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ONLINE ARTICLES

The association between anterior shoulder joint capsule thickening and glenoid deformity in primary glenohumeral osteoarthritis

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Background: Anterior shoulder joint capsule thickening is typically present in osteoarthritic shoulders, but its association with specific patterns of glenoid wear is incompletely understood. We sought to determine the relationship between anterior capsular thickening and glenoid deformity in primary glenohumeral osteoarthritis.

Methods: We retrospectively identified 134 consecutive osteoarthritic shoulders with magnetic resonance imaging and computed tomography scans performed. Axial fat-suppressed magnetic resonance imaging slices were used to quantify the anterior capsular thickness in millimeters, measured at its thickest point below the subscapularis muscle. Computed tomography scans were used to classify glenoid deformity according to the Walch classification, and an automated 3-dimensional software program provided values for glenoid retroversion and humeral head subluxation. Multinomial and linear regression models were used to characterize the association of anterior capsular thickening with Walch glenoid type, glenoid retroversion, and posterior humeral head subluxation while controlling for patient age and sex.

Results: The anterior capsule was thickest in glenoid types B2 (5.5 mm, 95% confidence interval [CI]: 5.0-6.0) and B3 (6.1 mm, 95% CI: 5.6-6.6) and thinnest in A1 (3.7 mm, 95% CI: 3.3-4.2; $P < .001$). Adjusted for age and sex, glenoid types B2 (odds ratio: 4.4, 95% CI: 2.3-8.4, $P < .001$) and B3 (odds ratio: 5.4, 95% CI: 2.8-10.4, $P < .001$) showed the strongest association with increased anterior capsule thickness, compared to glenoid type A1. Increased capsular thickness correlated with greater glenoid retroversion ($r = 0.57$; $P < .001$) and posterior humeral head subluxation ($r = 0.50$; $P < .001$). In multivariable analysis, for every 1-mm increase in anterior capsular thickening, there was an adjusted mean increase of 3.2° (95% CI: 2.4-4.1) in glenoid retroversion and a 3.8% (95% CI: 2.7-5.0) increase in posterior humeral head subluxation.

Conclusions: Increased thickening of the anterior shoulder capsule is associated with greater posterior glenoid wear and humeral head subluxation. Additional research should determine whether anterior capsular disease plays a causative role in the etiology or progression of eccentric glenohumeral osteoarthritis.

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: Shoulder arthroplasty; anterior capsule; osteoarthritis; shoulder; glenoid

This study was approved by the New England Baptist Hospital Institutional Review Board.

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It is becoming increasingly apparent that the pathogenesis of glenohumeral arthritis seems mediated by a complex interaction between osseous anatomy and the surrounding soft tissues.[1,6,16] Most attention has been directed toward the rotator cuff musculature,[1,6,9,12,16] while other soft-tissue structures (eg joint capsule) have been less well studied.

The anterior shoulder joint capsule is typically thickened and contracted in primary glenohumeral osteoarthritis.[15,17] There is recent evidence showing substantial synovitis, fibrosis, and mixed inflammatory cell infiltrate in the anterior capsule of osteoarthritic shoulders.[3] Furthermore, humeral head cartilage wear patterns in glenohumeral arthritis have been correlated with preoperative range of motion, potentially implicating a thickened and contracted anterior capsule.[11] However, little is known about whether anterior capsular disease is involved in the etiology or progression of certain patterns of glenohumeral arthritis. Given the notion that anterior capsule overtightening in instability surgery can lead to capsulorrhaphy arthropathy and accelerated posterior glenoid wear,[13,14] one could posit that thickening and contracture of the anterior capsule might be associated with the development of eccentric glenoid erosion in primary glenohumeral arthritis. Indeed, our anecdotal impression intraoperatively has been that the anterior capsule of posteriorly worn glenoids is often impressively thickened. Empirically testing this observation is an important next step toward characterizing the potential involvement of the anterior capsule in the pathogenesis of eccentric shoulder osteoarthritis.

