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The Humeroscapular Motion Interface

[Original Articles: Shoulder]

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Abstract

Motion between the humerus and scapula commonly is described as glenohumeral motion. However, humeroscapular motion occurs at two distinct sites. In addition to the motion at the diarthrodial glenohumeral joint, movement occurs between the proximal humerus and related structures and the surrounding sleeve of structures, including the acromion, deltoid, coracoid, coracoacromial ligament, and the muscles attached to the coracoid. This site of nonarticular shoulder motion is defined as the humeroscapular motion interface. Nonarticular humeroscapular motion can be documented and measured using standard magnetic resonance imaging techniques. The maximum average interfacial motion using axial images was 29.1 mm, which occurred at the level of the maximum diameter of the humeral head. Interfacial motion varied depending on the site measured. If pathologic conditions such as adhesions secondary to trauma or surgery interfere with or obliterate this space at sites of significant sliding motion, overall shoulder motion will be limited. Successful treatment of shoulder stiffness related to humeroscapular restraints is likely to require restoration of the normal sliding motion at the humeroscapular motion interface, in addition to resolving restraints affecting the glenohumeral joint motion.

Humeroscapular motion is dependent not only on the smooth gliding between the humerus and scapula at the diarthrodial joint surfaces, but also on the sliding between the smooth undersurface of the coracoacromial arch, deltoid, coracoid process and conjoined tendons, and the upper surface of the proximal humerus and rotator cuff. This nonsynovial articulation is the humeroscapular motion interface. During normal shoulder motion, substantial sliding occurs at the humeroscapular motion interface, as is observed on anatomic dissection or during open procedures on the shoulder. The excursion varies depending on the site measured and the motion performed. Stiffness after shoulder surgery or trauma must be understood and treated in terms of potential pathologic condition at the humeroscapular motion interface.

The interfacial sliding motion that normally occurs at the humeroscapular motion interface can be shown in vivo using magnetic resonance (MR) imaging. Magnetic resonance imaging has the ability to show a wide range of tissue contrast with excellent soft tissue resolution.[1,2,4,6,8,9,11,12,16,17,19] The distinction of the various soft tissues that form the motion interface as seen on MR images allows the in vivo demonstration of the humeroscapular motion interface and the ability to measure the excursion that occurs between the superficial and deep surfaces of the motion interface.

The first purpose of this study was to define and show, in vivo, the humeroscapular motion interface using MR images of subjects with no history of shoulder disorders. The second purpose of this study was to measure the interfacial motion that occurs at various sites during shoulder motion using the MR images. Attention was directed toward measuring the areas of greatest axial excursion and the axial boundaries of humeroscapular motion.

MATERIALS AND METHODS

Using MR imaging, the dominant shoulder in five volunteers with no history of shoulder pain or trauma was imaged. All participants were men ranging in age from 27 to 40 years. Four right shoulders and one left shoulder were imaged. The MR study was performed using a General Electric SIGNA scanner(Waukesha, WI) operating at 1.5 Tesla. Shoulder coils were used to enhance signal to noise ratios. The imaging parameters included three-dimension data acquisition after determination of image field with coronal scout film, 0.9-mm slice thickness in axial plane, 128 contiguous slices from the deltoid tuberosity to the superior surface of the acromion, repetition time of 25 ms, echo time of 6 ms, flip angle of 45°, 256 × 192 matrix, and total acquisition time of 10 minutes and 16 seconds for each series of images.

The volunteer was strapped into place to minimize total body motion during the scan. The initial series of images were obtained with the volunteer actively positioning the humerus in maximal external rotation with the elbow extended. After each scan series was completed, the volunteer was asked to actively internally rotate the elbow approximately 10° to 15° from the external rotation position. Once the subject was stationary, a second series of images was obtained This sequence of events occurred six times, for an acquisition of 768 images obtained during 1.5 hours.

