (46.7%), B1 (13.9%), B2 (36.6%), and C (0.4%). Glenoid retroversion averaged 17° ± 11° (range, 9°of anteversion to 55° of retroversion). Glenoid contact position ratio averaged 0.6 ± 0.1 (range, 0.1-0.9), indicating that the average shoulder was posteriorly decentered.

Relationship of patient's sex, age, and diagnosis to radiographic measurements

The glenoid type distribution demonstrated a notably higher frequency of B2 glenoids (42%; 95% confidence interval [CI], 37%-47%) and a lower frequency of A2

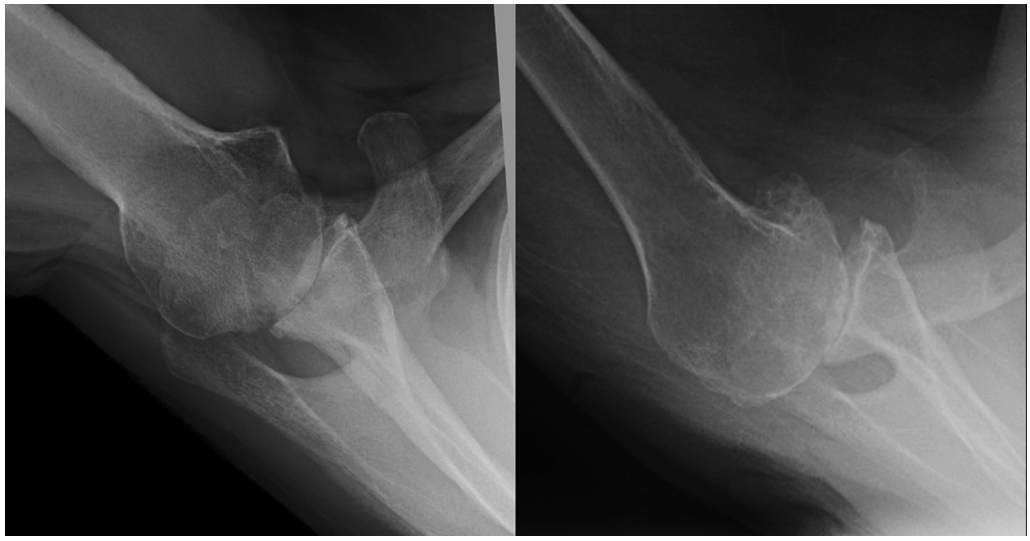

Figure 3 Standardized axillary radiographs of type B2 glenohumeral pathoanatomy characterized by posterior centering of the humeral head on the glenoid with a biconcavity of the glenoid surface. Whereas both meet the definition of B2 pathoanatomy, the shoulder on the *left* has less posterior decentering and less retroversion than the shoulder on the *right*.