In this context, we sought to determine the relationship between anterior capsular thickening and eccentric glenohumeral osteoarthritis. Specifically, we hypothesized that glenoid deformities with more severe posterior erosion and humeral head subluxation will be associated with thicker anterior shoulder capsules.

Methods

Sample and study design

We retrospectively identified all patients who underwent total shoulder arthroplasty (anatomic or reverse) from 2015 to 2020 for primary glenohumeral osteoarthritis by a single fellowship-trained shoulder surgeon. Patients were included in our analysis if they had both magnetic resonance imaging (MRI) and computed tomography (CT) scans performed on the affected shoulder for preoperative surgical planning. To achieve a homogenous sample, we excluded shoulders with an indication for surgery other than primary glenohumeral arthritis with an intact rotator cuff. This study was approved by our institutional review board.

Radiographic assessments

Glenoid morphology was graded using CT scans according to the modified Walch classification,[2] which consists of 7 subtypes (A1, A2, B1, B2, B3, C, and D), through a consensus reading by 2 fellowship-trained shoulder surgeons. Because of the low frequency of C (n = 3) and D glenoids (n = 2), these Walch subtypes were excluded from the analysis, leaving a total of 134 shoulders in the final analysis. We used an automated 3-dimensional software program (BLUEPRINT; Wright Medical, Memphis, TN, USA) to quantify glenoid retroversion and humeral head subluxation for each patient.

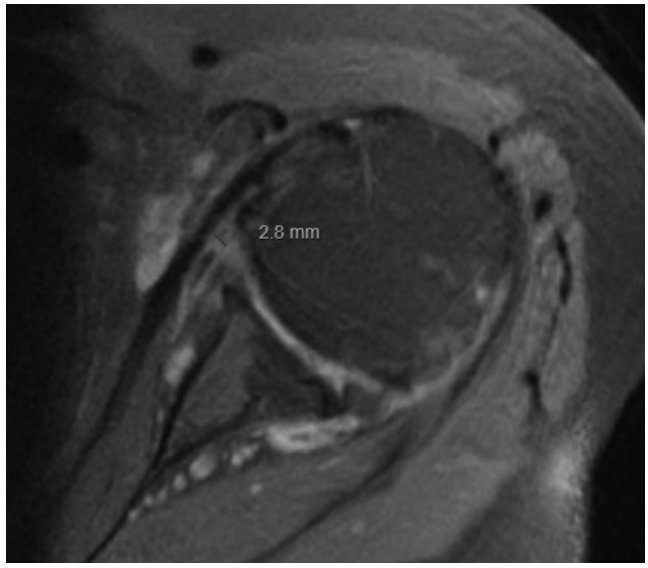

Figure 1 Anterior shoulder joint capsule measurement on axial MRI. *MRI*, magnetic resonance imaging.

Axial fat-suppressed MRI slices were used to measure the thickness of the anterior shoulder joint capsule in millimeters.[4] The capsule was measured at its thickest point below the subscapularis muscle (Fig. 1). Measurements were performed by a shoulder surgery fellow (M.E.M.). A random sample of 50 MRI scans were given to a senior orthopedic surgery resident to determine interobserver reliability and intraclass correlation coefficient (ICC). The ICC value was 0.70. In general, ICC values <0.40 indicate poor reliability; 0.40 to 0.59, fair reliability; 0.60 to 0.74, good reliability; and 0.75 to 1.00, excellent reliability.[1]

Statistical analysis

We used Pearson correlation coefficients to determine the association of anterior capsular thickening with glenoid retroversion and posterior humeral head subluxation. One-way analysis of variance with Bonferroni post hoc testing was conducted to evaluate the relationship between Walch glenoid types and anterior capsular thickening.

To minimize potential confounding, multinomial logistic and linear regression models were used to characterize the association of anterior capsular thickening with Walch glenoid type, glenoid retroversion, and humeral head subluxation while controlling for patient age and sex. For the linear regression models, results were presented as adjusted differences in glenoid retroversion or humeral head subluxation in the form of regression coefficients (β) with 95% confidence intervals (CIs). For the multinomial logistic model, we selected Walch glenoid type A1 as the reference category, and the results were presented as adjusted odds ratios (ORs) with 95% CIs.

