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Atrophy of the supraspinatus belly

Assessment by MRI in 55 patients with rotator cuff pathology

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A study of 5 fresh cadaveric shoulders demonstrated that an oblique-sagittal plane which crosses the scapula through the medial border of the coracoid process offers a view of the supraspinatus fossa mostly limited by bone.

This view could easily be reproduced by MRI and we called it the Y-shaped view. It allowed a reliable measurement of supraspinatus muscle atrophy by the calculation of the occupation ratio (R) which is the ratio between the surface of the cross-section of the muscle belly and that of the fossa.

This ratio was calculated in a prospective study based on 55 shoulders divided into 3 groups with different rotator cuff status: group I, 15 controls; group II, 10 degenerative cuffs, without tears; group III, 30 operated tears. There was no difference between groups I (mean ratio 0.7) and II (mean ratio 0.62), but the ratio was decreased in group III (mean ratio 0.44), in which the extent of the tear in both the sagittal and coronal planes aggravated the muscle atrophy. We propose a three-stage classification to improve indications for rotator cuff tear treatment.

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Occasionally, the anatomical and functional results of reconstruction of full-thickness rotator cuff tears, where two tendons or more have been primarily sutured, are disappointing (Harryman et al. 1991). Therefore we raise the question whether there is a limit of muscle degeneration beyond which direct tendon repair cannot be safely proposed.

Such a limit cannot be appreciated solely on the basis of duration of symptoms, clinical presentation, or radiological and sonographic evaluation of the size of the tear. Probably an evaluation of the torn cuff should be complemented by an assessment of the degeneration of the muscle belly (Goutallier et al. 1990). We attempted to develop a reproducible and reliable method to define supraspinatus muscle atrophy with help of MRI.

Material and methods

The aims of our anatomical study were to define the oblique-sagittal plane which offers the most extended osseous limits for the supraspinatus fossa and to define the lateral limits of the supraspinatus muscle attachment in this fossa.

The purpose of the radioclinical study was then to find a simple and reproducible method of measuring the muscular atrophy based on the oblique-sagittal plane previously defined by the anatomical study. The value of this method was then tested clinically.

Anatomical study

At first, 5 non-embalmed cadaveric shoulders were studied to assess the limits of the supraspinatus fossa. As this evaluation was independent of the rotator cuff status, dissection of the supraspinatus tendon itself was not necessary. The shoulders were deeply frozen and 4 slices were obtained by sawing parallel to the plane of the glenoid fossa, every 10 mm from the medial border of the coracoid process (slice 1), to the middle of the supraspinatus fossa (slice 4) (Figure 1). The limits of this fossa were then directly measured and divided into osseous (O) and muscular (M) limits: O representing the scapula and the clavicle, and M representing the deep surface of the trapezius (Figure 2). A ratio O/M of these 2 limits was then calculated.

Another 5 non-embalmed shoulders were then dissected to define the lateral attachment of the supraspinatus muscle on the scapula. The clavicle and the acromion were removed en bloc with the trapezoid muscle to obtain a view of the supraspinatus muscle from above, from the axial border of the scapula medially, to the great tuberosity of the humerus laterally. Then the continuity of the rotator cuff tendons was checked and the belly of the supraspinatus was carefully removed in order to keep the deepest

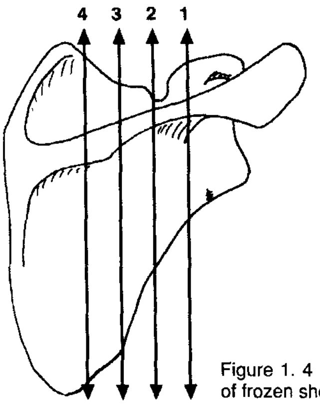

Figure 1. 4 levels of oblique-sagittal cross-sections of frozen shoulders (scapula viewed from the back).

