

# ATROPHY OF THE DELTOID MUSCLE FOLLOWING ROTATOR CUFF SURGERY

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**Background:** Less invasive procedures have recently been introduced to facilitate an earlier return to sports or work activities after rotator cuff repair. Few reports, however, have verified whether such procedures are really less invasive than conventional open repair. The purpose of this study was to compare the postoperative thickness of the deltoid muscle in patients treated with either conventional or mini-open rotator cuff repair.

**Methods:** Conventional open repair was performed from 1994 through 1997 in forty-three patients with rotator cuff tears. The mini-open deltoid-splitting approach was introduced in 1997, and the cases of thirty-five patients who underwent that procedure were reviewed. The two groups were compared with respect to the thickness of the anterior fibers of the deltoid muscle measured on the transverse magnetic resonance images, the degree of active forward flexion, and the times required for return to work and sports activities.

**Results:** The thickness of the anterior deltoid fibers did not change significantly after surgery in the mini-open repair group, whereas it was significantly decreased in the open repair group at six months as well as at twelve months postoperatively ( $p < 0.05$ ). At three months postoperatively, the mean University of California at Los Angeles score for active forward flexion in the patients treated with the mini-open repair (4.9 points) was significantly greater than that in the patients in the conventional open repair group (4.6 points) ( $p < 0.05$ ). In addition, the mean time-period required for return to work in the mini-open repair group (2.4 months) was significantly shorter than that required in the control group (3.4 months) ( $p < 0.05$ ).

**Conclusions:** The mini-open repair appeared to cause less postoperative atrophy of the deltoid muscle than did the conventional open rotator cuff repair, and patients treated with the mini-open repair recovered more quickly.

**Level of Evidence:** Therapeutic study, Level III-2 (retrospective cohort study). See Instructions to Authors for a complete description of levels of evidence.

Arthroscopically assisted rotator cuff repair<sup>1-6</sup> and arthroscopic rotator cuff repair<sup>7-9</sup> are assumed to be less invasive and to cause less atrophy of the deltoid muscle than open rotator cuff repair, although an earlier return to work or sports activities has not been clearly demonstrated with the use of these procedures.

Conventional open repair was performed from 1994 through 1997 for the treatment of rotator cuff tears at our institution. A mini-open deltoid-splitting approach<sup>10</sup> was introduced in 1997 in an attempt to make the surgery less invasive. A study was carried out to compare the outcomes of patients treated with the conventional open method and those treated with the mini-open repair with regard to changes in the thickness of the anterior deltoid fibers and the clinical outcome.

## Materials and Methods

Diagnosis of a rotator cuff tear was made with use of arthrography as well as magnetic resonance imaging, and the presence of a tear was explained to the patients. Although our study was performed without approval from the review board at our institution, all patients were informed of the study procedure, purposes, and known risks. They all agreed to undergo surgery for the tear and submitted a signed informed-consent form prior to surgery. The mini-open repair through the deltoid-splitting approach was performed by one of the authors (Y.H.) on thirty-five consecutive shoulders in thirty-five patients. Tears involving more than three tendons or those with tendon retraction of  $>5$  cm were treated with other procedures and were excluded from the mini-open repair group. The age of the patients ranged from thirty-nine to seventy-one years (mean, 60.6 years). There were twenty-one men and fourteen women. The right shoulder was affected in twenty-five patients and the left, in ten. Tears were classified by



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TABLE I Preoperative Data on the Patients

	Mini-Open Repair Group	Conventional Open Repair Group
No. of shoulders	35	43
Age* (yr)	60.6 (39-71)	58.1 (31-78)
Sex (M/F)	21/14	25/18
Side (right/left)	25/10	31/12
Size of tear (no. of shoulders)		
Small	4	5
Moderate	15	18
Large	16	20
Preop. UCLA score* (points)	13.8 (6-26)	14.3 (6-26)
Duration of follow-up* (mo)	30.6 (24-37)	61.6 (45-82)

\*The values are given as the mean, with the range in parentheses. UCLA = University of California at Los Angeles.

size intraoperatively after débridement according to the method of DeOrto and Cofield<sup>11</sup>. A small tear (<1 cm) was found in four patients, a moderate tear (1 to 3 cm) in fifteen, and a large tear (3 to 5 cm) in sixteen. The mean preoperative University of California at Los Angeles (UCLA) score<sup>12</sup> was 13.8 points in the mini-open repair group (Table I).