Table I Anterior shoulder capsular thickening by Walch glenoid type

Parameter	Anterior shoulder capsular thickening (mm)
Total* (n = 134)	5.1 ± 1.7 (1.9 to 10.9)
Walch glenoid type†	
A1 (n = 29)	3.7 (3.3 to 4.2)
A2 (n = 10)	4.6 (3.5 to 5.7)
B1 (n = 13)	4.1 (3.7 to 4.5)
B2 (n = 44)	5.5 (5.0 to 6.0)
B3 (n = 38)	6.1 (5.6 to 6.6)
P value (among groups)	<.001

* Values are given as the mean and standard deviation, with the range in parentheses.
† Values are given as the mean estimate and 95% confidence interval.

Statistical tests were 2-sided, with $P < .05$ denoting statistical significance.

Results

The thickness of the anterior shoulder capsule in osteoarthritic shoulders was 5.1 mm (standard deviation: 1.7 mm; range: 1.9-10.9 mm). The anterior capsule was thickest in glenoid types B2 (5.5 mm, 95% CI: 5.0-6.0) and B3 (6.1 mm, 95% CI: 5.6-6.6) and thinnest in A1 (3.7 mm, 95% CI: 3.3-4.2; $P < .001$; Table I). There was no correlation between patient age and anterior capsular thickness ($r = -0.05$; $P = .6$). Men had a thicker anterior capsule than women (5.7 vs 4.4 mm; $P < .001$). After adjusting for age and sex, glenoid types B2 (OR: 4.4, 95% CI: 2.3-8.4, $P < .001$) and B3 (OR: 5.4, 95% CI: 2.8-10.4, $P < .001$) showed the strongest association with increased anterior capsular thickness, compared to glenoid type A1 (Fig. 2).

Increased capsular thickness correlated with greater glenoid retroversion ($r = 0.57$; $P < .001$) and posterior humeral head subluxation ($r = 0.50$; $P < .001$; Figs. 3 and 4). In multivariable analysis, for every 1-mm increase in anterior capsular thickening, there was an adjusted mean increase of 3.2° (95% CI: 2.4-4.1) in glenoid retroversion and a 3.8% (95% CI: 2.7-5.0) increase in posterior humeral head subluxation (Table II).

Discussion

Anterior shoulder joint capsule thickening is typically present in osteoarthritic shoulders, but its association with specific patterns of glenoid wear is incompletely understood. Other soft-tissue structures of the shoulder (eg, rotator cuff muscle atrophy and fatty infiltration) have recently been implicated in the development of eccentric glenoid wear.[1,6,9,12,16] We sought to determine the relationship between the thickness of the anterior shoulder capsule and glenoid deformity in primary glenohumeral osteoarthritis.

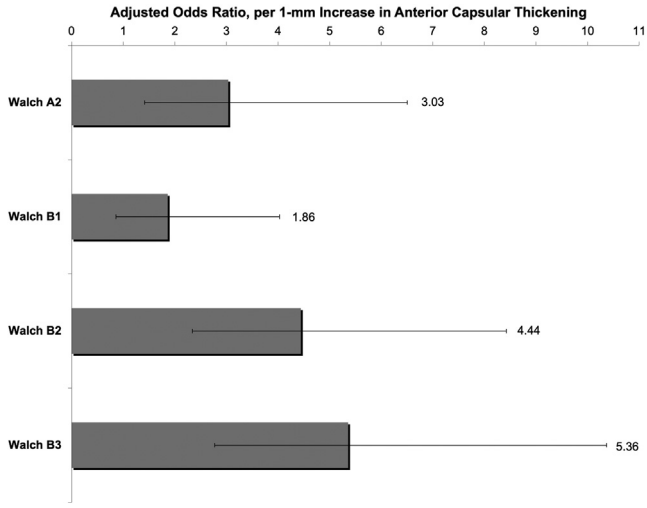

Figure 2 Risk-adjusted association of anterior capsular thickening with Walch glenoid type (reference category: A1 glenoid).

