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ORIGINAL STUDY

Restricted scapular mobility during arm abduction : Implications for impingement syndrome

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Scapular mobility plays a central role in normal shoulder function, and alterations in scapular mobility have been suggested as a factor in impingement syndrome. We therefore measured the effect of restricted scapular mobility during arm abduction on acromiohumeral and coracohumeral distances. For the control measurements, healthy volunteers (n = 10, all male, age range 25-35 years) underwent multislice computed tomography in a supine position, with the humerus actively maintained in the scapular plane at 45° internal rotation and 60, 90 or 120° abduction. To restrict scapular mobility a custom-made brace was then placed on each volunteer and fastened firmly with bandages, and the measurements were repeated. From the three-dimensional images the acromiohumeral and coracohumeral distances were measured. With the humerus in 90° abduction, the acromiohumeral distance was significantly reduced (Student's t test). This result suggests that impingement syndrome may have a functional component.

Keywords : medical imaging ; scapula ; shoulder ; subacromial impingement syndrome.

INTRODUCTION

Scapular mobility plays a central role in normal shoulder function. Scapular motion on the thorax is a complex three-dimensional combination of translation and rotation which in turn affects humeral mobility (*15*). During humeral elevation, the scapula moves on the thorax approximately half as much as it moves with respect to the humerus, and this allows the head of the humerus to remain relatively centered with respect to the glenoid (*7,12,15*). During arm elevation, the acromion must be tilted up to avoid impinging on the rotator cuff (*12*). If the scapula is unable to position itself to allow free glenohumeral elevation, the coracoacromial arc has a greater potential for impingement on the humeral head (*15*).

Painful arc of motion is a frequent cause of shoulder disability. It is caused by mechanical

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impingement on the rotator cuff as it passes under the coracoacromial arc (*10*). The term impingement syndrome refers to the compression of soft tissues between the coracoacromial arc and the head of the humerus during shoulder movement. Possible mechanisms include an increase in the volume of the structures beneath the arc due to pathology (e.g. haemorrhage, fibrosis or calcification) and a decrease in available space between the arc and the head of the humerus (*4*). The pain associated with impingement syndrome has been ascribed to compression of the supraspinatus and biceps tendons and of the greater tuberosity (*2*). Impingement syndrome can be progressive, and therefore the identification of aetiological factors is important (*18*).

Alterations in scapular mobility have been suggested as a factor in impingement syndrome (*6,12,18*). During physical examinations of patients with impingement syndrome, Neer (*18*) noted that when scapular movement was prevented manually and the arm was raised anteriorly, pain occurred. The type of scapular rotational tilt disorders that affect shoulder impingement was a concern previously. Endo *et al* concluded that in shoulder impingement syndrome, both upward and axial external rotations of the scapula were impaired at the painful arc angle of abduction (*6*). It remains unclear, however, whether altered scapular mobility might be a cause or a result of impingement. The purpose of this study was therefore to measure, with a three-dimensional imaging method in healthy volunteers, the effect of restriction of scapular mobility on acromiohumeral and coracohumeral distances during arm abduction.

MATERIALS AND METHODS

After the study was approved by our institution's ethics committee, 10 healthy male volunteers (age range 25-35 years) having no symptoms, signs or history of shoulder disease were enrolled in the study. Written informed consent was obtained from all study participants, and all procedures were in accord with the Helsinki Declaration.

The dominant upper extremity was evaluated in all participants ; all were right-handed. Multislice computed tomography (Brilliance 64-channel, Philips Medical Systems, The Netherlands) was performed to provide three-dimensional images of the bones of the shoulder.

Fig. 1. — Images were obtained with the humerus at a 30° angle relative to the coronal plane, at abduction angles of 60, 90 and 120°.

All images were obtained with the volunteers in a supine position, with the humerus at a 30° angle relative to the coronal plane, to ensure abduction in the same plane as the scapula (*9*) (fig 1). The internal rotation of the humerus was maintained at 45° in all volunteers in all images. With these constant parameters, images were obtained with the humerus in active abduction of 60, 90 and 120°. For the first two of these angles the elbow was maintained at 90° flexion, but due to the limited size of the scanner bore, for the image at 120° abduction, it was necessary for the elbow to be flexed at 120°.

