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Small anteroposterior inclination of the acromion is a predictor for posterior glenohumeral erosion (B2 or C)

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Background: Anatomic factors associated with static posterior translation of the humeral head with or without glenohumeral osteoarthritis are unknown. We tested the hypothesis that there is an association between glenoid wear, glenoid version, and/or anteroposterior acromial tilt.

Methods: Ninety-nine patients with glenohumeral joint degeneration involving advanced glenoid cartilage wear and/or rotator cuff disease scheduled for anatomic or reverse total shoulder replacement underwent standardized conventional radiographic and computed tomographic shoulder imaging. Measurements included glenoid version, humeral torsion, posterior acromial slope, and critical shoulder angle. The glenoid shape was classified according to Walch et al, and the integrity of the rotator cuff was assessed.

Results: Patients with glenoid type B2 or C had a median of 4° more glenoid retroversion ($P = .022$), a 5° less steep acromion (posterior acromial slope, 61° vs 56°; $P = .004$), and a higher combined score (glenoid version minus slope; odds ratio, 0.93 [95% confidence interval, 0.89-0.97]; $P < .001$; cutoff, –27°) than those with type A or B1. When the rotator cuff was torn, osteoarthritic changes were milder than when the cuff was intact (eg, $P < .001$ for supraspinatus).

Conclusion: The study's hypothesis that the bony anatomy of the scapula and in particular the acromion is correlated with the type of glenoid wear was confirmed. Both a more horizontal acromial orientation in the sagittal plane and increased posterior glenoid version are found in osteoarthritis of the shoulder associated with eccentric, posterior glenoid wear. Tears of the rotator cuff are significantly associated with concentric osteoarthritis of the glenoid.

Level of evidence: Level III; Cross-Sectional Design; Epidemiology Study

Keywords: Acromion; tilt; glenohumeral; glenoid; osteoarthritis; version; rotator cuff

Degeneration of the shoulder joint involving tears of the rotator cuff and/or osteoarthritis is frequent in patients with shoulder pain.[1,6] It has been shown that the lateral extensions of the acromion, as well as the superior tilt of the glenoid, may relevantly contribute to the development of both pathologies.[8,11] Biomechanically, this has been attributed to an altered mediolateral and inferosuperior orientation and

Approval for the study was obtained from the ethical committee responsible for our institution in Zurich (Basec No. 2016-00826).

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magnitude of the acting forces.[13] In the group with so-called primary osteoarthritis, there are patients in whom joint degeneration develops in an anteroposteriorly centered fashion and others in whom joint degeneration develops with a posteriorly subluxated humeral head. Factors leading to either centered or posteriorly subluxating osteoarthritis are unknown. We hypothesized that particular skeletal configurations could lead to imbalances of the anteroposterior forces and thereby to different patterns of shoulder degeneration.

For this reason, we determined whether the posterior acromial slope, glenoid version, critical shoulder angle (CSA), and/or humeral torsion are related to the development of eccentric rotator cuff tears or osteoarthritis.

Materials and methods

Study population

To identify a well-defined group of shoulders with marked degenerative changes and complete radiographic documentation, we decided to analyze a consecutive, retrospective series of patients who were scheduled to undergo total shoulder replacement in a 1.5-year period between March 2015 and September 2016 at our institution. Of the cases, 8 received an anatomic prosthesis whereas 91 received a reverse prosthesis. All included shoulders underwent preoperative computed tomography (CT) studies with an image through the epicondyles (to define humeral torsion), as well as fluoroscopically centered true anteroposterior, true lateral, and axillary lateral conventional radiographs.[5] Humeral head necrosis, cranial migration of the head with acetabulization, a dislocated acromioclavicular joint, malunited humeral fractures, and prosthetic revisions were excluded. For each of these 99 shoulders, clinical data were extracted from surgical and consultation reports.

Radiologic evaluation

The type of glenoid deformation was classified into A1, A2, B1, B2, or C according to Walch et al.[14] Glenoid version was measured as demonstrated in Figure 1 (anteversion, >90°; retroversion, <90°).

