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ORIGINAL ARTICLE

Deltoid muscle tropism does not influence the outcome of arthroscopic rotator cuff repair

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Abstract
Background Several different factors have been identified as causes of failure of rotator cuff (RC) repair. However, no studies focused on the role of the deltoid muscle. The aim of this study was to investigate the role of the deltoid tropism in the outcomes of arthroscopic RC repair procedures.
Materials and methods Nine male (45 %) and 11 female (55 %) patients who underwent arthroscopic RC repair were included in the study. The mean age was 63.5 ± 8.1 years (range 50–74 years), and the follow-up averaged 1.9 ± 1.3 years (range 1–5 years) after surgery. Clinical outcomes were assessed using the modified University of California, Los Angeles (UCLA) shoulder rating scale, Wolfgang criteria shoulder score and Oxford shoulder score (OSS). Functional outcomes were evaluated considering active and passive range of motion of the shoulder and muscle strength. The deltoid tropism was measured pre-operatively and post-operatively using T2-weighted transverse MRI images.
Results No statistically significant correlation was found between the thickness of each portion of the deltoid muscle (vD, lD and dD) and the UCLA shoulder rating scale, Wolfgang shoulder score and OSS. At the same time, no statistically significant relationship was detected between the thickness of each portion of the deltoid muscle (vD, lD and dD) and the functional outcomes.
Conclusions The deltoid tropism does not influence the results of arthroscopic RC repair. Early RC repair may prevent the reduction in the tropism of the deltoid muscle. Nevertheless, further prospective randomized studies with larger samples are necessary to clarify the role of deltoid tropism in the outcomes of arthroscopic RC repair procedures.

Keywords Deltoid muscle · Rotator cuff · Outcomes · Failure · Shoulder · Arthroscopy

Introduction

The incidence of rotator cuff (RC) tears is variable from 5 to 39 % in the population [1]. Although most RC repair procedures present excellent results in terms of pain relief and restoration of function, unsatisfactory outcomes and high re-tear rates have been reported in the literature [2, 3].

Several different factors may determine the failure of arthroscopic RC repair, such as age, smoke, rehabilitation, abuse of non-steroid anti-inflammatory drugs [3–6]. Moreover, current studies underlined the role of atrophy of the RC muscles, while other investigated the role of fatty infiltration of the RC muscles in outcomes of RC repair procedures [1, 7–9]. However, no studies focused on the role of the deltoid muscle.

The purpose of this study was to investigate the role of the deltoid tropism in the outcomes of arthroscopic RC repair procedures.

Materials and methods

Inclusion criteria were: diagnosis of rotator cuff tear, the absence of episodes of instability or dislocation of the shoulder, the absence of radiographic signs of fracture of

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the glenoid or greater tubercle or lesser tubercle of the humerus, arthroscopic repair of RC tears and execution of a pre-operative and post-operative MRI. Exclusion criteria were: no pre-operative or post-operative MRI of the operated shoulder, inflammatory joint disease at the time of surgery and at the last follow-up, pathology of the glenoid labrum, degenerative arthritis of the glenohumeral joint, symptomatic acromioclavicular joint arthritis and inability to complete the questionnaires due to language problems or cognitive disorders.

Enroled patients received complete and detailed information concerning the purpose of the study and gave their informed consent for any procedure provided by the study protocol.

Clinical evaluation

The post-operative clinical evaluation was performed at an average follow-up period of 1.9 ± 1.3 years (range 1–5 years). The following information was collected: age, sex, dominant arm, history of trauma to the affected shoulder, site of the rotator cuff injury, size of the RC tear and pathology of the biceps tendon.

A modified UCLA [10] shoulder rating scale was administered to assess post-operative shoulder pain (10 points), function (10 points), active forward flexion (5 points), strength (5 points) and patient satisfaction (5 points). The maximum score obtainable is 35, and the results were classified as excellent (34–35 points), good (28–33), fair (21–27) or poor (0–20). Furthermore, the Wolfgang criteria [11] were used to evaluate post-operative shoulder pain (4 points), active abduction (4 points), strength (4 points) and patient satisfaction (1 point or minus 1 point). The maximum score obtainable is 17, and the results were classified as excellent (14–17 points), good (11–13 points), fair (8–10 points) or poor (0–7 points). Finally, post-operatively, all patients completed the Italian version of the Oxford shoulder score (OSS) [12], a self-administered 12-item questionnaire that evaluates shoulder function, pain and strength in relationship with daily life activities. The minimum score is 12 point, and the maximum score is 60 points. The higher is the score, the worst is the condition of the shoulder.