An arthroscopic examination was carried out prior to the mini-open rotator cuff repair in all patients to precisely locate the tear and to directly inspect intra-articular lesions. Details of our mini-open deltoid-splitting approach have been described elsewhere<sup>10</sup>. In brief, a 3-cm-long skin incision was made starting from the middle of the anterior margin of the acromion and extending toward the axilla. The anterior deltoid fascia was cut along the skin incision, and the muscle was bluntly dissected and retracted. The coracoacromial ligament was resected, and then an acromioplasty was carried out under direct vision according to the method of Neer<sup>13</sup> by scraping the undersurface of the acromion with a nasal rasp. The torn rotator cuff was then repaired according to the standard McLaughlin technique<sup>14,15</sup>. The Concept Rotator Cuff Repair System (Linvatec, Largo, Florida) was used to make curved holes in the bone and to pass one, two, or three number-2 braided nylon sutures through the greater tuberosity to securely fasten the stump of the torn rotator cuff to the tuberosity. The deltoid muscle was not detached from the acromion in the mini-open repair group. The patients were followed for twenty-four to thirty-seven months (mean, 30.6 months) postoperatively.

Our control group consisted of another forty-three consecutive patients who had a conventional open repair, performed between 1994 and 1997 by the same surgeon (Y.H.), and were followed for forty-five to eighty-two months (mean, 61.6 months). Tears involving more than three tendons or those with tendon retraction of >5 cm were, however, excluded from this group just as in the mini-open repair group. The patients ranged in age from thirty-one to seventy-eight years (mean, 58.1 years). There were twenty-five men and eighteen women. The right shoulder was affected in thirty-one patients and the left shoulder, in twelve. A small tear was

found in five patients; a moderate tear, in eighteen; and a large tear, in twenty. The mean preoperative UCLA score was 14.3 points in the control group (Table I).

In this group as in the mini-open repair group, an arthroscopic examination was carried out prior to the open repair. A 5 to 6-cm incision was then made starting from the middle of the anterior margin of the acromion and extending toward the axilla. This incision was longer than the incision in the mini-open repair group, but it was placed on the same line. The anterior deltoid fascia was incised, and the muscle was bluntly dissected. The anterior fibers were divided provisionally about 2 cm from the anterior edge of the acromion while leaving their origin attached to the acromion. A number-1 braided silk suture was placed in the detached deltoid muscle as a marker to avoid unintentional distal extension of the split in the muscle and/or axillary nerve injury. We accomplished the acromioplasty under direct vision by removing bone spurs with a flat chisel followed by scraping the acromion with a nasal rasp. The bone was resected until the undersurface of the acromion became flat and a sufficient subacromial space was obtained. The space was considered to be sufficient if the greater tuberosity did not contact the undersurface of the acromion when the shoulder was passively elevated or abducted. The 2-cm-wide proximal stump of the deltoid muscle, which had been left attached to the acromion, was carefully protected throughout the anterior acromioplasty with a soft-tissue retractor, and only the undersurface of the acromion was abraded with chisels and rasps in the same fashion as in the mini-open repair<sup>10</sup>. After the rotator cuff repair, the deltoid was reattached to its insertion on the acromion with use of two number-2 braided nylon sutures, each of which was placed as a horizontal mattress suture.

An identical postoperative rehabilitation program was used for both the mini-open repair and control groups. The involved shoulder was kept in 90° of abduction and 30° of horizontal flexion by an abduction brace for three weeks postoperatively. The abduction brace was considered to be necessary to rest the anterior fibers of the deltoid muscle that had been

