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Alterations in Glenohumeral Kinematics in Patients With Rotator Cuff Tears Using Biplane Fluoroscopy

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Summary:
This study quantitatively measured the 3D glenohumeral translations during dynamic shoulder abduction (scaption) in patients with rotator cuff tears using a biplane fluoroscopy system, and found that the humeral head of the rotator cuff patients was positioned inferior and anterior compared to the controls throughout the scaption motion, which was in contradistinction to conventional teaching.

Abstract:
Introduction:
Rotator cuff tears are a common cause of shoulder pain and weakness. While it has been theorized that rotator cuff tears alter glenohumeral motion, there is a paucity of in vivo measurement of glenohumeral motion in patients with rotator cuff tears. The purpose of this study was to quantitatively measure the three-dimensional (3D) glenohumeral translations during dynamic shoulder abduction in the scapular plane (scaption) in patients with rotator cuff tears, and to compare it to glenohumeral motion in healthy shoulders. It was hypothesized that during scaption, patients with rotator cuff tears would demonstrate dynamic superior migration of the humeral head.

Methods:
This prospective cohort comparison protocol was approved by the governing IRB and informed consent was obtained prior to participation. A custom biplane fluoroscopy system measured the 3D position and orientation of the scapula and humerus of 14 patients with full-thickness rotator cuff tears of at least 1 cm (age: 60.4 ± 6.9 years, height: 1.76 ± 0.08 m, mass: 83.8 ± 13.9 kg) as they performed scaption over their full ROM. The data was analyzed at 12.5 frames/s. A high-resolution CT scan of each subject's shoulder was also obtained. The data from the rotator cuff patients was compared to the data from 10 asymptomatic controls (age: 29.7 ± 6.6 years; height: 1.84 ± 0.05 m; weight: 89.8 ± 9 kg).

The 3D geometries of the scapula and humerus were extracted from the CT data and the humeral head center was determined by fitting a sphere to the articular portion of the humeral head. The glenoid center was assumed to be midway between the superior and inferior glenoid rim points. For each frame, the 3D bone position and orientation were estimated using a contour-based matching algorithm (Model-Based RSA, Medis Specials BV, Leiden, the Netherlands), and the 3D position of the humeral head center was determined relative to the glenoid. For each subject the superior-inferior and anterior-posterior translation curves were resampled in 10° increments from 20° through 150° of arm elevation. A two-way ANOVA was performed with independent factors of subject group (rotator cuff patient, control) and arm elevation angle (20° - 150°).

Results:
The humeral head in shoulders with rotator cuff tears were positioned 1.2 mm inferior ($p < 0.001$; rotator cuff tear vs controls: -0.2 ± 1.6 mm vs. 0.9 ± 1.6 mm) and 0.8 mm anterior ($p = 0.003$; rotator cuff tear vs. controls: -3.3 ± 2.6 mm vs. -4.2 ± 1.0 mm) to the controls. There was no significant effect of arm elevation on the glenohumeral translations.

Discussion:
The humeral head of the rotator cuff patients was positioned inferior and anterior compared to the controls throughout the scaption motion which was contrary to our hypothesis. This is surprising, because it is known that patients with massive rotator cuff tears demonstrate a static superior migration. Therefore, we had hypothesized that patients with smaller full thickness tears, and who do not show static superior migration on standard x-ray examination, would show a small amount of dynamic superior migration during motion. Since the tears in our population were primarily located in the supraspinatus, it may be speculated that the superiorly directed pull of the supraspinatus tendon was missing due to the tear, but the inferiorly directed pull of the infraspinatus, subscapularis and teres minor remained intact. Therefore, a small, more inferior positioning was demonstrated during the active motion. Further study is needed to confirm this mechanism. A limitation of this study was that there was a disparity in age between the two populations. While our control group consisted of healthy young subjects, the rotator cuff tear patients were significantly older (t-test, $p < 0.001$). It is currently unknown whether there is an age effect on glenohumeral translation.

Clinical Significance:
It is currently unknown exactly why rotator cuff surgery is successful in restoring function to patients who have undergone rotator cuff repair. Studies have reported that even when there is a retear or incomplete healing after surgery patients often note significant pain relief and improvement of function. This study demonstrated that rotator cuff tears alter normal glenohumeral kinematics, but it was in contradistinction to conventional teaching.