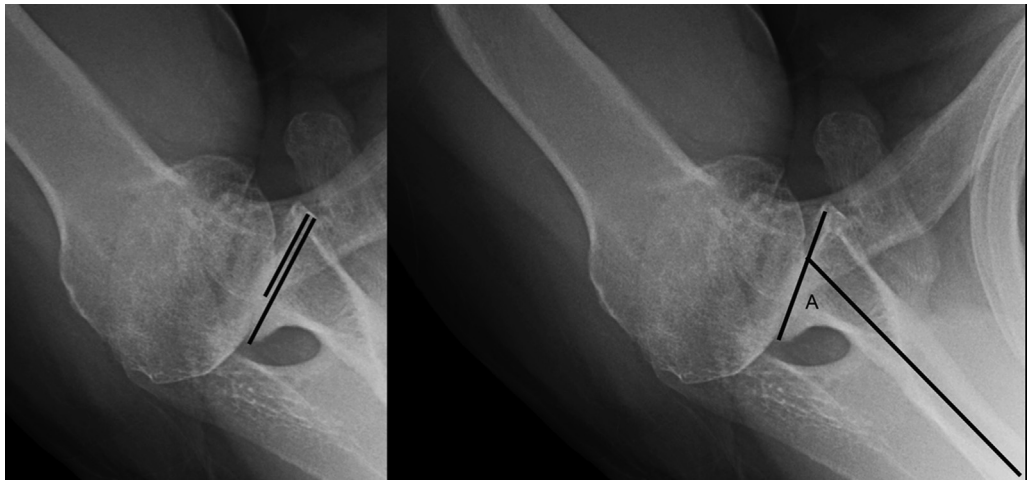

Figure 4 Measurements on the standardized axillary radiograph. The contact position ratio (*left*) is the ratio of the distance from the anterior glenoid lip to the point of humeral contact on the glenoid (*short line*) divided by the distance from the anterior to the posterior lip of the glenoid (*long line*); a ratio of 0.5 indicates that the humeral contact point is centered on the glenoid, whereas ratios >0.5 indicate posterior decentering. The glenoid retroversion (*right*) is 90° minus the angle *A* between the plane of the scapula (*long line*) and the plane of the glenoid face (*short line*).

glenoids (42%; 95% CI, 38%-48%) for men than for women (24% [95% CI, 18%-32%] and 55%, [95% CI, 48%-63%], respectively; Fig. 5). The arthritic shoulders of men were more retroverted (Fig. 6) and had greater amounts of posterior decentering (Fig. 7) in comparison to those of women. The mean ± SE glenoid retroversion was 18.2° ± 0.6° for men and 13.1° ± 0.8° for women (P = .013, ANOVA; $P < .001$, Kruskal-Wallis test). The mean ± SE contact position ratio was 0.627 ± 0.006 for men and 0.587 ± 0.009 for women ($P < .001$ for both ANOVA and Kruskal-Wallis test).

There was a statistically significant relationship between age and glenoid type. The mean ± SE age was 57.0 ± 3.8 years for A1, 64.3 ± 0.7 years for A2, 62.8 ± 1.2 years for B1, 62.1 ± 0.8 years for B2, and 48.2 ± 12.5 years for C (P = .013, ANOVA; P = .044, Kruskal-Wallis test). Age did not have a statistically significant relationship with glenoid retroversion (Spearman correlation = −0.05; P = .290) or contact position ratio (Spearman correlation = −0.08; P = .082).

There was a statistically significant relationship (P = .008, Fisher exact test) between diagnosis and glenoid type; there was a higher frequency of B2 types and a lower