resutured to the acromion in the conventional open repair group. In order to have identical postoperative rehabilitation programs, all patients in both groups wore the same abduction brace. Passive shoulder elevation from 90° to maximum elevation and active elbow flexion-extension were started one day postoperatively. In the third postoperative week, the abduction angle of the brace was gradually reduced, and muscle-strengthening exercises for the shoulder girdle (the trapezius, rhomboid major and minor, levator scapulae, and serratus anterior muscles) were started in the fourth postoperative week. The brace was discontinued and was changed to an abduction pillow three weeks postoperatively, and active-assisted elevation exercises were started. The pillow was abandoned, and active-assisted range-of-motion exercises in all directions were started four weeks postoperatively. Active range-of-motion exercises and a specially designed set of exercises to strengthen the deltoid and rotator cuff muscles<sup>16</sup> were initiated six weeks postoperatively. For six weeks after surgery, the patient was managed with traction at night with the arm kept in 130° of elevation in the scapular plane to reduce tension on the repaired cuff and to prevent contracture of the glenohumeral joint. Strenuous intrinsic or extrinsic muscle-training was initiated gradually two months after surgery.

The thickness of the anterior fibers of the deltoid muscle was measured on transverse T1-weighted (spin-echo method with a repetition time of 500 msec and an echo time of 20 msec) magnetic resonance images acquired preoperatively and at six and twelve months postoperatively with use of a 1.0-T magnetic resonance unit (Signa Horizon LX 1.0T; GE Medical Systems, Milwaukee, Wisconsin) with a 20-cm circular surface coil. These images were acquired in neutral rotation with the arm at the side, and three images intersecting through the coracoid process were used to evaluate each patient.

A line (L1) connecting the anterior and posterior edge of the glenoid was drawn on the image, and then a line (L2) was drawn parallel to L1 through the center of the head (O)

(Fig. 1). The center of the head was defined as the intersecting point of the two perpendicular bisectors of lines XY and YZ, where X, Y, and Z were arbitrarily placed on the articular surface of the head<sup>17</sup>. On L2, the length of segments AB and EF, which represented the thickness of the anterior and posterior deltoid muscle fibers, respectively, was measured and averaged for each shoulder. The measurement was carried out in a blinded fashion by one of the authors (S.S.) who did not participate in the surgery or know whether a patient had undergone conventional open repair or a mini-open repair.

The patients in both groups were physically examined by the same physician (Y.H.). The groups were compared with respect to the UCLA score at three, six, twelve, and twenty-four months postoperatively to evaluate the clinical outcome. The patients were seated in a chair, keeping the trunk straight in order to minimize the effects of trunk movement on the measurement of active forward flexion. Both shoulders were elevated simultaneously in the sagittal plane, and the angle between the long axis of the humeral shaft and a perpendicular line passing through the acromion was measured for the affected shoulder.

Work or sports activity was permitted one to two months postoperatively at the patients' discretion once useful muscle power and range of motion were restored in the involved shoulder. A survey of the patients was conducted by mail or telephone interview to determine the time required for the return to work or sports activity. The return to work was defined as the time when the patient was able to engage in physical labor with no limitations, and the initiation of work activities was defined as the time at which the patient could engage in desk work. Return to sports activities was defined as the time when the patient was able to play sports with no limitations, and its initiation was defined as the time when training for sports resumed.

The age of the patients, size of the tear, and preoperative UCLA scores in the two groups were compared with use of the

