# Subscapularis Function and Structural Integrity After Arthroscopic Repair of Isolated Subscapularis Tears

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**Background:** Results of arthroscopic repair of isolated subscapularis tendon tears have not been widely studied. A detailed evaluation of subscapularis function with subscapularis strength quantification has not been performed to date.

**Purpose:** To evaluate postoperative subscapularis muscle function and to assess the clinical outcome and structural tendon integrity with postoperative magnetic resonance imaging after arthroscopic repair of isolated subscapularis tears.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** In a prospective study, isolated subscapularis tendon tears in 21 patients were treated with an all-arthroscopic repair. The average age of the study population was 43 years. The mean interval between trauma and surgery was 5.8 months. In 19 patients, a traumatic event caused the onset of symptoms. Subscapularis muscle function was assessed with specific clinical tests and the Constant scoring system. Postoperative subscapularis strength was evaluated with a custom-made electronic force measurement plate. All patients underwent postoperative magnetic resonance imaging to assess structural integrity of the repair.

**Results:** The average duration of follow-up was 27 months. The Constant score increased from 50 points preoperatively to 82 points postoperatively ($P < .01$). Most positive preoperative lift-off and belly-press tests were reversed by surgery, with a rate of 5 (24%) persistent positive tests after surgery. In operated shoulders, subscapularis strength in the belly-press (65 vs 87 N; $P < .05$) and the lift-off position (44 vs 68 N; $P < .05$) was significantly reduced compared with the contralateral shoulder. Magnetic resonance imaging revealed an intact repair in 20 patients. Atrophy of the upper subscapularis muscle portion was present in about one-fourth of the patients and in all patients with a positive postoperative belly-press test.

**Conclusion:** Arthroscopic repair of isolated subscapularis tendon tears achieves substantial improvement of shoulder function and a low rerupture rate. Despite excellent clinical results, a significant postoperative subscapularis strength deficit compared with the contralateral shoulder persists that can be quantified with use of the force measurement plate. Atrophy of the upper subscapularis muscle is present in 25% of the patients in the postoperative course.

**Keywords:** arthroscopic subscapularis tendon repair; force measurement plate; postoperative MRI; clinical subscapularis test

Open repair of isolated full-thickness subscapularis tendon tears achieves good clinical results, as shown in several studies.[1,2,6-8,11,12,20] Clinical outcomes after arthroscopic repair of isolated subscapularis tendon tears have been reported in very few studies with mainly small patient populations.[1,3,19,21] The development of specific clinical tests and advanced imaging techniques improved our rate of accurate diagnosis of the often overlooked isolated subscapularis tendon tear. The subscapularis muscle represents the single anterior part of the transversal "force couple," and subscapularis reconstruction is important for centering the humeral head and restoring normal glenohumeral joint biomechanics.[4,16,25,29,31] Some studies reported persistent subscapularis muscle insufficiency in the postoperative course in a substantial percentage of patients despite good clinical results.[7,11,21,32] It was shown that subscapularis function is not adequately reflected in the commonly used shoulder scores.[2,11,21] Postoperative subscapularis muscle insufficiency was attributed to advanced fatty infiltration

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and atrophy of the muscle, occurring during the time interval between trauma and surgery.

The purpose of the present study was to evaluate the functional outcome after arthroscopic repair of isolated subscapularis tendon tears, to quantify subscapularis muscle strength with a specific testing apparatus, and to correlate functional parameters with muscle atrophy and fatty muscle infiltration on a standardized postoperative MRI.

## MATERIALS AND METHODS

Between 2003 and 2006, twenty-two patients with an isolated subscapularis tendon tear were treated with an all-arthroscopic repair. Twenty-one patients were available for final follow-up (follow-up rate of 95%). The local institutional review board approved the study, and all patients gave written informed consent. In all cases, the indication for operative repair was a clinically symptomatic subscapularis tendon tear with persistent pain and weakness of the shoulder. All operations were performed by the senior author (A.B.I.).

Only patients with confirmed isolated full-thickness subscapularis tendon tears at arthroscopy were included in the study.

The study group consisted of 16 men and 5 women who had an average age of 43.7 years (range, 18-61 years) at the time of operation. The dominant shoulder was involved in 15 (71%) patients. Nineteen patients reported a traumatic onset of symptoms. The interval from onset of symptoms to surgery averaged 5.8 months (range, 0.2-14 months). In 10 cases, a traumatic rupture was caused by a forced abduction and external rotation of the shoulder, 8 patients reported a fall on the outstretched arm, and 1 patient reported a direct anterior blow against the shoulder.