Table I Descriptive statistics for preoperative characteristics

	No.	Mean ± SD (range) or No. (%)
Age at surgery (yr)	544	63 ± 11 (24-90)
Male sex	544	374 (68.8)
Right surgical shoulder	544	297 (54.6)
Work-related problem	543	38 (7.0)
Insurance	508	
Commercial		214 (42.1)
Medicare		213 (41.9)
Medicaid		18 (3.5)
Medicare and Medicaid		3 (0.6)
L&I		30 (5.9)
Self-pay		3 (0.6)
Other		27 (5.3)
Body mass index (kg/m^2)	544	30 ± 6 (15-58)
Marital status	542	
Married		405 (74.7)
Domestic partner		8 (1.5)
Widowed		35 (6.5)
Divorced		18 (3.3)
Single		70 (12.9)
Other		6 (1.1)
Race	544	
White		522 (96.0)
Black or African American		5 (0.9)
Native American Indian or Native Alaskan		3 (0.6)
Native Hawaiian or other Pacific Islander		2 (0.4)
Asian		4 (0.7)
Other or mixed		8 (1.5)
Alcohol use	542	355 (65.5)
Narcotics use	533	116 (21.8)
Tobacco use	542	
Never		289 (53.3)
Quit		216 (39.9)
Passive		9 (1.7)
Yes		28 (5.2)
Prior surgery	473	162 (34.2)
Primary diagnosis	544	
Osteoarthritis (degenerative joint disease, osteoarthritis)		442 (81.2)
Capsulorrhapy arthropathy		40 (7.4)
Secondary degenerative joint disease		27 (5.0)
Post-traumatic arthritis		17 (3.1)
Chondrolysis		10 (1.8)
Avascular necrosis		4 (0.7)
Rheumatoid arthritis		2 (0.4)
Other		2 (0.4)
Preoperative surgical shoulder SST score	544	3.9 ± 2.5 (0.0-11.0)
SST 1	544	306 (56.2)
SST 2	544	45 (8.3)
SST 3	544	127 (23.3)
SST 4	544	159 (29.2)
SST 5	544	298 (54.8)
SST 6	544	258 (47.4)
SST 7	544	90 (16.5)
SST 8	544	330 (60.7)
SST 9	544	180 (33.1)
SST 10	544	27 (5.0)
SST 11	544	45 (8.3)
SST 12	544	246 (45.2)
SF-36, physical functioning	489	65 ± 22 (0-100)
SF-36, role physical	482	46 ± 29 (0-100)
SF-36, role emotional	488	85 ± 24 (0-100)
SF-36, mental health	485	78 ± 16 (15-100)
SF-36, bodily pain	499	39 ± 20 (0-100)
SF-36, vitality	483	59 ± 21 (0-100)
SF-36, general health	488	73 ± 19 (10-100)
SF-36, social functioning	486	74 ± 27 (0-100)
SF-36, physical component summary	418	42 ± 21 (−18 to 95)
SF-36, mental component summary	418	84 ± 20 (18-119)
Glenoid type	538	
A1		13 (2.4)
A2		251 (46.7)
B1		75 (13.9)
B2		197 (36.6)
C		2 (0.4)
Glenoid retroversion (°)	538	17 ± 11 (−9 to 55)
Contact position ratio	538	0.6 ± 0.1 (0.1-0.9)

SD, standard deviation; *L&I*, Labor & Industries; *SST*, Simple Shoulder Test; *SF-36*, 36-Item Short Form Health Survey.

frequency of types A1 and A2 among the osteoarthritis cases. There was a statistically significant relationship between diagnosis and glenoid retroversion. The mean ± SE glenoid retroversion was 6.5° ± 3.6° for chondrolysis, 11.0° ± 6.7° for avascular necrosis, 12.0° ± 2.0° for rheumatoid arthritis, 13.3° ± 2.3° for secondary degenerative joint disease, 16.9° ± 2.5° for post-traumatic arthritis, 16.9° ± 0.5° for osteoarthritis, and 18.3° ± 2.0° for capsulorrhaphy arthropathy ($P = .030$, ANOVA; $P = .037$, Kruskal-Wallis test). Diagnosis did not have a statistically significant relationship with contact position ratio; mean ± SE contact position ratio was 0.727 ± 0.099 for avascular necrosis, 0.655 ± 0.155 for rheumatoid arthritis, 0.617 ± 0.018 for capsulorrhaphy arthropathy, 0.617 ± 0.005 for osteoarthritis, 0.616 ± 0.025 for post-traumatic arthritis, 0.587 ± 0.032 for secondary degenerative joint disease, and 0.539 ± 0.047 for chondrolysis ($P = .181$ ANOVA; $P = .368$ (Kruskal-Wallis test).