Functional evaluation

Two blinded examiners (S.P. and V.C.) performed all the functional evaluations. A standard universal goniometer was used to perform all measurements. The degrees of passive anterior elevation (sagittal plane), passive internal and external rotation (90° of abduction) were measured with the patient in a supine position according to the standard measurements guidelines. At the same time, the degrees of active anterior elevation, external and internal rotation were measured. Care was taken to fix the scapula with one hand, while the other hand of the examiner's rotated the shoulder into position. One examiner held the shoulder position, while a second examiner obtained the measurement after a firm endpoint was established.

Muscle strength was measured with a conventional dynamometer during active anterior elevation, external and internal rotation. The results were expressed in kilograms. Three measurements were taken for each variable, and the arithmetic average was used for statistical purposes [13–15].

MRI evaluation

Pre-operative and post-operative MRI has been performed in all patients. MRI scans were obtained by spin-echo coronal oblique, sagittal oblique and axial T2-weighted images [repetition time (RT): 3200 ms; echo time (ET): 85 ms]. On T2-weighted transverse MRI images, the pre-operative and post-operative thickness of the ventral (vD), lateral (lD) and dorsal (dD) portion of the deltoid muscle was measured in designated directions from the centre of the humeral head (centre of rotation) perpendicularly or parallel to the glenoid surface (Fig. 1). The thickness of

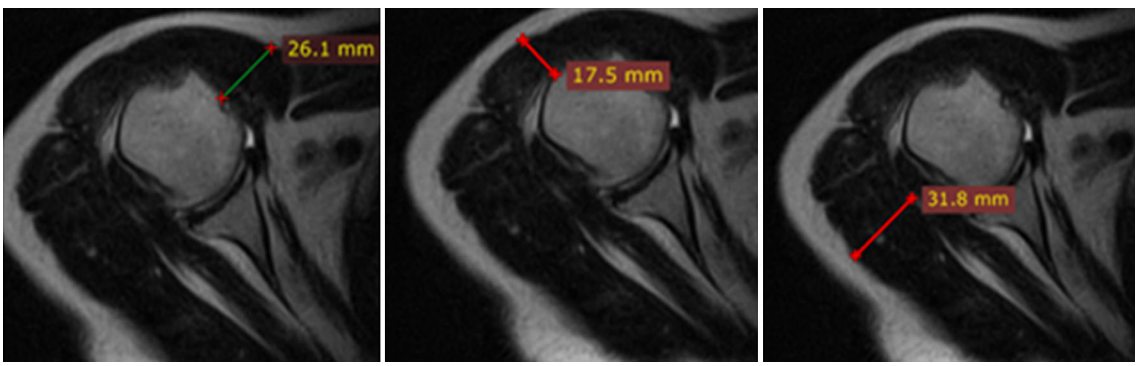

Fig. 1 Measurement of the tropism of the ventral, lateral and dorsal portion of the deltoid

each portion of the deltoid muscle was expressed in centimetres. Two measurements were taken for each parameter, and the mathematical average has been used for statistical purpose.

Surgical procedure

Patients underwent brachial plexus block (associated, in 21 patients, with general anaesthesia) and were placed in beach chair position. The arm was suspended at approximately 45° of abduction and 20° of forward flexion. Distraction of the shoulder joint was accomplished with 4.5–6.5 kg of traction. A diagnostic arthroscopy was then performed to evaluate the extent of the RC tear, any lesions of the biceps tendon, and other associated lesions. To control bleeding, we used radiofrequency, adrenalin admixture to the irrigation fluid, and asked the anaesthesiologist to lower the systolic blood pressure to 90 mm Hg if possible. An arthroscopic pump maintained fluid pressure at 40 mm Hg, increasing it temporarily on demand. A subacromial decompression was performed in the presence of a type III acromion.

The lateral portal was used to mobilize the RC back to its bony insertion. Using a burr through the lateral portal, the footprint of the greater tuberosity was abraded. The rotator cuff repair was performed placing one or two row of suture anchors just in the lateral aspect of the footprint. The number of suture anchors and of suture rows varied with the size of the tear and the type of repair technique.

Post-operative management

Post-operatively the arm was supported using a sling with an abduction pillow for 4 weeks. Active elbow flexion and extension were allowed, but terminal extension was restricted. Passive external rotation was started from the first day after surgery and maintained within a comfortable range. Overhead stretching was restricted until 4 weeks post-operatively to avoid damaging the repair. At 6 weeks, the sling was removed, and overhead stretching with a rope and pulley were started. Isoinertial strengthening and rehabilitation of the rotator cuff, deltoid and scapular stabilizers were initiated at 10 or 12 weeks after the operation, as previously described. Rehabilitation was continued for 6 months. Heavy manual work and overhead activities were allowed after a good restoration of shoulder strength, which occurred 6–10 months after surgery.