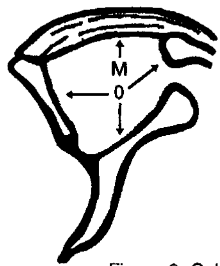

Figure 2. Calculation of the ratio O/M between osseous (O) and muscular (M) limits of the supraspinatus fossa on an oblique-sagittal anatomical slice.

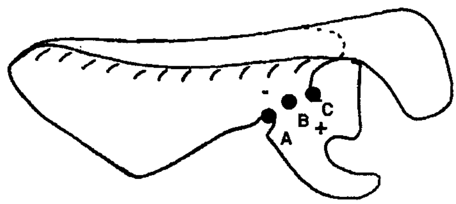

Figure 3. Position of the lateral attachment of the supraspinatus muscle in its fossa from an above view.

muscular fibers and the aponeurosis attached to the bone. To define the lateral limit of this attachment, the distances were recorded between this limit and 3 defined landmarks: A, bottom of the scapular notch, C, base of the scapular spine just above the spino-glenoid notch, and B, midpoint of the line between A and C, which represents grossly the course of the suprascapular pedicle (Figure 3) (Bigliani et al. 1990). These distances were measured in millimeters; positive if lateral to those 3 bony landmarks and negative if medial.

Radioclinical study

A prospective clinical and MRI study was then carried out on 55 persons divided into 3 groups. Group I consisted of 15 asymptomatic volunteers: 5 men and 10 women, mean age 45 (14–74) years. Group II consisted of 10 patients having tendinopathy without tears: 5 men and 5 women, aged 50 (30–53) years, and group III of 30 patients with rotator cuff tears: 17 men and 13 women, aged 52 (27–67) years. Groups II and III were operated on by the same surgeon. An endoscopic acromioplasty was performed to treat tendinopathies with both intraarticular and subacromial assessments of the tendons. Open surgery was performed when a tear was diagnosed preoperatively (group III). In none of these patients did A-P radiography reveal a superior migration of the humeral head.

At the time of surgery, the size of the tear was anatomically described in both the sagittal and coronal planes, independently of the size of the patient. In the sagittal plane, the lesions were classified into 4 types: (a) only supraspinatus ruptured (including less than a quarter of the anterosuperior fibers of the infraspinatus torn, or only laminated); (b) supraspinatus and rotator interval ruptured; (c) supraspinatus and infraspinatus torn, with a rupture of more than a quarter of the fibers of the latter muscle; (d) complete tear, when more than 2 tendons were totally torn (including the subscapularis). In the coronal plane, we used the grading score, according to Patte (1990), based on the position of the viable tendon stump with regard to the apex of the humeral head: grade 1 at the great tuberosity, grade 2 at the apex of the humeral head and grade 3 at the level of the glenoid fossa. Operations included the following: 26 direct repairs, 3 deltoid flaps and 1 acromioplasty, without repair.

All MRI images were obtained with a 1Tesla unit (Magneton Impact, Siemens, Germany) The patient lay supine in a pain-free position, with the arm in neutral rotation along the chest and a curved loop surface coil was used. The examination was performed, using T1- and T2-weighted sequences in axial, coronal and oblique-sagittal planes. Particular attention was paid to the orientation of this last sequence, according to the scout axial view. The oblique-sagittal images were taken parallel to the plane of the glenoid fossa, every 4 mm from the great tuberosity to the medial aspect of the scapular fossa, making sure that images of the planes defined in the anatomical study were obtained.

The quantitative analysis was then performed on the spin-echo T1-weighted oblique-sagittal images (TR: 480ms, TE: 12ms, FOV: 250 × 250, matrix: 380 × 512).