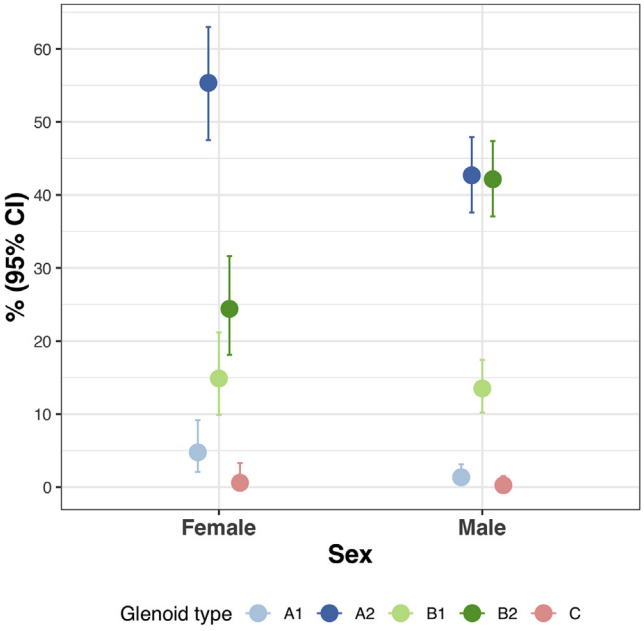

Figure 5 The percentage (95% confidence interval [*CI*]) distribution of the 5 glenoid types by sex. Note that male shoulders had a higher percentage of B2 glenoids and a lower percentage of A2 glenoids than female shoulders.

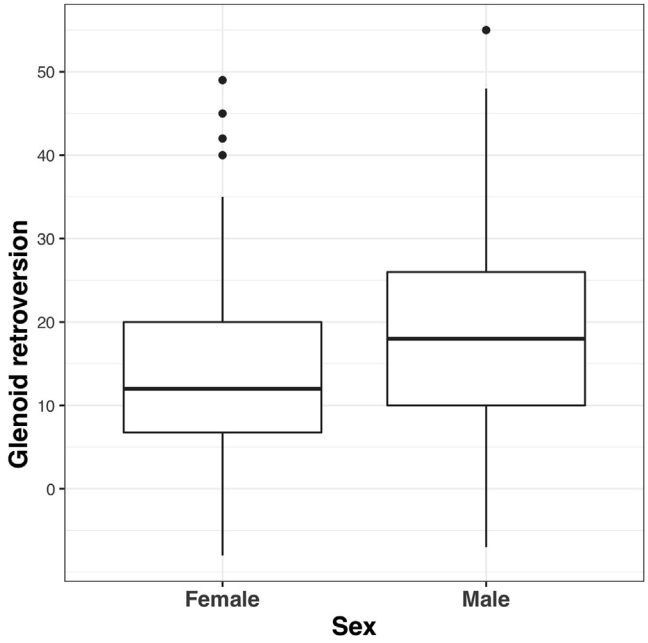

Figure 6 A box plot of glenoid retroversion by sex. The *vertical axis* shows the retroversion in degrees. Note that the male shoulders show a greater degree of retroversion than the female shoulders.

Inter-relationship among glenoid type, glenoid version, and amount of decentering of the humeral head on the glenoid

The degree of retroversion and the amount of decentering for individual shoulders varied widely within each glenoid type (Figs. 8 and 9). On average, types B2 and C glenoids had the greatest degree of retroversion (Fig. 8). Types B1 and B2 glenoids had the greatest amounts of posterior decentering (both had mean contact position ratios of 0.70), whereas on average, types A1 and A2 showed centered humeral heads (mean contact position ratios of 0.52 and 0.53, respectively; Fig. 9). The 5 glenoid types differed significantly with respect to both retroversion and contact position ratios ($P < .001$ for both ANOVA and Kruskal-Wallis test).

Relationship between the glenoid pathoanatomy seen on preoperative standardized axillary radiographs and the patient's comfort and function assessed by the SST

The preoperative SST scores were on average 0.9 point lower for type A glenoids than for type B glenoids (Fig. 10). The difference was smaller (0.3 point) and statistically not significant when adjusted for the effect of variables such as patient's sex; men had a higher frequency of glenoid type B (56% vs. 40% for women) and higher mean SST score (4.4 vs. 2.7 for women). Neither the degree of retroversion nor the amount of decentering had a statistically significant effect on the preoperative SST score when adjusted for the effect of demographic variables and prior shoulder surgery (Table II). A large portion of the difference between the unadjusted and adjusted effects can be attributed to the adjustment for the sex of the patient. Specifically, on average, men had more retroverted glenoids (18.2° vs. 13.1° for women), higher mean contact position ratios (0.63 vs. 0.59 for women), and higher mean SST scores (4.4 vs. 2.7 for women).