The axial images were reviewed at a second MR terminal. Axial images were selected that represented the same level during each series of image acquisitions. Figure 1 shows MR axial views of a shoulder with external and internal rotation of the humerus. Four representative levels were chosen, based on the reliability of accurate identification of specific anatomic structures. The structures were selected for their ability to represent the axial boundaries of the humeroscapular motion interface and the site of maximal interfacial motion in the current protocol. These sites included the tip of the coracoid process, the widest axial section of the humeral head, the inferior aspect of the articular surface of the humerus, and the level of the deltoid tuberosity. Images were processed on film for anatomic drawings and measurements.

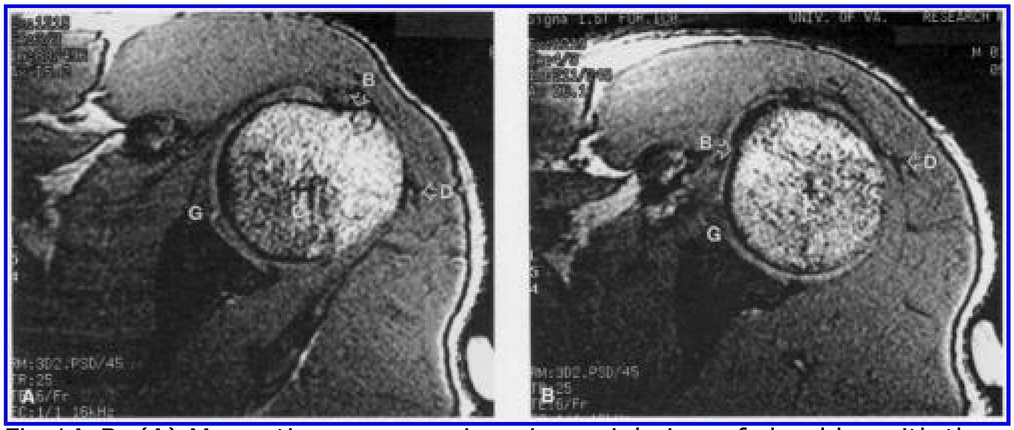

Fig 1A-B. (A) Magnetic resonance imaging axial view of shoulder with the arm at the subject's side, actively held in maximal active external rotation with the elbow extended. B = bicipital groove; C = center of humeral head in relation to articular surface; D = deltoid raphe; G = anterior glenoid. (B) Magnetic resonance imaging axial view of same subject with maximal active internal rotation, elbow extended. Note the position change of points B and D.

Key anatomic structures, such as the glenoid, humerus, coracoid process, biceps tendon and groove, and fibrous intradeltoid bands, were traced onto tracing paper (24 drawings per subject, 120 total images) by an experienced reader of MR images. Attention was focused on determining a consistently identifiable structure throughout the image series. These areas included the anterior aspect of the glenoid, the medial edge of the intertubercular groove, the intersection of a fibrous band (raphe) of the deltoid with the motion interface, and the center of rotation of the articular surface of the humerus. At the most caudal level (deltoid tuberosity), the lateral edge of the scapula was used as a reference for humeral rotation.

Accurately measuring the excursion that occurs in an arc is challenging. This measurement can be performed directly with a measuring device or indirectly using points of reference, their subtended angles, and simple geometry. In the clinical setting, such as the operating room, the excursion that occurs on the surface of the humerus as it rotates is assessed readily. However, for the purpose of improving the accuracy of the measurements from the axial MR images, specific reference points were identified, the change in angle with motion was determined, and the measurements were converted to arc lengths.

The center of rotation of the humeral articular surface was determined using a chart consisting of a series of concentric circles. Lines were drawn from the center of rotation of the humeral head to each reference point(anterior edge of glenoid, deltoid raphe and motion interface intersection, medial edge of the intertubecular groove, and coracoid process). All measurements were referred to a fixed scapular position to quantify accurately interfacial motion because scapular motion necessarily accompanies active glenohumeral positioning.

Using the formula for determining arc lengths (arc length[excursion] =[DELTA] angle/360° × 2[pi]r), the interval excursions and the overall excursions between the scapular and humeral components of the motion interface were determined at each of the four selected axial levels. For example, at the level of the coracoid tip, the axial interfacial motion measured was the motion between the deep surface of the deltoid and the coracoid process versus the motion of the surface of the humerus, specifically at the medial edge of the intertubercular groove (Fig 2).

