Measurement of the anteroposterior translation of the humeral head using MRI

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Summary. Anteroposterior translation of the humeral head within the glenohumeral joint was investigated using MRI. Ten normal shoulders, 11 recurrent anterior dislocations, 10 stabilised shoulders after the Putti-Platt operation and one shoulder with multidirectional instability, were scanned. The arm was positioned in internal and external rotation and in an overhead position. Gradient echo volume acquisition scans were carried out, and 22 were suitable for evaluation. Consistent results were obtained in the normal shoulders. The unstable and unstable shoulders showed higher variance, but there was no significant anterior translation in external rotation in any group. The range of external rotation was significantly reduced in the unstable and stabilised shoulders. A trend towards posterior translation was found in internal rotation with a mean of 1 (± 0.44) in normal, 0.89 (± 1.67) in unstable and 1.6 (± 1.4) in stabilised shoulders.

Résumé. Nous avons examiné le déplacement antéro-postérieur de la tête humérale dans l'articulation glénohumérale en utilisant l'imagerie par Résonance Magnétique (IRM). Nous avons étudiés 10 épaules normales, 11 épaules avec une instabilité antéro-postérieure, 10 épaules stabilisées par la procédure de Putti-Platt et une épaule avec une instabilité multidirectionnelle. Nous avons mis le bras en 3 positions différentes: en rotation interne, en rotation externe et en abduction complète. Nous avons utilisé l'imagerie par echo de gradient. 22 épaules se prêtaient bien à l'évalua-

tion. Nous avons obtenu des résultats constants dans les épaules normales. Les épaules instables et stabilisées montraient une plus grande variance. En rotation externe, nous n'avons pas trouvé un déplacement significatif dans aucune groupe. Cependant, la rotation externe était significativement réduite dans les épaules instables et les épaules stabilisées ($P < 0.01$). Nous avons trouvé une tendance à un déplacement postérieure quand le bras était mis en rotation interne, avec une moyenne de 1 (± 0.44) mm dans les épaules normales, 0.89 (± 1.67) mm dans les épaules instables et 1.6 (± 1.4) mm dans les épaules stabilisées.

Introduction

Long term reviews of anterior dislocation of the shoulder have shown that there is a significant risk of developing symptomatic osteoarthritis [3, 4, 10, 11, 12]. Severe limitation of external rotation and advanced osteoarthritis of the glenohumeral joint are associated with posterior subluxation of the humeral head in many cases. Many authors have concluded that patients with significant internal rotation contractures, caused by a tight anterior capsular repair, are at an increased risk of developing posterior subluxation and osteoarthritis [2, 4, 10, 11, 12].

CT scanning [14], plain radiographs [5] and ultrasound [8, 9] have been used to measure the position of the humeral head in the glenohumeral joint. Shoulders with anterior instability showed abnormal anterior translation of the humeral head.

Only one study has described the biomechanical changes produced by anterior reconstruction; cadavers were used and abnormal posterior translation of the head found after the Bankart repair [7]. Since the main purpose of the Putti-Platt operation is to shorten the subscapularis and anterior capsule, this procedure may produce even more posterior translation of the humeral head.

We investigated the anteroposterior translation of the humeral head after the Putti-Platt operation by using magnetic resonance imaging (MRI) and compared the findings in normal volunteers and patients with glenohumeral instability. One of the problems is producing a standard axial section of the glenohumeral joint and we achieved this by using contiguous thin section MRI evaluated using 3D reconstruction software.

Materials and methods

The study involved 32 dominant shoulders in 30 persons, and these included 10 shoulders of normal volunteers, 11 shoulders with recurrent anterior instability, 10 after Putti-Platt operations and one shoulder with multidirectional instability. Approval of the local ethical committee was obtained.