Statistics

All statistical analyses were performed by a biostatistician. Spearman's correlation coefficient was used to determine the relationship between the thickness of the vD, lD and dD with the clinical and functional outcomes. The Wilcoxon signed-rank test was used to assess the modification of the deltoid tropism from pre-operatively to post-operatively.

Results

Demographics

Nine male (45 %) and 11 female (55 %) patients who underwent arthroscopic RC repair were included in the study group. The mean age was 63.5 ± 8.1 years (range 50–74 years), and the follow-up averaged 1.9 ± 1.3 years (range 1–5 years) after surgery. The dominant arm was injured in 14 patients (70 %). The right shoulder was involved in 13 (65 %) patients, while the left shoulder was involved in the other seven (35 %) patients. Twelve (60 %) patients had a history of trauma of the affected shoulder, while 7 (35 %) patients had a massive RC tear. Four (20 %) patients had a lesion of the long head of the biceps tendon, while 15 (75 %) patients had a tendinopathy.

Clinical outcomes

According to modified UCLA shoulder rating scale, 1 patient (5 %) had an excellent outcome, 13 (65 %) had a good outcome, 1 (5 %) had a fair outcome and 5 (25 %) had a poor outcome. The mean UCLA total score was 26.3 ± 7.2 points (range 13–33 points). According to Wolfgang criteria, 11 (55 %) had an excellent outcome, 5 (25 %) had a good outcome, 3 (15 %) had a fair outcome and 1 (5 %) had a poor outcome. The mean Wolfgang score was 13.5 ± 2.7 points (range 7–17 points). The mean OSS was 20.7 ± 8.8 points (range 14–45 points).

Functional outcomes

The mean passive anterior elevation was 171° ± 22.2° (range 120°–180°). The passive internal rotation was 90° in all patients, while the passive external rotation averaged 41° ± 6.6° (range 30°–45°). The mean active anterior elevation was 157.5° ± 41.4° (range 40°–180°). The active internal rotation was 90° in all patients, while the mean active external rotation was 35° ± 11.3° (range 20–45°).

The mean muscle strength during anterior elevation was 4.8 ± 2.1 kg (range 1.5–9 kg). The mean muscle strength during internal rotation was 6.6 ± 3 kg (range 2.1–11.5 kg), while the muscle strength of external rotation averaged 5.1 ± 2.1 kg (range 2.4–9 kg).

MRI outcomes

No statistically significant correlation has been found between the thickness of each portion of the deltoid muscle

Table 1 Statistical comparison between the deltoid tropism and the clinical outcomes

Clinical score	vD	lD	dD
UCLA	$R = 0.06556$	$R = -0.17176$	$R = -0.0141$
	$P = 0.7777$	$P = 0.45661$	$P = 0.95163$
Wolfgang	$R = 0.07085$	$R = -0.22107$	$R = -0.00098$
	$P = 0.76024$	$P = 0.33554$	$P = 0.99662$
OSS	$R = -0.03819$	$R = 0.40784$	$R = 0.13088$
	$P = 0.86947$	$P = 0.06647$	$P = 0.57176$

UCLA University of Carolina, Los Angeles shoulder score, *OSS* Oxford shoulder score, *vD* ventral deltoid, *lD* lateral deltoid, *dD* dorsal deltoid, *R* and *P* Spearman's correlation coefficient result

(vD, lD and dD) and the UCLA shoulder rating scale, Wolfgang shoulder score and OSS (Table 1). At the same time, no statistically significant relationship has been detected between the thickness of each portion of the deltoid muscle (vD, lD and dD) and the functional outcomes.

The mean pre-operative thickness of the vD was 1.8 ± 0.5 cm (range 1.1–2.9 cm), while the mean post-operative thickness of the vD was 1.8 ± 0.5 cm (range 1.2–2.7 cm). No statistically significant modification was found between the pre-operative thickness and the post-operative thickness of the vD ($P > 0.05$). The mean pre-operative thickness of the lD was 1.9 ± 0.3 cm (range 0.7–1.5 cm), while the mean post-operative thickness of the lD was 1.2 ± 0.2 cm (range 0.9–1.3 cm).