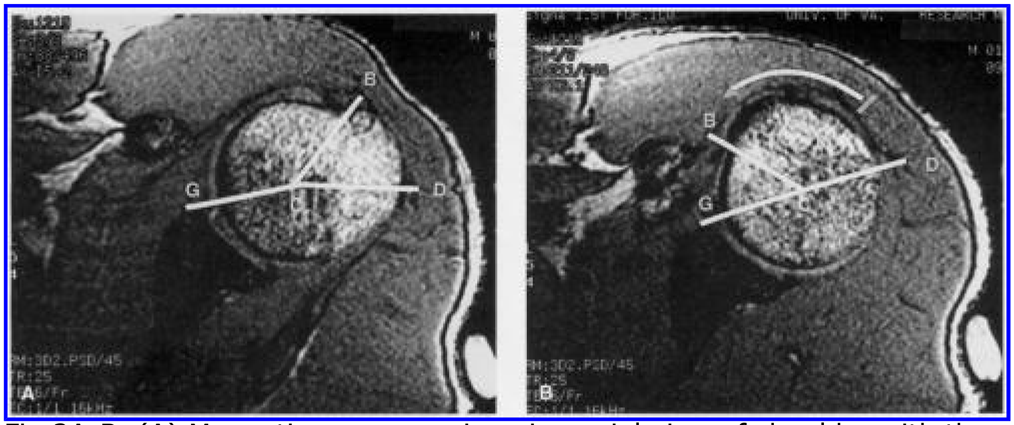

Fig 2A-B. (A) Magnetic resonance imaging axial view of shoulder with the arm at the subject's side. Angular excursion at the humeroscapular motion interface was measured using the anterior glenoid of the scapula as a reference point. G = anterior glenoid. (B) Humeroscapular interfacial motion is shown by differential motion between points B(bicipital groove) and D (deltoid raphe).

RESULTS

The widest axial section of the humeral head had the greatest arc of motion (Level 2). On average, this motion was determined to be 31.1 mm (Table 1). The excursion at the level of the deltoid insertion (Level 4) was 16.4 mm on average. The variation in excursion is related to the radius of the motion arc, as predicted from the formula for determining arc lengths. The humerus is smaller at the metaphysis than at the proximal humeral head region.

Axial Level	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average	Standard Deviation	Range
1	36.2	21.3	23.9	38.8	29.8	30	7.6	21.3 to 38.8
2	34.9	19.4	26.8	39.7	39.6	31.1	8.7	19.4 to 39.7
3	30.2	16.8	21.0	35.8	33.1	28.3	8.8	16.8 to 35.8
4	22.4	10.3	11.2	22.3	15.7	16.4	5.8	10.3 to 22.3

TABLE 1. Humeral Surface Excursions(mm)

The motion that occurred at the undersurface of the deltoid is minimal when measured close to the deltoid origin on the acromion with the arm at the side (Table 2). The motion arc at the deltoid insertion on the humerus was determined to be 16.4 mm on average for the five subjects.

Axial Level	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average	Standard Deviation	Range
1	2.3	0.0	5.6	4.6	−0.4	2.4	2.7	−0.4 to 2.3
2	3.6	−0.8	2.2	9.9	−4.4	2.1	5.4	−0.8 to 9.9
3	6.5	5.6	2.1	3.3	−0.8	3.3	2.9	−0.8 to 6.5
4	22.4	10.3	11.2	22.3	15.7	16.4	5.8	10.3 to 22.3

TABLE 2. Deltoid Excursions (mm)

Because the scapula and the center of rotation of the humeral articular surface were used as references for all measurements, coracoid excursion would be predicted to be 0 (Table 3). This measurement serves as a control for the accuracy of the method of measurement. The average excursion was 0.2 mm, verifying the ability to label precisely points of reference.