The arm was positioned in maximum active internal and external rotation, and in full elevation with internal rotation. No special preconditioning was obtained before the scan. All scans were carried out on a 1.0 Tesla Siemens Impact Magnet with a 3.5 inch (8.9 cm) Field of View surface coil. An axially oriented coherent Gradient Echo (FISP sequence) was obtained in each of the 3 positions. Imaging parameters were a TR of 32 milliseconds (ms), a TE of 10 ms and a flip angle of 40°. Thirty-two contiguous sections were obtained with 256 phase encoding steps producing a 256² matrix. Total acquisition time was 4 minutes and 24 seconds for each position.

The data set was evaluated using internal 3D reformat software. True axial sections of the glenoid, perpendicular to the plane of the glenoid and to the scapular wing, were obtained. Three sections of each of the images were produced: one through the middle of the glenoid; the 2 others 2 mm and 4 mm deeper (Fig. 1). A best fit circle was applied to the subchondral bone of the humeral head and its centre was considered as the centre of the head. A tangential line was drawn to the articular surface of the glenoid and its midpoint defined. A perpendicular was dropped through the centre of the head to the tangential line, and the position of the head with respect to the centre of the glenoid was measured (Fig. 2a, b). This was repeated on all 3 axial sections, and the translation of the head was defined as the mean of these 3 measurements.

Every patient was assessed by clinical examination, a questionnaire and all, except the normal volunteers, had anteroposterior and axillary lateral radiographs taken of the affected shoulder. Student's *t*-test was used for statistical analysis.

Results

One of the normal volunteers was scanned twice. Two images of each examination were repeated to determine reproducibility (2SD) which was found

Fig. 1. Image of 3 perpendicular planes of the shoulder produced by using internal 3D reformat software. The arm is externally rotated

Fig. 2a, b. MRI showing the method of measuring the position of the humeral head in the axial plane. **a** The humeral head in a normal shoulder is centred with the arm externally rotated; and **b** the head is displaced posteriorly with the arm internally rotated

Fig. 3. Posterior translation of the humeral head (mm) of normal (I), unstable (II) and stabilised (III) shoulders (*status bar* = SEM)

to be 0.76 mm for internal rotation, 0.28 mm for external rotation and 1.52 for the overhead position.

We were concerned with establishing normal measurements, so only high quality scans in which all the anatomical points could be reliably identified were included. Twenty-two scans in 20 patients were evaluated: 7 in the control group, 9 dislocations, 5 who had Putti-Platt operations and one unstable shoulder with multidirectional instability. The mean age of the remaining patients was 30.9 years (range 26 to 35 years), 27.3 years (range 17.2 to 54.2 years), 33 years (range 17.2 to 54.2 years) and 23.6 years respectively.

A mean of 6 (range 2 to 16) true dislocations had occurred in the unstable group. The mean follow up after the Putti-Platt operation was 6.3 years (range 1.2 to 20 years), and there were no recurrences. Radiographs of the unstable shoulders showed Hill-Sachs lesions in 2, fracture of the anteroinferior glenoid rim in 2, and mild osteoarthritis in one. Radiographs of the stabilised shoulders showed Hill-Sachs lesions in 2 and mild osteoarthritis in one [15].

The results of measurement of humeral head translation are shown in Table 1. Posterior translation from the neutral position in internal rotation was significant in the normal group ($P < 0.01$). Although there was a posterior shift of the head in the unstable group it was not statistically significant. Posterior translation was greatest in the stabilised group, but was not statistically significant ($P = 0.067$), possibly because of the higher

Fig. 4. The relation of posterior translation with the arm in internal rotation to the extent of the loss of external rotation following Putti-Platt repair (negative value = posterior translation)

variance (Fig. 3). There was no significant translation with the arm externally rotated or in the overhead position, but in the stabilised group there was a trend towards posterior translation in the overhead position.

In the normal group, the position of the head was significantly different in internal compared with external rotation ($P < 0.01$) and in internal rotation compared to overhead ($P < 0.05$). There was no significant difference between external rotation and overhead, or between the different positions in the unstable and unstable groups.

The one multidirectionally unstable shoulder showed anterior translation in internal and external rotation, and overhead (4.5 mm, 2.13 mm and 4.13 mm respectively).