### Clinical Evaluation

All patients underwent a standard physical examination before and after the operation, including the patients' history and the general health status. The final follow-up evaluation was performed by an independent examiner who was not a member of the surgical team. Patients were evaluated with the Simple Shoulder Test (SST)[14] and the scoring system of Constant and Murley,[5] using the absolute Constant score and the age- and gender-adjusted Constant score.[14] Subscapularis muscle testing included measurement of passive external rotation with the arm at the side, as well as active and passive internal rotation testing with the hand on the back compared with the contralateral side.[17] For specific assessment of subscapularis function, the lift-off test and the belly-press test as described by Gerber and colleagues[11,12] were performed.

### Subscapularis Strength Evaluation

For quantitative measurement of subscapularis muscle strength, we developed a special testing apparatus. With this electronic force measurement plate (FMP), subscapularis strength was measured in the belly-press and the lift-off position (Figure 1). Both tests are specific for the subscapularis muscle, as they test internal rotation strength in a position of maximal extension and internal rotation. This isolates the subscapularis muscle from other internal rotators, as shown by Tokish et al.[30] With use of a sling and a variable adjustment, the plate could be placed at the correct position for all patients. The testing positions were explained in detail to all patients with a special focus on maintaining internal rotation while pressing against the FMP and were trained before testing. Strength testing was performed 3 times each on the operated and on the contralateral shoulder.

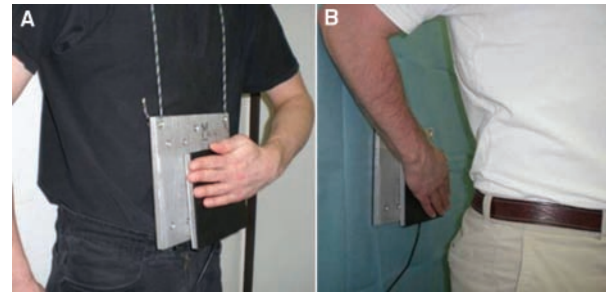


**Figure 1.** Subscapularis strength measurement with the force measurement plate in the belly-press position (A) and in the lift-off test position (B).

The calibrated FMP is based on adapted elongation of a resistance strain gauge within a force measurement cell that is capable of registering differences from 0.2 to 500 N with an accuracy of 0.2%. The captured signal is transformed into an electronic signal. The load cell is fixed between 2 aluminum plates capable of measuring error-free force amplitudes. Signal recording was computerized using a 12-bit USB analog-to-digital transducer (NI USB 6008; National Instruments, Munich, Germany) at a sampling rate of 100 Hz. The continuous signal was quantified into time and amplitude to draw amplitude-time diagrams. The detected voltage difference was transformed into Newtons (N) with use of a calibration factor, calculated by a software program (Labview 7.0; National Instruments). Calibration of the FMP was performed with a universal testing machine (Zwick 1120; Zwick GmbH, Ulm, Germany). Force values in Newtons (N) were evaluated by calculating a mean value between the maximum value and the 70% value generated over a 3-second period.

### Radiographic Evaluation

All patients underwent standard radiographs, including a true-anteroposterior radiograph in neutral rotation and a Y-shaped view radiograph before and after surgery. Glenohumeral osteoarthritis was classified according to the criteria of Samilson and Prieto.[27]

A preoperative MRI scan was available in all patients. On the MRI scan tear location, tear size, tendon retraction, and subscapularis muscle atrophy and the fatty infiltration grade (FIG) of the subscapularis muscle were noted according to the MRI grading system, described by Fuchs et al,[10] based on the Goutallier CT score.[13,24] Minor fatty infiltration with FIG 0 and FIG 1 was considered minimal fatty infiltration, FIG 2 moderate, and FIG 3 and 4 advanced fatty infiltration of the muscle.[7]

Postoperatively, all patients underwent a standardized MRI using a 1.5 Tesla MRI scanner (Magnetom Espree; Siemens Medical Solutions, Erlangen, Germany) with a dedicated shoulder coil. The magnetic resonance examination included the following sequences: paracoronal T1-weighted spin echo (repetition time [TR] 510 ms, echo time [TE] 15 ms) and fat-suppressed intermediate-weighted turbospin echo (TSE; TR 2800 ms, TE 45 ms), axial fat-suppressed intermediate-weighted TSE (TR 2800 ms, TE 45 ms), and parasagittal T2-weighted TSE (TR 4200 ms, TE 90 ms).