Axial Level	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average	Standard Deviation	Range
1	−0.5	0.9	2.0	−0.9	−0.4	0.2	1.2	2.0 to −0.9
2	−4.4	0.4	−0.9	4.3	1.6	0.2	3.2	4.3 to −4.4
3	1.3	2.8	−0.4	−0.5	−2.0	0.2	1.9	2.8 to −2.0

TABLE 3. Coracoid Excursions (mm)

The differential motion or humeroscapular interfacial motion that occurred between the undersurface of the deltoid and medial edge of the bicipital groove was calculated from previous measurements (Table 4). Humeroscapular interfacial motion averaged 29.1 mm at the widest axial level of the humeral head with the arm at the side. Predictably, the interfacial motion at the level of the deltoid insertion was 0.0 mm (Table 5,Fig. 3).

Axial Level	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Average	Standard Deviation	Range
1	33.9	21.3	18.3	34.2	30.2	27.6	7.3	18.3 to 34.2
2	26.6	20.2	24.7	29.8	44	29.1	9	20.2 to 44.0
3	28.4	11.2	18.9	32.6	33.9	25	9.7	11.2 to 33.9
4	0	0	0	0	0	0	0	0

TABLE 4. Motion Interface (mm)

Humeral Level	Humeral Excursion	Deltoid Excursion	Interfacial Excursion
Coracoid tip	30.0 ± 7.6	2.4 ± 2.7	27.6 ± 7.3
Head center	31.1 ± 8.7	2.1 ± 5.4	29.1 ± 9.0
Distal head	28.3 ± 8.8	3.3 ± 2.9	25.0 ± 9.7
Deltoid insertion	16.4 ± 5.8	16.4 ± 5.8	0.0

TABLE 5. Humeroscapular Interface Motion(mm)