Discussion

This is the largest study of preoperative glenohumeral pathoanatomy in a well-characterized set of patients before elective anatomic shoulder arthroplasty and the first study to investigate in detail the inter-relationships among patient's age, sex, diagnosis, glenoid type, glenoid version, humeral centering on the glenoid, and self-assessed comfort and function.

The 544 shoulders in this study had a distribution of glenoid type and version similar to that in previous smaller studies (Table III).[7,10,12,18,23,29,32-35,39,43,45,49] However, patient's sex, diagnosis, and age were found to have correlations with the pathoanatomy that have not been previously described in detail. Male patients were more likely to have retroverted and type B2 glenoids with greater

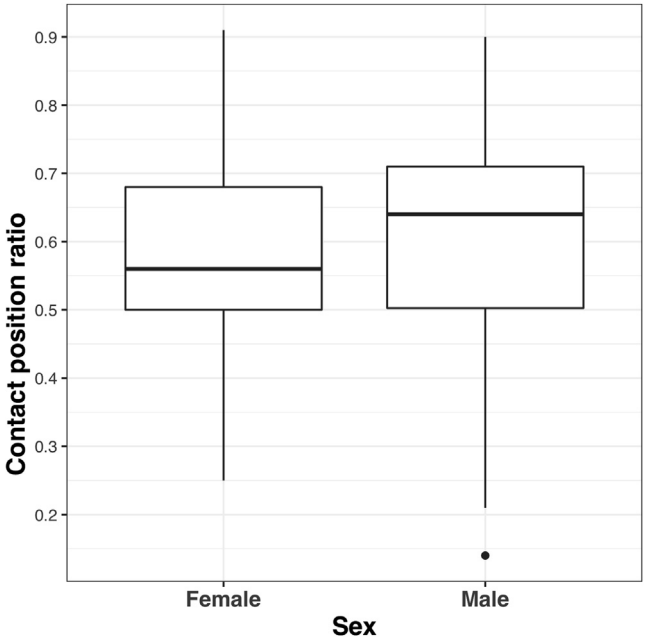

Figure 7 A box plot of the contact position ratio by sex. Note that a contact position ratio of 0.5 indicates that the humeral head is centered on the glenoid. Note also that whereas the average arthritic shoulders of both sexes are posteriorly decentered, the male shoulders show a higher amount of posterior decentering.

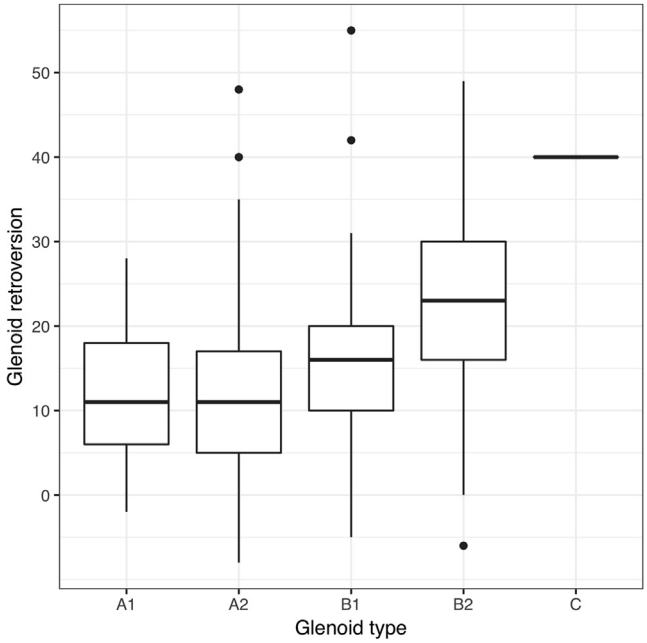

Figure 8 Box plot showing the glenoid retroversion (*vertical axis* in degrees) for the different glenoid types. Types B2 and C glenoids had the greatest degree of retroversion.

amounts of posterior humeral decentering. Shoulders with osteoarthritis were more likely to be retroverted and to be of type B2. Patients with glenoid types A2, B1, and B2 tended to be older than those with glenoid types A1 and C. These results indicate that studies of the effects of glenoid pathoanatomy need to be adjusted for the potentially confounding effects of sex, diagnosis, and age.