The mean range of external rotation of both shoulders in the 3 groups is shown in Table 2. External rotation was not significantly different with the arm adducted and in 490° abduction in the unstable and stabilised group, but they were both significantly different compared to normal ($P < 0.01$). External rotation of the scanned shoulders compared to the opposite side was significantly reduced, both in adduction and abduction ($P < 0.05$), but it was significantly reduced only in adduction in the stabilised group ($P < 0.01$). There were no differences between the groups or between the scanned and opposite shoulders in any other direction.

In the Putti-Platt group the shoulders with more restriction of external rotation showed more posterior translation with the arm internally rotated (Fig. 4), but because of the small numbers this was not statistically significant (logistic regression $R^2 = 0.74$, $P = 0.14$).

Table 1. Anteroposterior translation of the humeral head (negative value = posterior translation, positive value = anterior translation)

Group	Shift in internal rotation (mm)		Shift in external rotation (mm)		Shift in overhead position (mm)	
	Mean	SEM	Mean	SEM	Mean	SEM
Normal	-1.01	0.17	0.05	0.20	-0.01	0.39
Unstable	-0.89	0.55	0.11	0.34	0.11	0.51
Stabilised	-1.60	0.64	-0.06	0.59	-0.50	1.18

Table 2. Range of external rotation in clinical examination ($\pm$ SD)

Group	External rotation at the side of the body (degrees)		External rotation in 90° of abduction (degrees)	
	Scanned	Contralateral	Scanned	Contralateral
Normal	71 ($\pm$ 7)	71 ($\pm$ 7)	90 ($\pm$ 0)	90 ($\pm$ 0)
Unstable	48 ($\pm$ 14)	61 ($\pm$ 16)	64 ($\pm$ 20)	86 ($\pm$ 11)
Stabilised	42 ($\pm$ 14)	64 ($\pm$ 10)	72 ($\pm$ 18)	83 ($\pm$ 10)

Discussion

The main purpose of the Putti-Platt operation is to incise and overlap the subscapularis and anterior capsule creating a double layer and eliminate the posttraumatic laxity [13]. The effect is to restrict external rotation.

In 1982, Neer et al. reported 26 shoulder replacements for severe arthritis following recurrent dislocations, all but 4 of whom had previous operations; their average age was 45 years [12]. Glenoid involvement was severe with erosion of its posterior rim. The tight capsule was implicated as the cause of these degenerative changes [12].

Two further reports in 1985 and 1990 described 7 and 10 patients respectively who developed severe glenohumeral osteoarthritis many years after anterior capsular repair [3, 4]. All had restricted movement and 3 had posterior subluxation. These authors agreed with Neer's conclusion that the tight capsular repair was responsible and they made a theoretical biomechanical analysis of the changes. MacDonald et al. reported 10 patients who underwent a secondary release for painful internal rotation contractures following anterior repair (7 by the Putti-Platt operation) and emphasised that, although osteoarthritis can result from recurrent dislocation, it more often occurs when there has been an operation [11].

Lusardi et al. described 19 patients with severe internal rotation contractures after anterior reconstruction carried out an average of 11.2 years previously for recurrent instability; 9 required an arthroplasty and the others were treated by subscapularis lengthening and capsular shift [10]. They concluded that these patients were at risk of

glenohumeral osteoarthritis and posterior subluxation.

In spite of these reports, anteroposterior translation of the humeral head after anterior capsular repair has not been previously studied in vivo.

Glenohumeral motion in the horizontal plane was investigated by Howell et al. in 20 normal subjects and 12 patients with anterior instability [5]. Axillary lateral radiographs were taken by placing the arm in 4 different variations of 90° of abduction. In the controls, the head was centred in the glenoid throughout the horizontal plane of movement, except with the arm in maximal extension and external rotation when the head was 4 mm posterior to the centre of the glenoid. In 7 of the 12 patients, anterior translation occurred.