To evaluate the atrophy of the supraspinatus muscle, we calculated the occupation ratio (R) of the supraspinatus fossa by the muscle belly. This analysis was based on the ratio between the surface of the muscle S1 and the surface delineated by the limits of the fossa S2 (Figure 4). The selected oblique-sagittal image was digitalized in order to use a calculation program (Sigma, Ilab, Rennes, France). The limits of the surfaces were drawn by hand, and the ratio, R=S1/S2, was automatically calculated. The readings were made by two radiologists and a surgeon, using a blinded technique.

The correlation and relative error between the results achieved by the 3 readers were calculated and

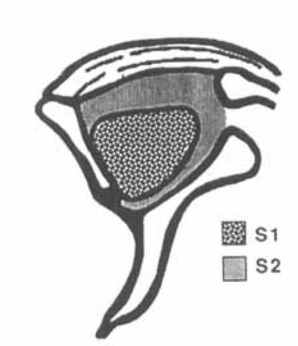

Figure 4. Calculation of the occupation ratio R on the oblique-sagittal view. S1 Surface of the supraspinatus muscle, S2 surface of the entire supraspinatus fossa.

Table 1. Ratio between osseous (O) and muscular (M) limits of the supraspinatus fossa

Shoulder	Slice 1	Slice 2	Slice 3	Slice 4
1	2.5	0.6	1	0.75
2	2.4	0.6	0.9	0.9
3	2.2	0.75	0.82	0.93
4	2.75	0.62	1.1	1.32
5	2.24	0.7	0.93	0.98
Mean	2.4	0.6	0.9	0.9

Table 2. Position of the lateral attachment of the supraspinatus (in mm)

Shoulder	Point A	Point B	Point C
1	–5	–3	–2
2	–5	–2	+5
3	–7	–2	+5
4	–5	–2	+3
5	–5	0	+10
Mean	–5.4	–1.8	+4.2

the final result was a mean of these values expressed from 0 (empty fossa) to 1 (full fossa). Then the mean values of R in the different clinical populations were analyzed, using a statistical analysis based on nonparametric tests (Mann-Whitney, Kruskall-Wallis). The level of significance was 0.05.

Results

Radioanatomical study

In the first 5 shoulders, slice 1 demonstrated the highest O/M ratio, between 2.2 and 2.75 (Table 1). At this level, the scapula is cut through the medial border of the coracoid process and the lateral border of the spine, just above the spinoglenoid notch. Moreover, the clavicle partially closes the anterosuperior part of the fossa. The particularly low ratio of slice 2 corresponded to the bottom of the coracoid notch. Even if the spine was posteriorly more expanded on slices 3 and 4, the disappearance of the coracoid process and the anterior projection of the clavicle resulted in a lower ratio, leaving only the deep surface of the trapezoid muscle as the superior limit of the fossa .

The lateral bony attachment of the supraspinatus muscle always remained medial to points A and B (mean distances were, respectively, –5.4 mm and –1.8 mm), but spread laterally to point C in 4 of the 5 dissections (mean + 4.2 mm, –2 to 10 mm) (Table 2). This lateral extension overhung the spinoglenoid notch and the suprascapular pedicle, as it crossed the spine of the scapula.

This preliminary anatomical study suggested that slice 1 provided the largest bony limits for the supraspinatus fossa and probably represented the most reliable level for the calculation of the occupation ratio. Moreover, this slice demonstrated that the supraspinatus muscle kept the posterior bony attachment at this level. Therefore it was decided to continue the radioclinical study by measuring the occupation ratio on the MRI view corresponding to this anatomical slice 1: we called it the Y-shaped view.

Radioclinical study

This Y-shaped view was found to be easily reproducible, since it was available for all the 55 clinical cases. When 3 readers (r1, r2, r3) calculated the occupation ratio, the relative error was 12 (3–30%). The positive correlation coefficient was never under 0.9 (r1–r2: 0.9, r2–r3: 0.93, r1–r3: 0.96).