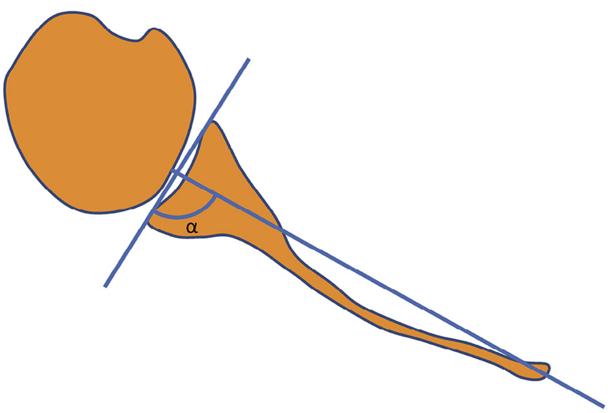

Figure 1 Glenoid version (α) measured in axial computed tomography plane in a right shoulder (anteversion, >90°; retroversion, <90°).

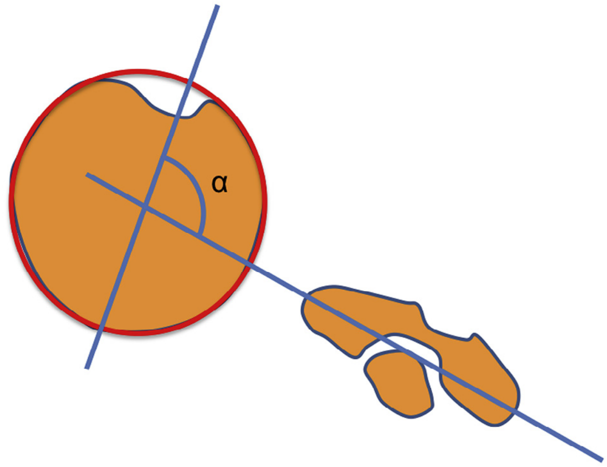

Figure 2 Humeral torsion (α) measured in sagittal computed tomography plane in a right shoulder.

Rotator cuff integrity was determined by combining the information from the surgical reports, medical history, CT scans, magnetic resonance imaging studies, and ultrasound examinations. Each tendon's status was classified as intact or a complete full-thickness tear. On all 99 CT scans, fatty infiltration of the rotator cuff muscles was categorized according to Goutallier et al.[3]

On axial CT, a merged scan combining the axial plane of the elbow and the humeral head was used to evaluate torsion, defined as the angle between the transepicondylar axis and a line connecting the intertubercular sulcus with the center of the humeral head (Fig. 2). On conventional radiography, the posterior slope was determined in the scapular Y-view projection (Fig. 3). The angle was measured by constructing two lines: one projecting onto the scapula from the center of the supraspinatus fossa to the visible distal scapular body and the other connecting the center of the acromioclavicular joint and the most posterolateral edge of the acromion. On anteroposterior views, we measured the CSA (Fig. 4).[8]

Statistical methods

Data are presented as medians (interquartile ranges [IQRs]) because they were mostly not normally distributed. The Wilcoxon rank sum test was used to test anatomic configurations of the shoulder and glenoid version, as well as anatomic configurations and the CSA. The χ^2 test was used to verify the relation between rotator cuff tears and glenoid version. Spearman correlation was used to test the correlation between humeral torsion and tear patterns, as well as anatomic configurations and the CSA. A cutoff value for glenoid version minus posterior acromial slope was calculated using receiver operating characteristics. The described method for the measurement of the posterior acromial slope was evaluated for interobserver correlation by a shoulder fellow and an orthopedic resident, who compared radiographs of 21 nonpathologic shoulders using the scapular Y view with 3 different humeral rotations each, to eliminate radiographic confounding factors. Statistical significance was assumed for $P < .05$. Stata/IC (version 13; StataCorp, College Station, TX, USA) was used.

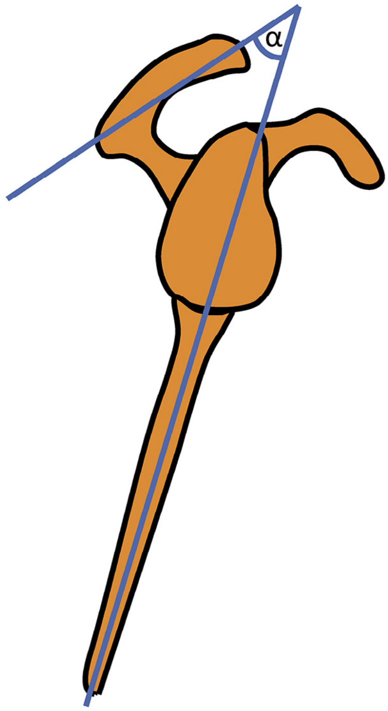

Figure 3 Posterior acromial slope (α) measured on radiographic scapular Y view.