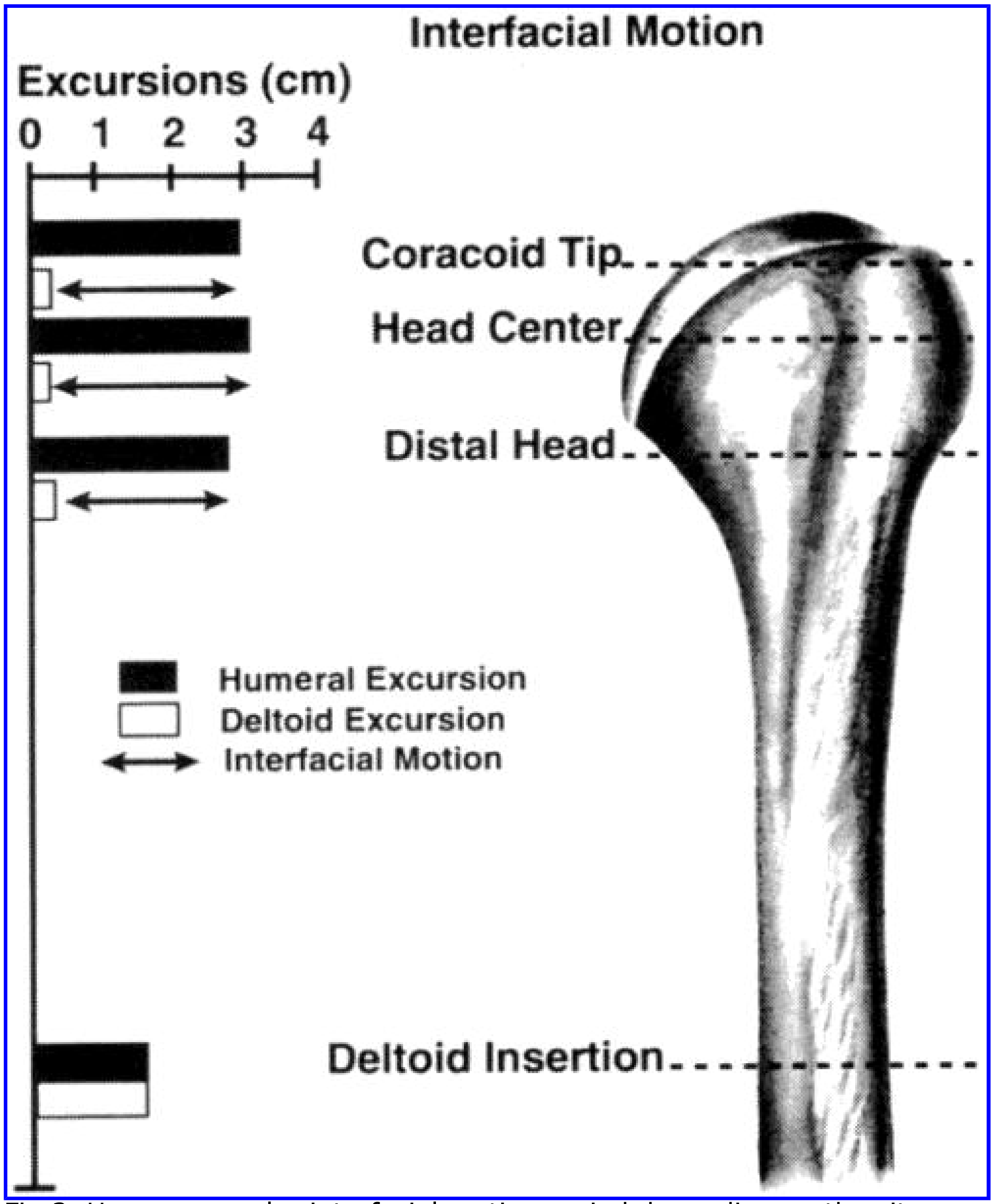

Fig 3. Humeroscapular interfacial motion varied depending on the site measured. Maximum average interfacial motion was 29.1 mm and occurred at the level of the maximum axial diameter of the humeral head.

DISCUSSION

Humeroscapular motion commonly is discussed in terms of the glenohumeral joint.[1,7-10,13-15,18] However, movement between the humerus and scapula occurs not only at the glenohumeral joint, but also at the humeroscapular motion interface. The presence of the subacromial bursa throughout much of the motion interface suggests the importance of motion at this nonsynovial articulation. Adhesions or other pathologic conditions that limit the normal sliding that occurs at the humeroscapular motion interface adversely affect shoulder motion.

The amount of decreased motion depends on the site of the adhesions or pathologic conditions. For example, an adhesion between the coracoid and the proximal humerus substantially would restrict humeroscapular motion. Approximately 3 cm of interfacial motion occurred at this site when the arm, in an unelevated position with the elbow extended, was rotated from a position of comfortable external rotation to internal rotation. Conversely, an adhesion close to the deltoid insertion site would not be expected to limit substantially the humeroscapular motion. This study is limited to the evaluation of humeroscapular motion with the arm at the side because of high resolution MR scan technology. Clinically relevant limitations in shoulder motion can be detected with the arm at the side but often are more apparent with the arm in an abducted or elevated position.

This study does not attempt to define an absolute measurement of humeroscapular motion. Variance and confidence levels cannot be determined with the current study protocol. However, the results of this study show the concept of humeroscapular motion separate from the diarthrodial glenohumeral joint motion using MR imaging. An important followup study would be the determination of normalized values of humeroscapular motion in subjects without pathologic conditions of the shoulder. Multiple sessions of MR imaging with a similar motion protocol could provide the data necessary to establish the normal range of humeroscapular motion, including the statistical determination of variance and confidence levels. Establishing the normal range of humeroscapular motion may provide the ability to define shoulder stiffness as a result of an abnormality of the humeroscapular motion interface using new technology such as cine MR imaging.

Various conditions must be considered when evaluating restrictions in shoulder motion. Humeroscapular motion may be limited by capsuloligamentous contracture, arthritis, avascular necrosis, infection, fracture, dislocation, or conditions that interfere with the normal sliding motion at the humeroscapular motion interface. Most conditions that limit humeroscapular motion by affecting the glenohumeral joint surface can be diagnosed with a routine history, physical examination, and plain radiographs. However, the differential diagnosis for conditions affecting the normal motion at the humeroscapular motion interface has not been defined.