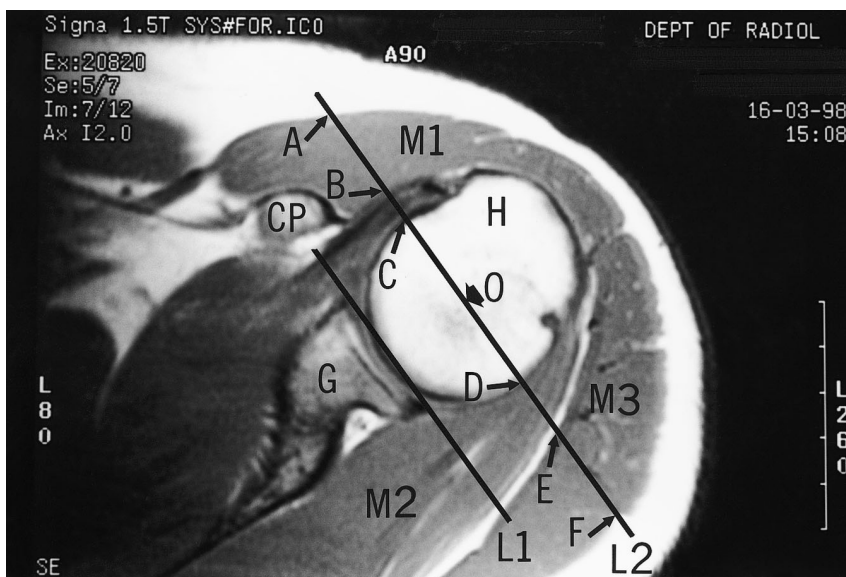


Fig. 1  
Measurement of the thickness of the deltoid muscle fibers on a T1-weighted magnetic resonance image. H = humeral head, G = glenoid, CP = coracoid process, M1 = the anterior fibers of the deltoid, M2 = infraspinatus muscle, M3 = the posterior fibers of the deltoid, O = the center of the humeral head, segment AB = the thickness of the anterior deltoid fibers, CD = the diameter of the humeral head, EF = the thickness of the posterior deltoid fibers, L1 = the line connecting the anterior and posterior edges of the glenoid, and L2 = the line drawn parallel to L1 through the center of the humeral head.

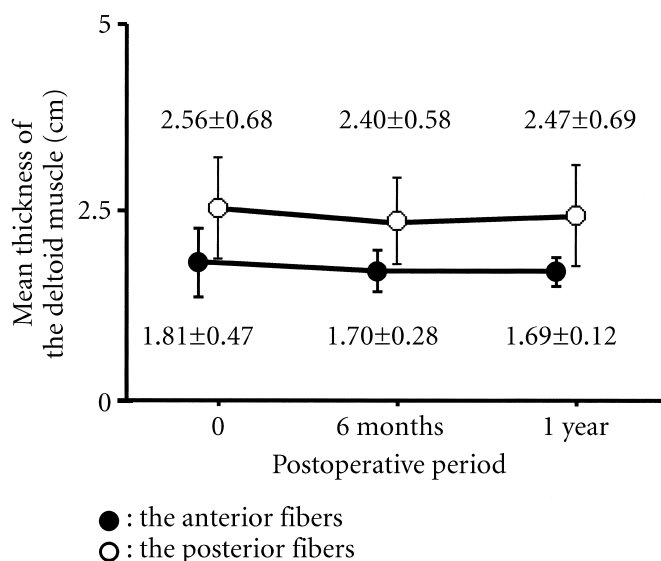


Fig. 2  
Changes in the mean thickness (in centimeters) of the anterior and posterior fibers of the deltoid muscle in the mini-open repair group.

Mann-Whitney U test, whereas differences between the groups with respect to gender and the side of involvement were assessed with use of the chi-square test. In addition, the two groups were compared with regard to the supraspinatus muscle-belly ratio<sup>18</sup> and the grades of morphologic change of the supraspinatus muscle belly<sup>18</sup> on preoperative oblique coronal T1-weighted images (spin-echo method with a repetition time of 500 msec and an echo time of 20 msec) with use of the Mann-Whitney U test. The clinical outcome and the time required for return to work in the two groups were also compared with use of the Mann-Whitney U test. The preoperative and postoperative thickness of the anterior and posterior fibers of the deltoid muscle were compared in each group with use of the Kruskal-Wallis test. The groups were compared with respect to the thickness of the deltoid preoperatively and at six and twelve months postoperatively with use of the Mann-Whitney U test. The tests for statistical analysis were used with the significance level set at 0.05.

## Results

No significant differences were found between the mini-open repair and control groups with respect to age, gender, affected side, tear size, or preoperative UCLA score. The two groups had no significant differences with respect to the preoperative supraspinatus muscle-belly ratio or the grades of morphologic change of the supraspinatus muscle belly.

No ruptures of the repaired rotator cuff were detected on magnetic resonance images acquired six or twelve months postoperatively for either the mini-open repair group or the control group. Clinically, no patient had a defect in the deltoid. No patient had atrophy of the anterior deltoid in the mini-open repair group on physical examination, but twenty-six shoulders (60%) in the control group had slight atrophy

compared with that on the unaffected side. Scar formation (low signals in T1-weighted and T2-weighted magnetic resonance images) was seen in the deltoid muscle, in the area where the muscle had been split during surgery, on magnetic resonance images acquired six and twelve months postoperatively in both groups.