We found that increased thickening of the anterior shoulder capsule was associated with greater posterior glenoid wear and humeral head subluxation. In particular, the anterior capsule was thickest in the more posteriorly worn glenoid types B2 and B3. It is possible that more severe anterior capsular disease could lead to a greater amount of posterior humeral subluxation and asymmetric glenoid wear. This phenomenon would be similar to the concept of capsulorrhaphy arthropathy and posterior glenoid wear due to anterior capsule overtightening.[13,14] Conversely, anterior capsular abnormalities may develop secondary to glenohumeral osteoarthritic changes. Further characterization of this relationship would require a temporal analysis rather than a single-point-in-time analysis.

Our findings support the growing notion that eccentric glenohumeral arthritis may be due to more than predetermined bony abnormalities, with surrounding soft-tissue imbalances from the joint capsule and the rotator cuff playing a potential role.[1] Indeed, there is growing evidence that shoulder arthritis is likely governed by a complex interaction between osseous architecture and soft-tissue balance.[10] The finding that anterior capsular disease is present in osteoarthritic shoulders is further corroborated by the fact that the average capsular thickness in our sample was about 5.1 mm, compared with an average thickness of 2.4 mm in a study of 8 cadavers without shoulder pathology.[5]

Given recent immunohistologic data showing synovial fibrosis and inflammation in the anterior capsule of osteoarthritic shoulders,[3] a promising area of investigation is whether targeted pharmacologic modulation of anterior capsular disease could be beneficial in the prevention or management of primary glenohumeral arthritis. Another point that merits further consideration is whether early joint-preservation interventions in the form of focal anterior capsular release could play a role in preventing or slowing the progression of posterior glenoid wear and humeral head

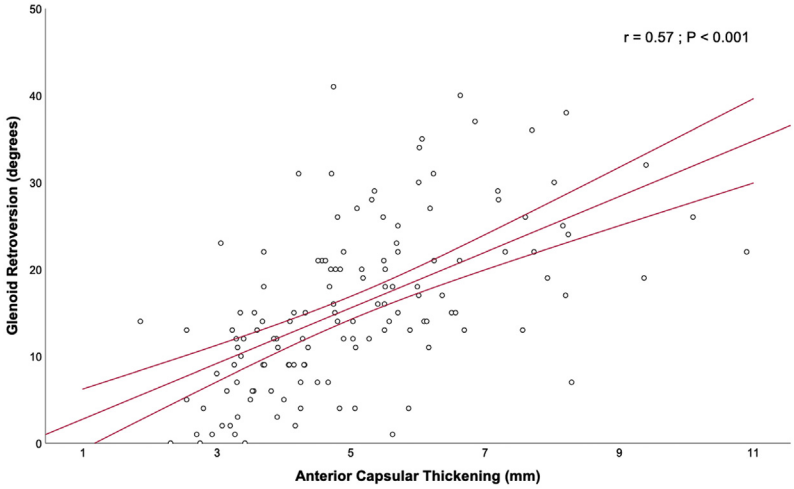

Figure 3 Correlation between glenoid retroversion and anterior capsular thickening.