After these control images were obtained, a custom-made brace was placed on each volunteer to restrict scapular mobility. Although the scapula was not completely immobilized by the brace, the goal was to restrict scapular motion as much as possible and then observe whether this would affect anatomic relations during arm movement. The brace was molded from plaster cast material and extended beyond the palpable scapular boundaries in all directions. It was fastened firmly with bandages, and this arrangement did not involve the clavicle of the imaged shoulder (fig 2). Images were then obtained at the same three angles of abduction as in the control images.

During the scans, participants wore protective shields for the thyroid and trunk. These were positioned so as not to interfere with image acquisition. Each image required 3 seconds of radiation exposure, which amounted to a total of 18 seconds per volunteer for the entire study.

Fig. 2. — To restrict scapular mobility, a custom-made brace was placed on each volunteer and fastened firmly with bandages.

From the resulting three-dimensional images obtained during restricted and unrestricted scapular mobility, the shortest distances between the acromion and the head of the humerus, and between the coracoid and the head of the humerus, were measured (fig 3a,b). The effects of restricted versus unrestricted scapular mobility on these distances were evaluated statistically with the use of Student's t test. The effects of abduction angle within the restricted and unrestricted conditions were evaluated with a one-sample test. Statistical analyses were performed with SPSS statistical software (SPSS Inc., version 11.5). Statistical significance was defined as a p value of < 0.05.

RESULTS

Coracoid process – humeral head distances obtained during restricted scapular mobility at 60, 90 and 120° of abduction did not differ significantly from the corresponding distances in the control images ($p > 0.05$). Acromion process – humeral head distances obtained during restricted scapular mobility at 60 and 120° of abduction likewise did not differ significantly from the corresponding distances in the control images. However, with the humerus in 90° of abduction, the acromion process – humeral head distances were significantly shorter during restricted scapular mobility ($p = 0.03$, table I). During unrestricted scapular motion, the acromion process – humeral head distances at 120° abduction were also significantly shorter than those during unrestricted scapular motion at 90° of abduction ($p < 0.001$).

DISCUSSION

In 1972 Neer introduced the idea of a syndrome caused by the coracoacromial ligament and the anterior third of the acromion impinging on the

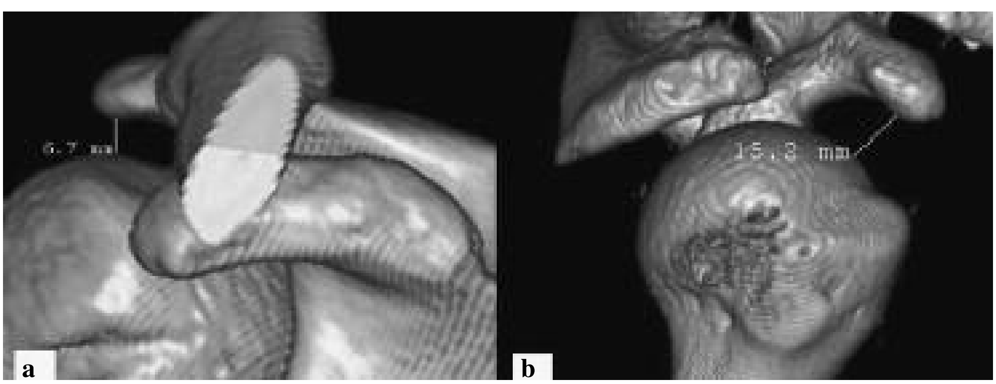

Fig. 3. — From the images obtained during restricted and unrestricted scapular mobility, the shortest distances were measured (a) between the acromion and the head of the humerus, and (b) between the coracoid and the head of the humerus.

Table I. — Shortest acromiohumeral and coracohumeral distances during arm abduction with restricted and unrestricted scapular mobility

Scapular mobility condition	Abduction (degrees)	Mean distance (millimetres)	*p* value
AH Unrestricted Restricted	60	9.94 9.06	0.592
AH Unrestricted Restricted	90	10.07 7.26	**0.031**
AH Unrestricted Restricted	120	6.46 6.78	0.858
CH Unrestricted Restricted	60	15.92 14.32	0.478
CH Unrestricted Restricted	90	15.91 13.45	0.218
CH Unrestricted Restricted	120	10.22 11.40	0.501

AH : Acromiohumeral distance.
CH : Coracohumeral distance.

rotator cuff (*17*). Since then, studies have demonstrated that encroachment on the coracohumeral (*5*) and subacromial (*8*) space is associated with symptoms and signs of impingement.