The patients in this study were substantially disabled before their shoulder arthroplasty as indicated by an average preoperative SST score of only 3.9 of 12. However, patients with more advanced glenohumeral disease (ie, type B glenoids, greater retroversion, greater decentering) did not have worse shoulder comfort and function.

This study is important because of the rapidly expanding interest in the relationship between the anatomy of the shoulder before anatomic arthroplasty, surgical technique, and surgical outcome.[4,6,11-13,18,19,24,26,27,29,30,31,34,39,44,47,48] Whereas some published literature shows worse outcomes after total shoulder arthroplasty in shoulders with biconcave or retroverted glenoid anatomy on preoperative images,[12,24,29,31,47,48] other authors have shown that these preoperative glenoid characteristics do not have an adverse effect on total shoulder outcomes.[6,11,26,27,30,34,39,44]

Consistent with their definitions, types B2 and C glenoids were typically more retroverted and types B1 and B2 glenoids had the greatest amount of posterior decentering. However, within each glenoid type, shoulders demonstrated substantial variability in the degree of glenoid version and the amount of decentering of the humeral head

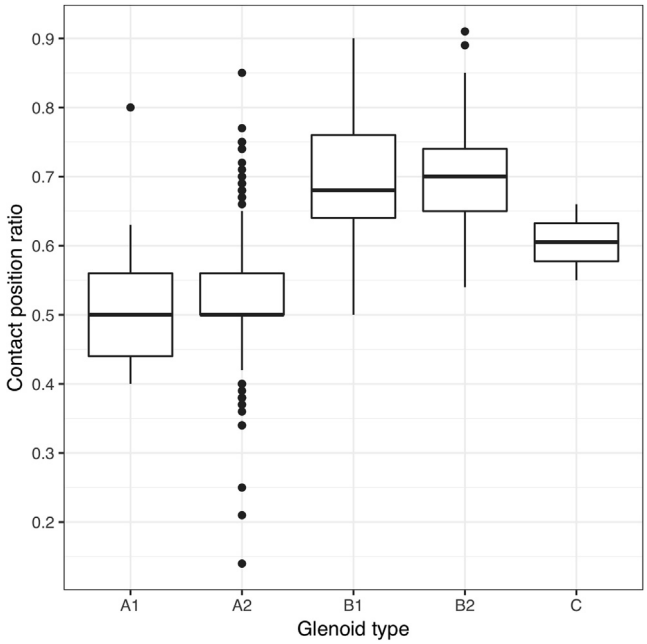

Figure 9 Box plot showing the contact position ratio (*vertical axis*) for the different glenoid types. Types B1, B2, and C glenoids had the greatest amount of posterior decentering (contact position ratio > 0.5).

on the glenoid.[3,11,21,22,36] In characterizing glenoid pathoanatomy, it becomes apparent that the assignment of arthritic glenoids to the different types is not always straightforward. For example, A1 and A2 glenoids are