Abnormalities of the humeroscapular motion interface usually are secondary to previous trauma or surgery, especially surgical procedures for rotator cuff pathologic conditions. The relationship between prior trauma or surgery distinguishes motion interface pathologic conditions from other soft tissue conditions that restrict shoulder motion, especially idiopathic frozen shoulder, which is primarily a problem of the glenohumeral capsule.[3,13,18] Posttraumatic or postoperative stiffness should not be considered a variant of idiopathic frozen shoulder because the clinical characteristics, pathologic conditions, and treatment are not the same.

The diagnoses of posttraumatic and postoperative stiffness are made from the history of significant trauma or previous surgery, limitation of humeroscapular motion, and plain radiographs that do not show pathologic changes of the glenohumeral joint. The physical examination may suggest the motion interface site affected, such as the location of previous surgical incisions. Occasionally, the clinical examination will reveal traction of the soft tissues in the area of previous surgery related to an adhesion involving the motion interface. This most commonly will be seen in patients who have undergone surgical treatment of rotator cuff disease, followed by an extended period of immobilization. If the patient is unable to regain the normal sliding motion of the humeroscapular motion interface, rotation of the arm will produce a visible traction at the site of the surgical incision. Attempts at increasing the motion will be associated with an increased level of visible traction and an increase in the patient's pain.

Surgical treatment of posttraumatic or postoperative stiffness begins with reestablishing the motion interface by eliminating adhesions. For example, in a patient who has undergone rotator cuff surgery and in whom substantial adhesions at the motion interface have developed, it is unlikely that continued therapy or manipulation will reestablish the normal sliding that occurs at the humeroscapular motion interface. Surgical treatment would include exposure through the prior surgical site. Adhesions between the coracoacromial arch and the underlying rotator cuff would be sharply incised. This includes adhesions not only at the acromion but also at the undersurface of the coracoid, which would affect axial motion or internal and external rotation as suggested by the axial motion shown in this study. Once the humeroscapular motion interface is reestablished, additional steps to release the glenohumeral capsuloligamentous restraints often are unnecessary for the diagnosis of posttraumatic or postoperative stiffness. If a release of the humeroscapular motion interface adhesions does not reestablish normal motion, it is likely that the previous surgery or trauma has additionally affected the rotator cuff or underlying glenohumeral joint capsule at an associated site. Although release of the glenohumeral joint capsule may be necessary at the site affected by the trauma or prior surgery, a complete capsular release indicated for the treatment of idiopathic frozen shoulder generally is unnecessary.[5] Techniques developed to treat idiopathic frozen shoulder such as a manipulation or an arthroscopic capsular release are likely to be ineffective in reestablishing humeroscapular motion interface when the diagnosis is defined correctly as posttraumatic or postoperative stiffness. Finally, after release of the adhesions of the humeroscapular motion interface, early postoperative movement is essential to maintain the motion and to encourage the restoration of an enduring sliding surface.[3,16]

Motion between the humerus and scapula occurs at the glenohumeral joint and the humeroscapular motion interface. The humeroscapular motion interface is defined as the sliding surface bordered by the deep sides of the deltoid, acromion, the coracoid process and its tendons on one side and the superficial surfaces of the humerus, rotator cuff, biceps tendon, and its sheath on the other side. Using standard MR technology, the greatest amount of interfacial motion occurred at the wides axial section of the humerus. This motion decreased as the distance from this site increased. Interfacial motion was absent at the level of the deltoid insertion. Normative values of axial interfacial motion were not established. In addition, motion in other planes, such as the sagittal and coronal planes, may reveal significant variance to the absolute measurement of axial interfacial motion. The purpose of this investigation was to define the humeroscapular motion interface and to measure the variation in interfacial motion that occurs at various axial levels. Appreciating the concept of a humeroscapular motion interface provides substantial clinical insight when encountering problems of humeroscapular stiffness, especially when the stiffness is related to prior trauma or surgery. Restoration of motion at the entire humeroscapular interface is likely to be a valuable adjunct to the operative management of these challenging conditions.

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