The highest value obtained for the occupation ratio, 0.87, was found in group I. Aggravation of the tendinopathy resulted in a decreased ratio (Table 3). The differences in the mean values of R between the 3 groups of patients were significant when the severity of the tendinopathy was considered (p 0.001), but were not age-related (p 0.5). On the contrary, there was an age-related difference within group I, between the 5 healthy volunteers under 40 years (R 0.77, SD 0.05, mean age 25) and the other 10 who were older than 40 years (R 0.67, SD 0.06, mean age 56) (p 0.03).

In group III, there was no difference in the occupation ratio when the tear involved only the supraspinatus or extended to the rotator interval. The difference dramatically increased when the infraspinatus was torn or when the tear involved more than 2 tendons (0.32, SD 0.1) (Table 4).

The drop in this ratio also correlated with the coronal retraction of the tendon stump: 0.59 (SD 0.11) for grade 1, 0.41 (0.12) for grade 2 and 0.30 (0.11) for

Table 3. Occupation ratio of the supraspinatus fossa related to grade of supraspinatus tendinopathy

Grade	n	Occupation ratio, mean (SD)
I	15	0.7 (0.09)
II	10	0.62 (0.11)
III	30	0.44 (0.15)

Table 4. Occupation ratio of the supraspinatus fossa related to the extent of the tear

Tears	n	Occupation ratio, mean (SD)
Supraspinatus alone	11	0.55 (0.14)
Supraspinatus and rotator interval	4	0.55 (0.19)
Supraspinatus and infraspinatus	6	0.36 (0.04)
More than 2 tendons	9	0.32 (0.1)

Decrease of the occupation ratio is significant between a tear of the supraspinatus alone, and a tear which extends to the infraspinatus or to more than 2 tendons (p 0.001)

Figure 5. MRI oblique-sagittal view demonstrating the lateral attachment of the supraspinatus muscle on the spine of the scapula, above the the supraglenoid notch (black arrows).

grade 3 (p 0.0004). Lastly, when a large capsulotomy was required for the repair, the ratio was 0.33 (0.09) and up to 0.50 (0.16) when such capsulotomy was not necessary (p 0.004).

Discussion

Tendinopathies of the rotator cuff muscles should be considered as part of a disease of the whole muscle. Previous experimental and radioclinical studies have demonstrated that the muscles atrophy and the fatty degeneration worsen with the anatomical extent of a full-thickness tear and the duration of the symptoms (Björkenheim 1989, Goutallier et al. 1994, Nakagaki et al. 1994). A reliable and reproducible analysis of this atrophy may be of importance to explain clinical or surgical failures and understand the course of the disease and improve the indications and techniques for surgery.

The calculation of the occupation ratio of the supraspinatus is reliable. It concerns an easily delineated surface, which is compared to an anatomical landmark represented by the limits of the supraspinatus fossa on the Y-shaped view. It has been shown to be mostly osseous and therefore hardly changes with time and the condition of the shoulder. The ratio is easy to calculate and we found a good correlation between the results of 3 independent readers. Most MRI softwares permit this calculation in a prospective manner at the time of the examination.

We found that this bony landmark made the analysis easily reproducible from one patient to another and in the course of time. Thus, pre- and postoperative evaluations become possible, especially as there are no misleading radiological artefacts because of the distance of the Y-shaped view to the operation site. This difficulty is encountered with other measurements using the coronal plane from the supraspinatus fossa to the humeral great tuberosity, where the tendon to be repaired is anchored (Nakagaki et al. 1994).

Our anatomical study demonstrated that the supraspinatus belly insertion spreads more laterally than has been classically described (Gardner et al. 1980). This attachment on the anterior aspect of the spine, above the supraglenoid notch, can be visualized on the oblique-sagittal view and may limit the medial retraction of the muscle (Figure 5). Thus the diminution of the occupation ratio can be interpreted much more as an atrophy than as a retraction.