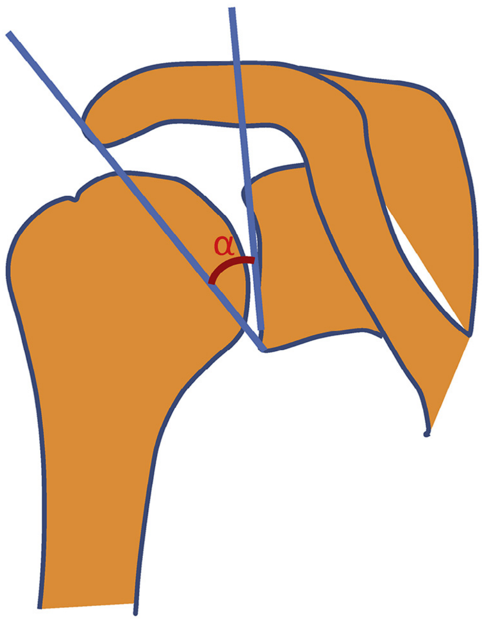

Figure 4 Critical shoulder angle (α) measured in radiographic anteroposterior projection.

Results

Interobserver and intraobserver correlations of measurement of the CSA and of version of the glenoid have been reported previously.[2,7] In this study, measurement of the posterior acromial slope was performed by 1 examiner, who measured every scapula twice, blinded from the first result. The Pearson correlation coefficient was 0.880 for internal rotation, 0.877 for normal rotation, and 0.910 for external rotation ($P < .001$ each), showing a very strong reproducibility of the measurements.

Table I Anatomic configuration of shoulder and glenoid version (N = 99)

Anatomic configuration	Glenoid types A and B1 (n = 77)		Glenoid types B2 and C (n = 22)		*P* value*
	Median	IQR	Median	IQR	
Glenoid version, °	90.0	7.0	86.0	9.0	.022
Posterior slope, °	56.0	11.0	61.0	9.0	.004
Critical shoulder angle, °	34.0	6.0	31.5	8.0	.023
Glenoid version minus posterior slope, °	–36.0	14.0	–24.5	6.0	<.001
Humeral torsion, °	122.0	13.0	124.5	11.0	.584

IQR, interquartile range.
* Wilcoxon rank sum test.

Several morphologic parameters showed a significant association with Walch B2 or C scores (Table I): The median posterior acromial slope was 56.0° (IQR, 11.0°) for Walch A or B1 glenoids but 61.0° (IQR, 9°) for Walch B2 or C glenoids ($P = .004$). Glenoid version was 90.0° (IQR, 7.0°) for Walch A or B1 glenoids and 86.0° (IQR, 9.0°) for Walch B2 or C glenoids ($P = .022$). Furthermore, the median CSA for Walch A or B1 glenoids was 34° (IQR, 6°); for Walch B2 or C glenoids, it was 31.5° (IQR, 8°) ($P = .023$). For the combination of glenoid version and posterior acromial slope, arbitrarily calculated as glenoid version minus posterior acromial slope, the median value was –36° for Walch A or B1 glenoids (IQR, 14°) and –24.5° for Walch B2 or C glenoids (IQR, 6°) (odds ratio, 0.93 [95% confidence interval, 0.89-0.97]; $P < .001$; cutoff, –27°). Humeral torsion was not different in the A or B1 group and the B2 or C group.

As expected, tears of the cuff tendons were significantly associated with a higher CSA and better anteroposterior concentricity than osteoarthritis (Fig. 5, Table II).

Discussion

The primary purpose of our study was to analyze whether and how the scapular anatomy is related to the pattern of shoulder degeneration with specific attention to the development of posterior subluxation as described by Walch et al.[14] Static posterior subluxation as seen in B2 and C glenoids is not typically associated with rotator cuff tears but with a small CSA. Osteoarthritis seems to be accelerated by a short lateral acromion (ie, small CSA), as this configuration increases compressive load during scapular abduction. For posterior subluxation to occur and a B2 or C deformity to develop, however,