Ultrasound evaluation of the position of the humeral head was reported in 150 normal shoulders, 34 patients with multidirectional and 23 with unidirectional instability [8, 9]. Various positions were assessed and all the unstable shoulders showed significant anterior translation, and in multidirectional instability inferior translation, compared to the controls and the opposite shoulder.

Increased anterior translation has been observed with cross-body movement following tightening of the posterior capsule in cadavers [2]. The motion of the humeral head, the magnitude of contact force and its location, and the contact area have also been measured in cadavers [7]. A typical Bankart lesion was then created, followed by a Bankart repair with or without tightening of the capsule. The conclusion was that the increased contact force and its posterior shift, might be re-

lated to degenerative arthritis reported in clinical cases [7].

We have not found any report of in vivo measurements on stabilised shoulders. The difficulty is to produce standard views or sections on which measurements can be made. Howell et al. accepted that plain radiographs frequently could not be interpreted [5], and there is a similar problem with CT scans because minor changes in the plane of axial sections can distort identification points. Ultrasound measurement has similar difficulties. Georgousis et al. reported an accuracy of ± 1 mm, using Howell's method with a new positioning device; measurement of the head against the glenoid in the horizontal plane varied from 4 mm to -3 mm in neutral rotation and 5 mm to -5 mm in 90° of external rotation [1]. This variance does not support the findings of others that there is no significant translation of the head in the neutral position [2, 5, 6], and the accuracy of their measurements could be questioned.

MRI has the advantage of using internal 3D reformat software which allows the plane of the image to be altered in any plane subsequent to the scan. A standard true axial section of the glenoid, perpendicular to the plane of the glenoid and to the scapular wing can be obtained, using identification points on the skeleton, and the level of axial section selected.

We applied the best fit circle to the subchondral bone of the humeral head. Soslowsky et al. showed that the glenohumeral articular surfaces have the same radii within 2 mm in 88% and within 3 mm in every case; they suggested that the joint surfaces might be approximated by a section of a sphere with small deviations of less than 1% of the radius and that the subchondral surfaces are similar in curvature to the corresponding cartilage surfaces [16]. The subchondral bone is usually well defined on the gradient echo images and it is easy to fit a circle and use its centre as the centre of the head. It is more difficult to determine the centre of the glenoid on axial sections as the anterior or posterior margins are not always clearly visible, especially after injury or operation. We were unable to evaluate 10 scans for this reason. Repeated measurements from normal shoulders were consistent, but unstable and stabilised shoulders showed high variance.

Significant anterior and posterior translation has been demonstrated in cadaveric shoulders with the conclusion that the translation is induced by tightness of the capsule and glenohumeral ligaments [2, 6]. This could be increased by operative repair of the capsule. The translations occur most

with passive positioning of the arm since extreme arcs of rotation could not be achieved actively [2, 6]. This could explain why we did not find significant translation with the arm in external rotation in any of the subgroups since the shoulder was positioned actively. Clinical examination had shown that external rotation was significantly ($P < 0.01$) reduced in unstable shoulders probably because of apprehension, and in stabilised shoulders as a result of the operation. This may have prevented significant anterior translation in the unstable group and possible posterior translation in the stabilised group.

Cadaver studies suggest that anterior translation would occur during internal rotation, but we found posterior translation with the arm internally rotated with an average of 1 mm in normal, 0.89 mm in unstable and 1.6 mm in stabilised shoulders (Fig. 3). In the stabilised group there was also a positive correlation between loss of external rotation and the amount of posterior translation in internally rotated shoulders (Fig. 4). Although stabilised shoulders showed the greatest posterior translation in internal rotation and overhead, this was not significant presumably because we used active positioning of the arm. Our findings support those of others that the head is maintained with 1 mm or 2 mm of the centre of the glenoid in arcs of motion when the capsular tissues are not tight [2, 5, 6].

Posterior translation may be important in the development of osteoarthritis following anterior capsular repair and 3D MRI offers a highly reproducible means for evaluation, but there are limits to the possible positions of the arm due to the size of the MRI tube. We could not confirm significant posterior translation following repair, although there was a trend towards this.

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