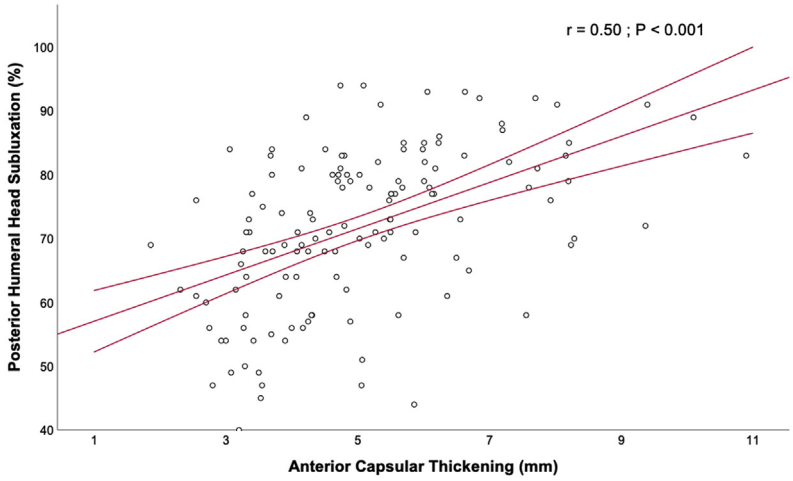

Figure 4 Correlation between posterior humeral head subluxation and anterior capsular thickening.

subluxation. During shoulder arthroplasty, anterior capsular releases (in conjunction with version correction) have been shown to recenter posteriorly subluxated humeral heads.[7,8]

The principal strengths of our study include the use of both MRI and CT scans to characterize our variables of interest and limiting our sample to patients with primary glenohumeral osteoarthritis to minimize heterogeneity. Nonetheless, our analysis was subject to several shortcomings that might be addressed in future research. First, the cross-sectional nature of this study does not allow causal inference. Therefore, we cannot determine whether anterior capsular changes precede the development and progression of glenoid deformity, or *vice versa*. A longitudinal natural-history study of glenoid morphology and anterior shoulder capsule characteristics would be of interest to study a possible causal relationship. Second, our sample was restricted to patients undergoing surgery for primary glenohumeral arthritis. As such, patients with the same diagnosis pursuing nonoperative treatment were not considered. Third, the limited number of glenoid types C and D precluded analysis of these types of glenoid morphology. On the other hand, the high number of glenoid types B2 and B3 is likely reflective of the nature of glenoid wear in osteoarthritic shoulders and less likely to be a result of selection bias, as we routinely acquire CT scans in every patient for preoperative planning. Fourth, we did not measure the posterior capsule as it was less well visualized compared to the anterior capsule, and anterior capsular disease is more typically seen in shoulder osteoarthritis. Fifth, the anterior capsular measurements may be influenced by the shape of the glenoid and the rotation of the shoulder while the MRI was performed. In internal rotation, the anterior capsule is more plicated and may appear thicker than in external rotation. Ideally, evaluation of the results should be done in strictly the same position, but this can be difficult in osteoarthritic shoulders. Finally, our results may

Table II Multivariable linear regression models for glenoid retroversion and posterior humeral head subluxation*

Predictor	Glenoid retroversion				Posterior humeral head subluxation			
	Adjusted mean increase in glenoid retroversion† (deg)	95% CI		*P*	Adjusted mean increase in humeral head subluxation† (%)	95% CI		*P*
		Lower	Upper			Lower	Upper	
Anterior capsular thickening, per 1-mm increase	3.2	2.4	4.1	<.001	3.8	2.7	5.0	<.001

CI, confidence interval.
* Models adjusted for age and sex.
† Represents the beta regression coefficient.

not be widely generalizable to all patient populations as the images were obtained at an urban orthopedic specialty hospital in the northeastern United States.

Conclusions

This advanced imaging study of osteoarthritic shoulders showed that increased thickening of the anterior shoulder capsule was associated with greater posterior glenoid wear and humeral head subluxation. Additional research should determine whether anterior capsular disease plays a causative role in the etiology or progression of eccentric glenohumeral osteoarthritis.