In a magnetic resonance imaging study of patients with impingement syndrome, Graichen *et al* (*8*) found that the acromiohumeral distance depended on the severity of disease, the presence of muscle activity and the angle of abduction. However, independent of disease severity, the acromiohumeral distance was significantly reduced during muscle activity at 90° of abduction. Our measurements made during restricted scapular mobility at 90° of abduction are consistent with this, and suggest the possibility that in patients with impingement syndrome, the involved scapula is less mobile. Further support for this possibility is provided by our measurements made in the control condition, when the scapula was free to move (table I) ; these values directly parallel those made by Graichen *et al* (*8*) in healthy controls during no muscle activity, at abduction angles of 60, 90 and 120°.

Pressures in the subacromial space have been studied in patients with impingement syndrome. Hyvönen *et al* (*11*) found that these pressures were higher in patients with impingement syndrome compared to patients with acromioclavicular dislocation, who served as the controls. In the patients with impingement syndrome, pressures increased significantly during arm abduction.

The possibility that anatomic characteristics can be an aetiologic factor in impingement syndrome has been suggested (*18*), but some studies have not confirmed this. In a study of the acromial slope and its relationship with shoulder impingement, Moses *et al* (*16*) found no significant relation between scapuloacromial angle and impingement. A study of the distance between the coracoid process and the lesser tuberosity similarly found no significant differences in shoulders with rupture of the subscapularis tendon compared to shoulders without rupture (*19*). These negative findings suggest the possibility that impingement syndrome can arise as a functional problem.

In a cadaver study of normal shoulders removed via forequarter amputation, Burns and Whipple (*2*) investigated anatomic relationships between the coracoacromial arc and subacromial structures. They bolted the scapula to an upright plywood frame and moved the humerus through various angles, and found that forward elevation of the humerus in the scapular plane resulted in impingement of the greater tuberosity against the anterior edge of the acromion. Our observations are consistent with this, and to explain the finding that humeral maneuvers in a normal cadaver can produce impingement, we suggest that the fixation of the scapula was a factor. This possibility is supported by the fact that the arcs of glenohumeral motion were limited to 90° or less, due to the scapula being fixed to the frame.

Several studies have revealed disturbances in scapulothoracic kinematics in conjunction with impingement syndrome (*1,3,13,14,20,21,22*). Su *et al* (*20*) investigated scapular kinematics in 40 swimmers (20 healthy and 20 with shoulder impingement). Before their swim practice session, the two groups had similar patterns of upward rotation of the scapula. After swimming, the impingement group demonstrated less upward rotation of the scapula, particularly at 45, 90, and 135° of humeral elevation. As a possible explanation for this reduction, the authors suggested that the serratus anterior and trapezius muscles were fatigued as a result of swimming practice. In a study of healthy volunteers, Tsai *et al* (*21*) demonstrated that repeated external rotation of the shoulder against resistance, to the point of fatigue, produced subsequent alterations in scapular kinematics.

Observations of altered kinematics of the scapula in patients with impingement syndrome do not answer the question of whether these alterations are a cause or an effect of impingement. Longitudinal studies of patients before and after they develop impingement syndrome would therefore be useful. Recently, Abbott and Richardson described a 49-year-old woman who had upper thoracic myofascial pain and spasms, and was treated with injections of botulinum toxin into her upper trapezii (*1*). The patient subsequently developed impingement syndrome bilaterally. The patient's physical examination at this point revealed that during active humeral abduction there was diminished scapular elevation. After botulinum therapy was stopped, the patient's symptoms markedly improved. The authors hypothesized that iatrogenic weakening of the upper trapezius impaired scapular rotation and predisposed the patient to develop impingement syndrome.

In conclusion, we found that in healthy volunteers, abduction and internal rotation of the humerus do not affect acromiohumeral distance when the scapula is free to move, but these maneuvers can reduce this distance at 90° of abduction when scapular mobility is restricted. This finding suggests the possibility that the origin of impingement syndrome has a functional component.

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