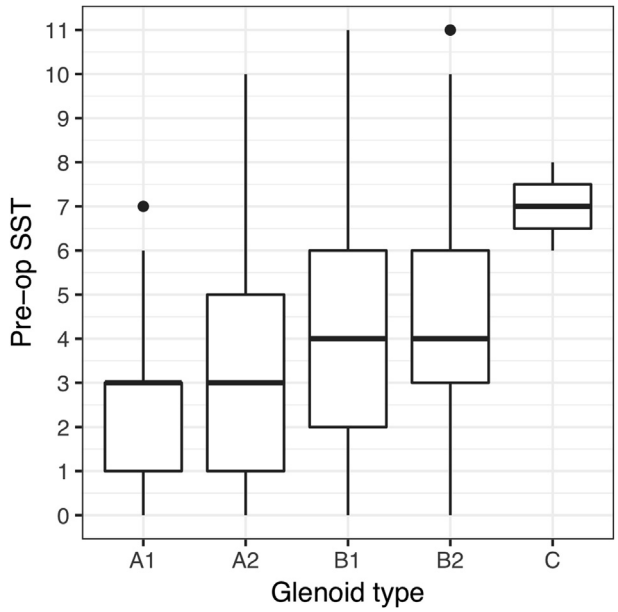

Figure 10 Box plot showing preoperative Simple Shoulder Test (*SST*) score (*vertical axis*) for the different glenoid types. Type A1 glenoids had lower SST scores, but this effect was small when adjustments were made for the patient's sex, age, diagnosis, and prior surgery. Nevertheless, it is of interest that the types of pathoanatomy generally thought to be more advanced (B1, B2, and C) were not associated with lower self-assessed comfort and function.

classically distinguished by the absence or presence (respectively) of glenoid wear. In practice, however, the degree of wear varies on a continuum between none and complete. Types A and B glenoids are classically distinguished by the absence or presence (respectively) of decentering. In practice, however, the amount of decentering varies on a continuum between none and complete.[15] Finally, B1 and B2 are classically distinguished by the absence or presence (respectively) of glenoid wear leading to a biconcavity. In practice, however, the degree of biconcavity varies on a continuum between none and substantial. Thus, glenoid typing requires the observer to establish dividing lines between "absent" and "present" in regard to these characteristics. To be consistent with the preponderance of the existing literature, the glenoid pathoanatomy was characterized using only the original 5 types: A1, A2, B1, B2, and C.[46] Recently, new glenoid types, including B0, B3, C2, and D, have been introduced as categories along the continuums of glenoid version, glenoid wear, glenoid biconcavity, and humeral decentering.[2,4,5,8,9,19,38] It seems likely, as shown by Figs 1-3 and as emphasized by Walker et al,[50] that glenohumeral pathoanatomy progresses over time, resulting in a gradual transition from one glenoid type to another. Version, wear, and decentering are continuous variables that may not lend themselves easily to strict categorical definitions for different glenoid types. For example, we noted that the version of centered glenoids (types A1 and A2) varied continuously from 8° of anteversion to 48° of retroversion without a discontinuity at 15° of retroversion, an amount of retroversion that has been suggested as the dividing line defining a "B3" glenoid.[2]

The results of this investigation need to be viewed in light of certain limitations. The 544 shoulders included in this analysis were from the practice of an individual, relatively high volume shoulder arthroplasty center. The patients' demographics and shoulder characteristics may not be the same as those found in other settings. For example, 96% of these patients were white; other populations of patients may have different distributions of pathoanatomy.

The measurements were made by an individual senior shoulder surgeon experienced in assessing the radiographic characteristics. This surgeon was one of the observers in a previous study of the interobserver variability in the analysis of standardized axillary views in 344 patients.[25] In that study, there was excellent correlation between observers: 0.81 for glenoid retroversion and 0.92 for the contact position ratio. The weighted κ statistic for glenoid type was 0.859.

The glenohumeral pathoanatomy was characterized using carefully standardized axillary views as previous described by many authors[15,25,27,28,39,43] rather than by 2- or 3-dimensional computed tomography (CT) scans; previous studies have found substantial agreement between plain radiographs and CT scans in classifying glenoid type, glenoid version, and humeral centering on the glenoid in shoulders with glenohumeral arthritis. Ho et al[14] found that postoperative measurements of glenoid version using axillary views were within 5° of the measurements on CT scans. In the paper of Ho et al,[14] CT scans and axillary views were used interchangeably by these authors to measure glenoid version. A paper by Aronowitz et al[1] reported that radiographs and CT scans showed similar observer agreement in classifying glenoid morphology in glenohumeral arthritis. In a recent article by Shukla et al,[41] 3 fellowship-trained shoulder surgeons blindly and independently evaluated radiographs and CT scans of 100 consecutive shoulders with primary glenohumeral osteoarthritis and classified all shoulders in 4 separate sessions. The first reading by the senior observer on the basis of CT scans served as the "gold standard" (distribution: A1, 18; A2, 12; B1, 20; B2, 25; B3, 22; C, 1; and D, 2). The average intraobserver agreement (κ coefficient) for radiographs was 0.73 (substantial; 0.72, 0.74, and 0.72), essentially identical to that for CT scans, 0.73 (substantial; 0.77, 0.69, and 0.72). Similarly, the average interobserver agreement for radiographs was 0.55 (moderate; 0.61, 0.51, and 0.53), which was essentially