Disclaimers:

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References

1. Aleem AW, Chalmers PN, Bechtold D, Khan AZ, Tashjian RZ, Keener JD. Association between rotator cuff muscle size and glenoid deformity in primary glenohumeral osteoarthritis. J Bone Joint Surg Am 2019;101:1912-20. https://doi.org/10.2106/JBJS.19.00086
2. Bercik MJ, Kruse K II, Yalizis M, Gauci MO, Chaoui J, Walch G. A modification to the Walch classification of the glenoid in primary glenohumeral osteoarthritis using three-dimensional imaging. J Shoulder Elbow Surg 2016;25:1601-6. https://doi.org/10.1016/j.jse.2016.03.010
3. Chainani A, Matson A, Chainani M, Marchand Colon AJ, Toth AP, Garrigues GE, et al. Contracture and transient receptor potential channel upregulation in the anterior glenohumeral joint capsule of patients with end-stage osteoarthritis. J Shoulder Elbow Surg 2020;29:e253-68. https://doi.org/10.1016/j.jse.2019.11.013
4. Choi YH, Kim DH. Correlations between clinical features and MRI findings in early adhesive capsulitis of the shoulder: a retrospective observational study. BMC Musculoskelet Disord 2020;21:542. https://doi.org/10.1186/s12891-020-03569-8
5. Ciccone WJ II, Hunt TJ, Lieber R, Pedowitz R, Esch J, Tasto JP. Multiquadrant digital analysis of shoulder capsular thickness. Arthroscopy 2000;16:457-61.
6. Donohue KW, Ricchetti ET, Ho JC, Iannotti JP. The association between rotator cuff muscle fatty infiltration and glenoid morphology in glenohumeral osteoarthritis. J Bone Joint Surg Am 2018;100:381-7. https://doi.org/10.2106/JBJS.17.00232
7. Gerber C, Costouros JG, Sukthankar A, Fucentese SF. Static posterior humeral head subluxation and total shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:505-10. https://doi.org/10.1016/j.jse.2009.03.003
8. Habermeyer P, Magosch P, Lichtenberg S. Recentering the humeral head for glenoid deficiency in total shoulder arthroplasty. Clin Orthop Relat Res 2007;457:124-32. https://doi.org/10.1097/BLO.0b013e31802ff03c
9. Hartwell MJ, Harold RE, Sweeney PT, Seitz AL, Marra G, Saltzman MD. Imbalance in axial-plane rotator cuff fatty infiltration in posteriorly worn glenoids in primary glenohumeral osteoarthritis: an MRI-based study. Clin Orthop Relat Res 2021;479:2471-9. https://doi.org/10.1097/CORR.0000000000001798
10. Landau JP, Hoenecke HR. Genetic and biomechanical determinants of glenoid version: implications for glenoid implant placement in shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:661-7. https://doi.org/10.1016/j.jse.2008.11.012
11. Matson AP, Kunkel Z, Bernal-Crespo VA, Chainani A, Chainani M, Finley SJ, et al. The histopathology of the humeral head in glenohumeral osteoarthritis. Osteoarthr Cartil Open 2021;3:100147. https://doi.org/10.1016/j.ocarto.2021.100147
12. Moverman MA, Puzzitiello RN, Menendez ME, Pagani NR, Hart PJ, Churchill RW, et al. Rotator cuff fatty infiltration and muscle atrophy: relation to glenoid deformity in primary glenohumeral osteoarthritis. J Shoulder Elbow Surg 2022;31:286-93. https://doi.org/10.1016/j.jse.2021.07.007
13. Rossi LA, Piuzzi NS, Shapiro SA. Glenohumeral osteoarthritis: the role for orthobiologic therapies: platelet-rich plasma and cell therapies. JBJS Rev 2020;8:e0075. https://doi.org/10.2106/JBJS.RVW.19.00075
14. Saltzman BM, Leroux TS, Verma NN, Romeo AA. Glenohumeral osteoarthritis in the young patient. J Am Acad Orthop Surg 2018;26:e361-70. https://doi.org/10.5435/JAAOS-D-16-00657
15. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14:756-60.
16. Walker KE, Simcock XC, Jun BJ, Iannotti JP, Ricchetti ET. Progression of glenoid morphology in glenohumeral osteoarthritis. J Bone Joint Surg Am 2018;100:49-56. https://doi.org/10.2106/JBJS.17.00064
17. Weinstein DM, Bucchieri JS, Pollock RG, Flatow EL, Bigliani LU. Arthroscopic debridement of the shoulder for osteoarthritis. Arthroscopy 2000;16:471-6.