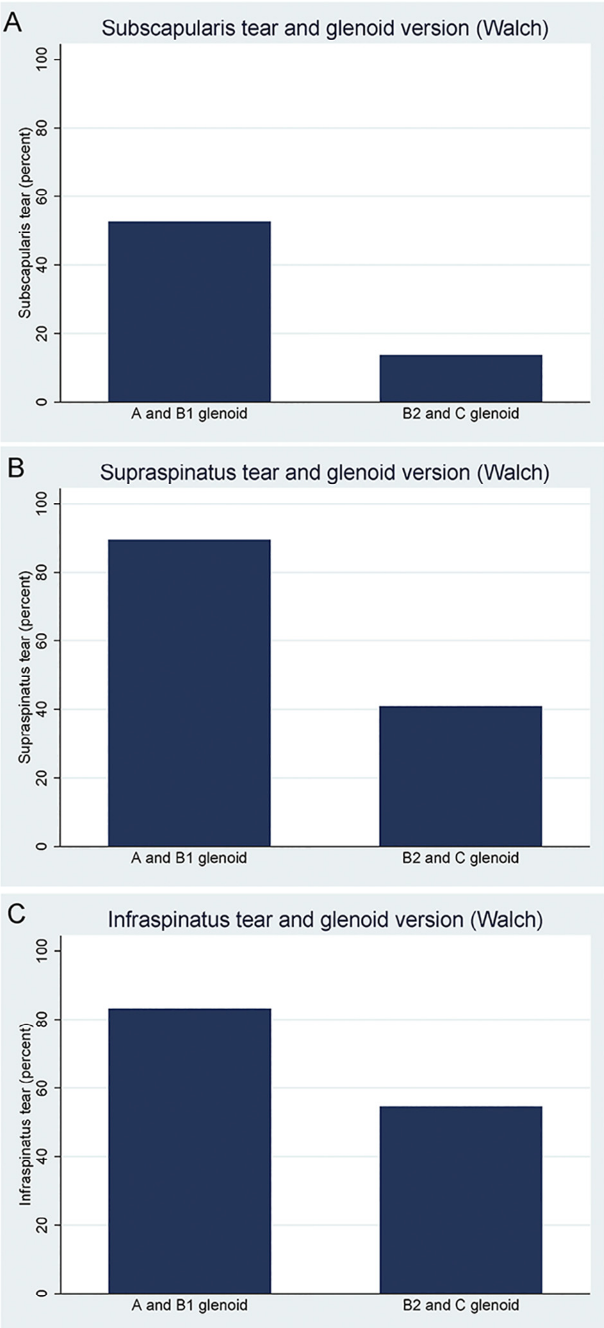

Figure 5 Bar charts of rotator cuff tears and glenoid version (Walch). (**A**) Subscapularis. (**B**) Supraspinatus. (**C**) Infraspinatus.

our results show that the small CSA has to be associated with a relatively horizontal acromion and with an increased posterior tilt of the glenoid in the horizontal plane (Figs. 6 and 7). Trying to interpret the mechanistic basis, one may speculate that a steep and relatively large, posteriorly overhanging acromion stabilizes posteriorly whereas a small, high and horizontal acromion allows the humeral head to subluxate posteriorly, particularly with anterior elevation of the arm. Three-dimensional analyses and modeling of the acromion and

Table II Rotator cuff tears and glenoid version (N = 99)

Tendon tear	Glenoid types A and B1 (n = 77)		Glenoid types B2 and C (n = 22)		*P* value*
	n	%	n	%	
Subscapularis	40	52.6	3	13.6	.001
Supraspinatus	69	89.6	9	40.9	<.001
Infraspinatus	64	83.1	12	54.6	.005

* χ^2 Test.

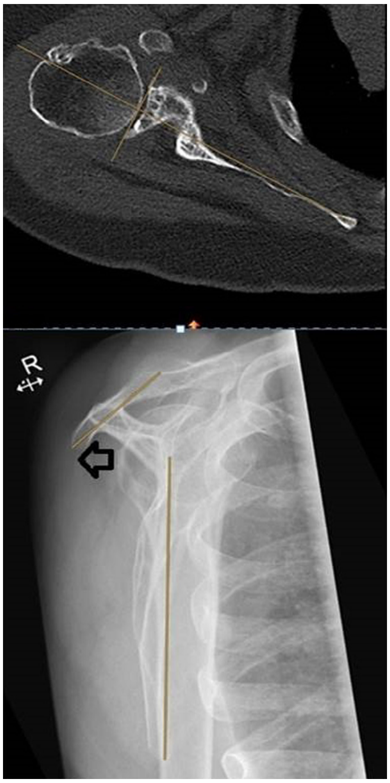

Figure 6 Walch type A glenoid and steep posterior acromial slope (45°). The *black arrow* depicts the direction of posterior humeral head force. *R*, right side.

glenoid shape are under way and may bring further understanding of the relative interaction.