The graph in Figure 2 illustrates the change in the mean thickness of the anterior and posterior fibers of the deltoid muscle in the mini-open repair group as measured on magnetic resonance images. No significant differences were detected in the thickness of the anterior or posterior deltoid fibers between the images acquired preoperatively and those acquired at six and twelve months postoperatively.

The graph in Figure 3 shows the change in the mean thickness of the deltoid muscle in the control group as measured on magnetic resonance images. The mean thickness of the anterior fibers at six and twelve months postoperatively was significantly smaller than it was prior to surgery ( $p < 0.05$ ). The mean thickness of the posterior deltoid fibers did not change significantly over time. No significant differences were found between the two treatment groups with respect to the mean thickness of the anterior or posterior deltoid fibers measured preoperatively and at six and twelve months postoperatively.

The UCLA scores at two years postoperatively (Table II) had improved significantly in both the mini-open repair and control groups compared with the preoperative scores ( $p < 0.01$ ). No significant differences were detected between the groups with respect to the UCLA scores for pain, function, active forward flexion, muscle strength, and patient satisfaction or the total score at two years postoperatively. However, a significant difference was found between the two groups with

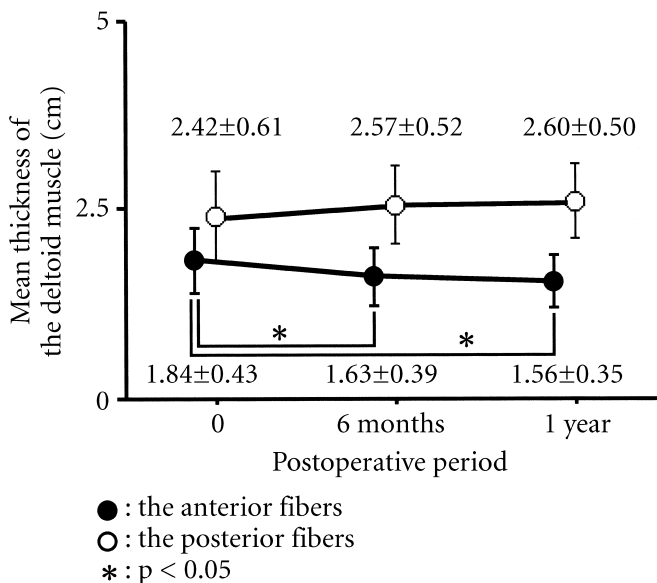


Fig. 3  
Changes in the mean thickness (in centimeters) of the anterior and posterior fibers of the deltoid muscle in the conventional open repair group.

TABLE II Score on the UCLA Rating System at Two Years Postoperatively\*

	Mini-Open Repair Group (points)	Conventional Open Repair Group (points)
Pain	9.5	9.5
Function	9.6	9.4
Active forward flexion	4.9	4.8
Strength of forward flexion	4.8	4.8
Satisfaction of the patient	4.6	4.5
Total	33.4	33.0

\*UCLA = University of California at Los Angeles.

spect to the mean UCLA score for active forward flexion at three months postoperatively (4.9 points for the mini-open repair group compared with 4.6 points for the conventional repair group;  $p < 0.05$ ) (Fig. 4), but no significant differences between the groups were detected in the other UCLA score categories preoperatively or at three, six, or twelve months postoperatively.

By twelve months after surgery, all patients in both the mini-open repair and conventional repair groups had returned to their work or sports activities at the same level as they had participated preoperatively. The mean time required prior to the initiation of work or sports activities was 2.4 months in the mini-open repair group and 3.4 months in the control group ( $p < 0.05$ ).