No statistically significant modification was found between the pre-operative thickness and the post-operative thickness of the lD ($P > 0.05$). The mean pre-operative thickness of the dD was 3.1 ± 0.8 cm (range 1.7–4.2 cm), while the mean post-operative thickness of the dD was 2.9 ± 0.8 cm (range 1.9–4.8 cm). No statistically significant modification was found between the pre-operative thickness and the post-operative thickness of the dD ($P > 0.05$).

Discussion

In the present study, the role of the tropism of the deltoid muscle in the outcomes of arthroscopic RC repair was evaluated.

No statistically significant relationship between the deltoid tropism and the clinical and functional outcomes of arthroscopic RC repair was found. Moreover, the deltoid thickness was not influenced by RC repair procedures. Indeed, no statistically significant modification of the deltoid tropism was detected comparing the pre-operative with the post-operative thickness of the muscle. It is possible to hypothesize that early RC repair could prevent the loss of the deltoid tropism, preserving its function.

The deltoid muscle contributes to shoulder flexion, abduction and extension range of motion (ROM). It is responsible for the vertical balance of the shoulder, contributing with RC muscles to glenohumeral stability [16]. The deltoid muscle can be divided into three anatomical portions: anterior or clavicular portion; lateral or acromial portion; and posterior or scapular portion [17]. However, in a study using fludeoxyglucose positron emission tomography (FDG-PET), Sakoma et al. [18] showed that the deltoid muscle has seven anatomical segments, which seem to represent its functional units working as segments. The anterior portion is responsible for flexion, adduction and medial rotation of the arm in synergy with the pectoralis major; the lateral portion allows abduction of the arm especially when the arm is medially rotated (it works synergically with the supraspinatus muscle during the first 30° of abduction); the posterior portion is responsible for extension, adduction and lateral rotation of the arm in synergy with the latissimus dorsi [19].

According to Meyer et al. [20], the measurement of the vD, lD and dD thickness on T2-weighted transverse MR images pre-operatively and post-operatively was taken in designated directions from the humeral centre of rotation perpendicularly or parallel to the glenoid surface. No marked muscles atrophy or deltoid detachment or tear has been found. The absence of evident atrophy is probably due to isometric contractions that seems to be sufficient to prevent deltoid atrophy as shown in previous studies [20]. Deltoid detachment is a complication of shoulder surgery, and principally of acromioplasty, characterized by abnormal deltoid silhouette (crease sign), pain, abduction weakness and poor clinical outcomes after surgery [21]. Isolated deltoid tears are more often located at the acromial insertion of the muscle and are a rare consequence of sports injuries or road accidents [22, 23]. Tears of the deltoid muscle or tendon associated with RC tears are uncommon, but they can be seen in patients with chronic massive RC tears. Partial thickness tears tend to involve the undersurface of the deltoid muscle and tendon [24].

Several factors may determine the failure of arthroscopic RC repair procedures [25–30]. Older age is associated with a slightly worse tendon quality and outcomes [31, 32], while smoking has a negative influence on RC repair clinical outcomes and it is associated with decreased healing of small-medium RC tears after repair [33]. Pre-operative weakness of forward flexion and external rotation has been well documented as a predictor of poor outcome [34, 35], while fatty infiltration and atrophy of RC muscles, as well as size of the RC tear correlate with a poor outcome after RC surgery (a lower FI is correlated with more function of an intact repaired cuff, instead RC repair in patients with grade 2 of FI and greater is associated with an high rate of re-tears) [36, 37]. We hypothesized also an

influence of the deltoid muscle in the outcomes of RC repair procedures, although our hypothesis was not confirmed.

Major strength of the study is that the assessment of the deltoid tropism has been made with a standardized method already used in other studies [30]. Other strengths are that all the operations were performed by a fully trained shoulder surgeon using a well-defined technique; the follow-up evaluations were performed by two blinded and independent examiners; and the evaluation of ROM and strength was performed according to the standard measurement guidelines.

We are aware of the limitations of the study. Firstly, the small sample of patient was enroled. Secondly, we did not have a control group without a RC repair. This would have allowed a comparison of the changes of deltoid thickness in patients who underwent a RC repair. Another limitation is that we did not perform an a priori power analysis and sample size calculation, and we enroled all the eligible patients managed in our institution during the index period.

The deltoid tropism does not influence the results of arthroscopic RC repair. Early RC repair may prevent the reduction in the tropism of the deltoid muscle. Nevertheless, further prospective randomized studies with larger samples are necessary to clarify the role of deltoid tropism in the outcomes of arthroscopic RC repair procedures.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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