In the past decade, the lateral extension of the acromion has been found to have a highly significant impact on the mediolateral and vertical balance and load of the shoulder joint. Nyffeler et al[11] could show that a full-thickness rotator cuff rupture is associated with a larger lateral acromial extension, measured with the acromion index. Moor et al[8] simplified the measurement and eliminated a deformity of the humeral head or greater tuberosity by introducing the CSA, which was found to be small in patients with primary osteoarthritis and large in those with rotator cuff tears.[9]

Conversely, anteroposterior balance of the joint has not received much attention yet. A recent study by Jacxsens et al[4] looked at the humeral head position and found more

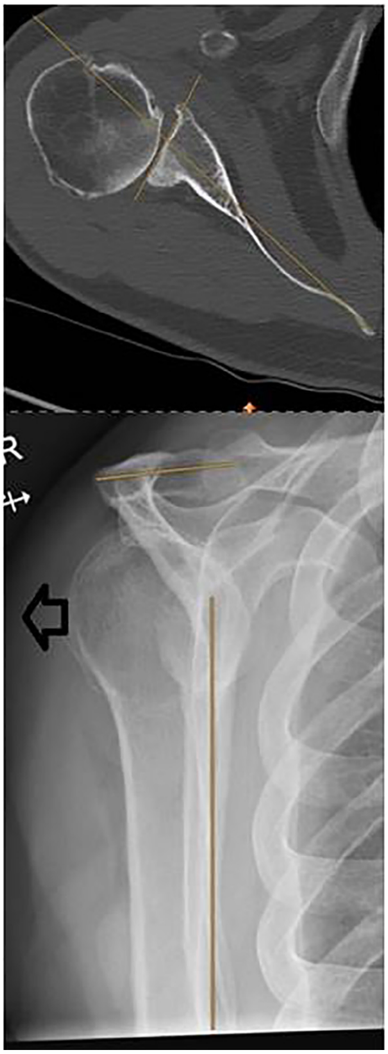

Figure 7 Walch type B glenoid and flat posterior acromial slope (84°). The *black arrow* depicts the direction of posterior humeral head force. *R*, right side.

posterior subluxations in patients with type B than in patients with type A glenoids, which—however—is more a definition than a finding.

In 2016, Scheyerer et al[12] found difficulties judging the integrity of the rotator cuff in patients with increased glenoid version and thereby posterior positioning of the humeral head with respect to the superiorly situated acromion. There seems to be a correlation with increased posterior version, a flat acromion, and the absence of rotator cuff tears that will need further analysis.

Our study looked at a broad range of parameters in patients with relatively advanced degenerative changes of the glenohumeral joint as determined with CT. Consequently, we have the limitation that we could not analyze early anatomic alterations. We included the orientation of the glenoid as an important parameter for anteroposterior stability. The substantial differences in the 2-dimensional analyses identified in this study do not exclude that further interesting findings may arise from future 3-dimensional analysis. As previously published, classifying glenoids according to Walch et al[14] may be challenging.[10] For this reason, we had 1 very experienced examiner classify all shoulders twice on separate occasions without knowledge of the result of the first reading.

A strength of the present data is that most of the findings have been obtained without any possible bias as the expected results were unknown. With more streamlined analyses, possibly including 3-dimensional reconstruction software on larger and specifically assorted patient collectives, it is very reasonable to assume that the statistical clarity will even increase.

Conclusion

In addition to the mediolateral and vertical direction, anteroposterior load and subsequent degeneration on the shoulder are determined by anatomic factors. We have shown that a posterior position of the acromion with steeper (smaller angle) posterior slope may be a protective factor against posterior joint degeneration, whereas a flat posterior acromial slope (larger angle) and especially the combination of a flat posterior acromial slope and an increased posterior glenoid version are risk factors strongly associated with posterior wear and posterior static subluxation. Tears of the rotator cuff are significantly associated with concentric osteoarthritis of the glenoid.

Disclaimer

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