

GLENOID INCLINATION IS ASSOCIATED WITH FULL-THICKNESS ROTATOR CUFF TEARS

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INTRODUCTION

Factors associated rotator cuff pathology include repetitive overhead arm activities, age, and scapular morphology. The best known anatomic association is the “hooked acromion” identified by Bigliani *et al.*, (1986). There may be other morphologic parameters that are associated with rotator cuff pathology. We hypothesized that the angle of the glenoid in the plane of the scapula (“glenoid inclination”) may also be associated with rotator cuff tendon pathology. The rationale for this theory is that the tendency of the humeral head to migrate superiorly, which may impinge the supraspinatus tendon between the humeral head and acromion, depends on the direction of the net muscular and gravitational forces acting on the humerus. If the net force is directed into the glenoid, superior migration should not occur. If the net force is directed too superiorly, the force transmitted to the humerus through the articular surface may insufficient to prevent superior migration of the humeral head. The net force acting on the humeral head can be decomposed into shear and compression. As glenoid inclination angle increases, the superior shear component increases. According to this theory, less deltoid force would be required to produce superior humeral head migration in a shoulder having greater glenoid inclination angle. The objective of this study was to test the hypothesis that glenoid inclination angle play a role in rotator cuff pathology. Two strategies were used to address this hypothesis: (1) an anatomic study was conducted to compare glenoid inclination angles in shoulders with full-thickness rotator cuff tears and normal shoulders; and (2) a computational model was developed to analyze the effect of glenoid inclination on superior humeral head migration.

We hypothesized that glenoid inclination angles would be greater in shoulders with rotator cuff tears.

MATERIALS AND METHODS

Measurement accuracy. A pilot study was conducted to assess the accuracy of measuring glenoid inclination from radiographs. The glenoid angle of four cadaver shoulders was measured radiographically and by three-dimensional digitization. Each shoulder was disarticulated from the torso. Soft tissue was dissected down to the rotator cuff. 600 micron lead beads were glued at the intersection of the spine and medial border of the scapula. Each scapula was placed on a x-ray cassette and an exposure made. The scapula was oriented so that it was parallel to the film.

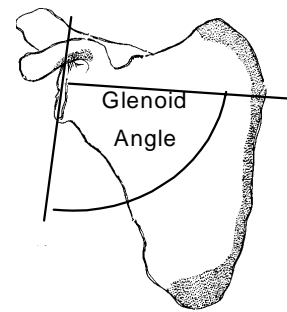


Figure 1. Glenoid inclination angle.

Radiographs were digitized using NIH Image. Four points were identified: (1) lead bead on medial border, (2) spinoglenoid notch, (3) superior glenoid tubercle, and (4) inferior glenoid tubercle. Lines were constructed between points 1 and 2 and between 3 and 4. Glenoid inclination angle was the angle between these two lines (Figure 1). Glenoid inclination was also computed using points digitized in

three dimensions directly from the specimens. A Flock of Birds electromagnetic tracking system equipped with a plastic digitizing stylus was used for digitizing landmarks. Glenoid inclination was computed from the digitized locations and compared to the radiographic measurements.

Anatomic study. Eight pairs of cadaver shoulders were tested (mean age 77; S.D. 10). One shoulder from each pair had a full-thickness rotator cuff tear, while the contralateral shoulder did not. Glenoid inclination angles were computed using the radiographic method. Differences in glenoid inclination angle between shoulder with tears and shoulders without tears were evaluated using a non-parametric sign test.

Mathematical model. An analytic model was developed to relate glenoid inclination angle with the minimum deltoid force necessary to produce superior migration of the humeral head. A planar model was constructed, and it assumed that (1) the glenohumeral joint reaction force acts perpendicular to the articular surface, (2) the glenohumeral joint has negligible friction, (3) superior humeral head migration does not occur when the net reaction force on the humerus can be represented as a non-negative linear combination of vectors normal to the glenoid articular surface. The radius of the glenoid articular surface was assumed to be 26.3 mm, and the distance from inferior to superior glenoid was 39 mm (Iannotti *et al.*, 1992). Rotator cuff forces were taken from electromyographic estimates of muscle force during the initiation of arm abduction (Laursen *et al.*, 1998). The line of action of the deltoid was assumed to be perpendicular to that of the supraspinatus. The lines of action of the infraspinatus and subscapularis were assumed to be 45° below the supraspinatus. The minimum deltoid force necessary to produce humeral head migration was computed at each glenoid inclination angle. All programming was done in MATLAB.

RESULTS

Measurement accuracy. The radiographic technique for measuring glenoid inclination was

validated by three-dimensional digitization. The average difference between glenoid inclination angles measured radiographically and by three-dimensional digitization was -0.17° (S.D. 3.5°).

Anatomic study. The average glenoid inclination angle measured in shoulders with full-thickness rotator cuff tears was 98.6° (5.6° S.D.); the mean glenoid inclination angle in normal shoulders was 91.0° (4.7° S.D.). The difference was found to be statistically significant ($P=0.008$).

Mathematical model. An increase in inclination angle from 90 to 98.6 decreases the predicted minimum deltoid force necessary to superiorly sublux the humeral head by 51%.

DISCUSSION

Glenoid inclination angle appears to be associated with the existence of full-thickness rotator cuff tears, and there is a mechanical explanation for this phenomenon. The mathematical model shows that glenoid inclination angle can significantly affect whether an imbalance of superior and inferior forces acting on the humerus will lead to superior migration of the humeral head. Theoretically, shoulders with a larger inclination angle would be more prone to subacromial impingement of the supraspinatus tendon. If subacromial impingement is related to the development of full-thickness rotator cuff tears, then the anatomic results are consistent with the theory.

This study cannot determine causality. Prospective studies will be required to determine whether the inclination causes the cuff tear or the cuff tear causes the inclination.

REFERENCES

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