### Discussion

The final clinical results in the group that had the mini-open rotator cuff repair were as good as those in the control open repair group, and they were also comparable with those reported in studies of arthroscopic or arthroscopically assisted rotator cuff repair<sup>4,5,9</sup>. Although arthroscopically assisted<sup>1-6</sup> and arthroscopic rotator cuff repair<sup>7-9</sup> have recently been introduced to minimize the invasiveness of the surgery, it has not been proved that they are less invasive. We postulated that postoperative deltoid atrophy would reflect the extent of surgical invasiveness. We measured the thickness of the deltoid muscle on magnetic resonance images and found that the anterior deltoid was significantly more atrophic in the open repair group at both six and at twelve months postoperatively compared with the preoperative findings ( $p < 0.05$ ), whereas no significant amount of atrophy was seen postoperatively in the mini-open repair group. It is possible that an alternative method of detaching and repairing the anterior deltoid fibers from the edge of the acromion might result in less atrophy following open repair. As postoperative atrophy of the deltoid muscle appears to reflect the extent of surgical invasiveness to the muscle, and as the deltoid muscle demonstrated less atrophy in the mini-open repair group than in the control group, it may be said that the mini-open repair is less invasive than the conventional open repair with detachment and repair of the anterior deltoid fibers.

Reduction in the function of the deltoid muscle, espe-

cially that of its anterior fibers, results in serious difficulty in shoulder flexion<sup>19</sup> because no other muscles can effectively compensate for its loss<sup>20</sup>. Since active forward flexion is closely related to the performance of almost all of the activities of daily living<sup>21</sup>, less deltoid atrophy and earlier recovery in shoulder flexion in the mini-open repair group could be expected to shorten the time required for return to activities compared with that in the control group. Patients in the mini-open repair group returned to work an average of about two and a half months postoperatively, which was about one month earlier than did those in the control group. As many patients request an earlier return to sports or work activities, a procedure that can provide a functional outcome that is as good as that after the conventional open repair but with a shorter recovery time should be the procedure of choice. A period of six to twelve weeks<sup>22-24</sup> has been reported as the time required for healing of the rotator cuff after repair, and no ruptures of the repaired cuff were detected on magnetic resonance images at six or twelve months postoperatively in the mini-open repair group. By twelve months after surgery, all patients in both groups had returned to work or sports activities at as high a level of participation as the preinjury level.

It is possible that our patients had better results than

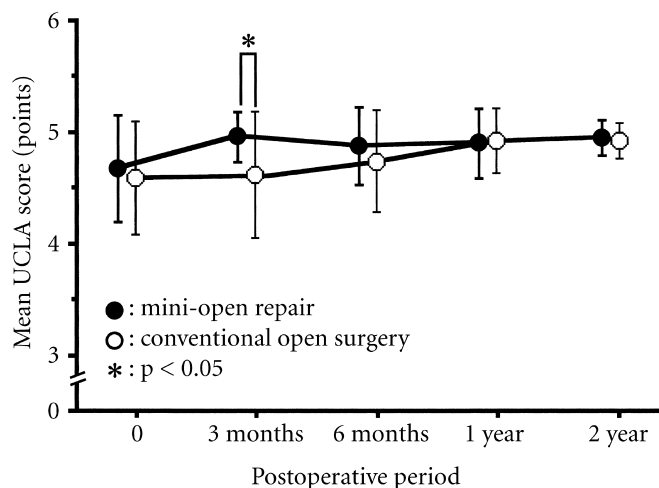


Fig. 4

The mean UCLA scores for active forward flexion in the two groups.

those reported to date in other studies<sup>4,5,9</sup> because none of our patients were professional athletes and none were receiving Workers' Compensation. The patients in the control group underwent surgery early in this study, and those in the mini-open repair group were treated later. Thus, the patients were not randomized, and it is possible that the surgeon's learning curve had an effect upon the results. However, we believe that the surgeon's learning curve had little effect on the outcome obtained in this study because the surgeon who performed all of these procedures was already very familiar with both acromioplasty and rotator cuff repair even prior to the start of this study.

Regarding the reasons for the muscle atrophy seen in the control group in this study, Groh et al. reported that reduction of deltoid function after shoulder surgery is caused either by loss of the origin of the deltoid muscle or by injury to the axillary nerve<sup>25</sup>. The temporarily detached anterior deltoid fibers were resutured as securely as possible after completion of the rotator cuff repair in the control group. Ruptures of the resutured deltoid muscle appeared not to have occurred. More extensive dissection and the resultant more extensive scar in the

deltoid muscle was assumed to have produced more deltoid atrophy in the conventional group than in the mini-open repair group. The axillary nerve was carefully protected during surgery, although it was difficult to exclude completely the possibility of an inadvertent injury to the nerve intraoperatively. ■

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