The radioclinical part of our study demonstrated that the ratio was never as high as 1.0 because of the fatty environment, particularly on the anterosuperior aspect of the supraspinatus muscle. This fatty layer can increase with obesity and artificially reduce the occupation ratio. The atrophy seems to develop with the evolution of the tendinopathy, even without a tear, and seemed more important in older patients who were asymptomatic. This is in relative contradiction to other reports, which consider fatty degeneration to be specific to the tear (Gouttallier et al. 1994). Atro-

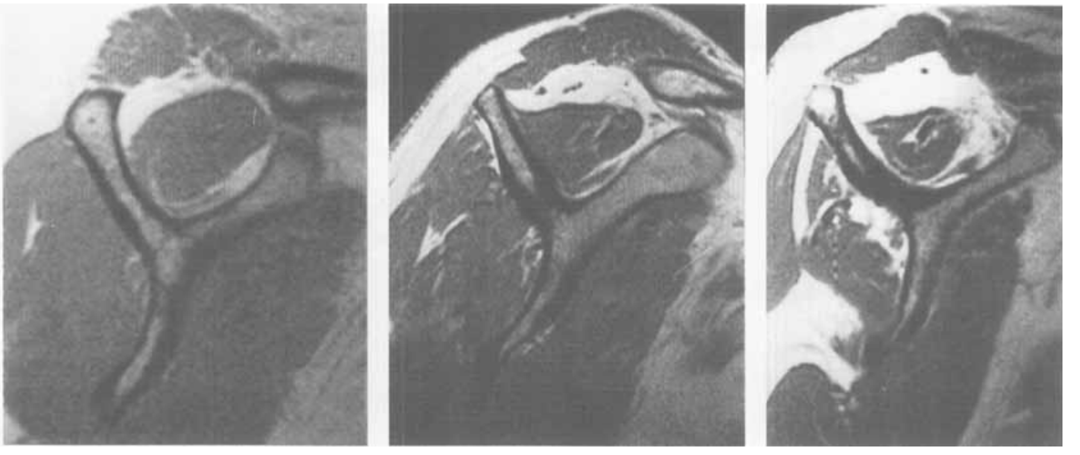

Figure 6. 3 grades of supraspinatus atrophy. From left to right: stage I, stage II, and stage III (the latter with associated infraspinatus atrophy) .

phy and fatty infiltration are two different expressions of the same muscle disease and this previous disagreement could be explained by the better sensitivity of the quantitative analysis we propose.

In any case, the supraspinatus tendon tear represents the first turning-point of this muscle disease. The occupation ratio is still above 0.5 when the tear involves the supraspinatus alone or extends to less than 25% of the superior fibers of the infraspinatus posteriorly or to the rotator interval anteriorly. The second turning-point is the extension of this tear to the entire infraspinatus or subscapularis or to both. The occupation ratio becomes half that of an asymptomatic shoulder or of a nonperforated tendinopathy. At this stage, an atrophy of the remaining non-ruptured muscle may develop, probably due to progressive inactivity of the shoulder (Goutallier et al. 1994).

The need for a large capsulotomy is associated with such a low occupation ratio, itself correlated with the extent of the tear, and one may question the elasticity and viability of the supraspinatus tendon and belly. This may explain suture failures (Harryman et al. 1991) in large tears and some disappointing results regarding strength, since the cross-sectional correlates well with muscle strength (Maughan et al. 1983).

We propose a classification of supraspinatus belly atrophy based on the occupation ratio of the supraspinatus fossa (Figure 6). In the case of a ratio between 1.00 and 0.60 (stage I), the muscle can be considered as normal or slightly atrophied. Values between 0.60 and 0.40 (stage II) suggest moderate atrophy. Values below 0.40 (stage III) indicate serious or severe atrophy.

In the case of rotator cuff tear, this preoperative MRI grading of atrophy may help in the choice of treatment. Grades I and II may predict a problem-free and reliable direct repair of the torn tendon. On the contrary, a grade III atrophy indicates surgical difficulties and unreliability of a direct suture.

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