Table II Unadjusted and adjusted effects of glenohumeral pathoanatomy variables on preoperative Simple Shoulder Test score (linear regression; N = 544)

	Unadjusted		Adjusted	
	difference (95% CI)	*P*	difference (95% CI)	*P*
Contact position ratio, per 0.1	**0.3 (0.1-0.4)**	**.003**	0.1 (−0.1 to 0.3)	.284
Glenoid retroversion, per 10°	**0.2 (0.0-0.4)**	**.023**	−0.0 (−0.2 to 0.2)	.830
Glenoid type				
A2	0.0 (Reference)		0.0 (Reference)	
A1	−0.6 (−2.0, 0.8)	.398	−0.4 (−1.6, 0.9)	.589
B1	0.6 (−0.0 to 1.2)	.068	0.5 (−0.1 to 1.1)	.113
B2	**1.0 (0.6-1.5)**	**<.001**	**0.6 (0.1-1.0)**	**.013**
C	**3.6 (0.1-7.0)**	**.042**	**3.4 (0.1-6.6)**	**.041**

CI, confidence interval.
Analysis on multiple imputed data sets (N = 5 data sets).
Covariates in the adjusted analysis were selected by backward elimination with the Akaike information criterion statistic. The selected adjustment variables are sex, age, work relationship, body mass index, marital status, alcohol use, narcotics, and prior shoulder surgery. **Bold** values indicate a significant difference denoted by a *P* value < .05.

Table III Reported distributions of preoperative glenoid morphology

Authors	Year	No.	%A1	%A2	%B1	%B2	%B3	%C	Imaging
Krukenberg et al[23]	2018	105	30	25	9	30		7	CT
Raiss et al[34]	2018	125	22	41	19	14	3	0	CT
Tanner et al[45]	2018	75	29	23	4	39		5	CT
Blinded for review purposes	2017	111	2	38	16	44		0	Radiographs
Blinded for review purposes	2017	75	14	31	20	35		0	Radiographs
Parks et al[32]	2016	80	27	25	23	23		4	CT
Hussey et al[18]	2015	344	38	16	17	23		7	CT
Raiss et al[33]	2014	45	20	31	13	31		4	CT
Gazielly et al[10]	2015	39	64	26	10	0		0	CT
Montoya et al[29]	2013	53	6	19	52	24		0	Radiographs
Greiner et al[12]	2013	90	18	26	25	23		9	CT/radiographs
De Wilde et al[7]	2013	34	17	10	3	70		0	CT
Wirth et al[51]	2012	44	45	9	16	30		0	Radiographs
Raiss et al[35]	2012	39	0	28	41	26		5	CT/MRI
Walch et al[49]	2011	333	27	29	19	23		1.2	CT/MRI

CT, computed tomography; *MRI*, magnetic resonance imaging.
Percentages may not add up to 100% because of rounding.

identical to that for CT scans, 0.52 (moderate; 0.63, 0.50, and 0.43).

Conclusion

This study documented the spectrum of preoperative arthritic glenohumeral pathoanatomy as reflected by glenoid type, glenoid version, and humeral decentering. Pathologic glenohumeral pathoanatomy was found to have previously unreported relationships to the patient's sex, age, and diagnosis. Contrary to what might have been expected, more advanced glenohumeral pathoanatomy (ie, type B glenoids, greater retroversion, greater decentering) was not associated with worse self-assessed shoulder comfort and function. Analyses of the effects of glenohumeral pathoanatomy need to be adjusted for potential confounders, such as age, sex, and diagnosis.

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