Tendon integrity was graded on axial and paracoronal T2-weighted, proton density-weighted, and short inversion recovery (STIR) sequences according to established MRI criteria.[10,24] The diagnosis of a rerupture was made if a tendon gap was filled with fluid-equivalent signal or a nonvisualization of the tendon with tendon retraction was present on 1 or more sections.[24] Arthrography was not performed routinely because contrast medium leakage through the open rotator interval after surgery would be a frequent finding. On the Y-shaped view in the parasagittal plane, the cranial-transversal diameter (CRTD) and the caudal-transversal diameter (CATD) of the subscapularis muscle were measured in millimeters as described by Scheibel et al[28] (Figure 2A). Subscapularis muscle atrophy was evaluated by measuring the muscle cross-sectional area (CSA) in square millimeters ($mm^2$). On the Y-shaped view, the subscapularis muscle borders were traced by using PACS software in a modified technique as described by Juul-Kristensen et al[18] (Figure 2B). The muscles' diameters and CSA on postoperative MRIs were compared with an age-, gender-, and body mass index (BMI)–adjusted control group, as no MRI of the contralateral shoulder could be obtained. The control group consisted of 60 male and 20 female patients at an average age of 48.4 years with no present rotator cuff tear or shoulder instability in both shoulders. The magnetic resonance images were assessed by 2 experienced musculoskeletal radiologists who were blinded to the clinical findings.

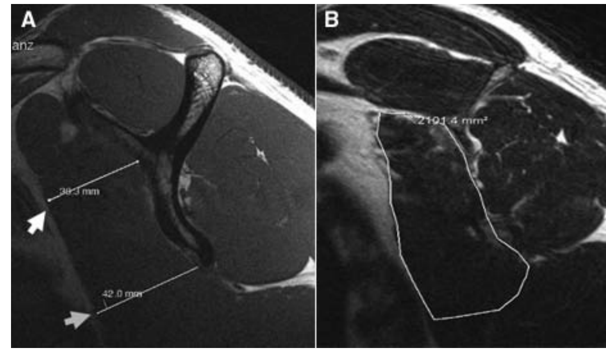


**Figure 2.** Subscapularis MRI parameters in the sagittal plane. A, Cranial-transversal diameter (white arrow) and caudal-transversal diameter (gray arrow) of the subscapularis muscle measured in millimeters. B, Subscapularis muscle cross-sectional area on the Y-shaped view measured in square millimeters.

## Operative Technique

The arthroscopic repair was performed with the patient in the beach-chair position. With a 30° arthroscope through the posterior portal and the shoulder in internal rotation and flexion, the extent of the tear also could be visualized in large tears (Figure 3).[33] In complete tears, we also used a lateral portal, with the arm in flexion and pulling the humerus posteriorly to visualize the lower tear margin. The integrity of the reflection pulley was checked.[15] Often these pulley structures are detached from their humeral insertion and scarred to the superolateral border of the subscapularis, forming the "comma sign," as described by Richards and Burkhart.[1,26] The long head of the biceps tendon was inspected with a probe and graded as torn or partially torn, subluxated out of the pulley sling, or completely dislocated in the joint. Subscapularis tear size was classified according to the classification of Fox et al[9]: type II tears (complete lesion of the upper 25% of the tendon), type III tears (complete lesion of the upper 50% of the tendon), and type IV tears (complete lesion >50% craniocaudal tendon diameter); type I tears, representing partial articular-sided tears of the upper subscapularis, were not included in the study. Also, shoulders with other concomitant rotator cuff tears were excluded from the study.

Tendon retraction was classified as follows: a tendon stump near the lesser tuberosity represented tendon retraction grade 1, a tendon stump at the level of the medial border of the humeral head represented tendon retraction grade 2, and a tendon stump found at the level of the glenoid or medially represented tendon retraction grade 3.

Intraoperative grading of cartilage lesions was performed using the modified Outerbridge[23] classification: cartilage swelling and softening (grade 1), fissuring within soft cartilage areas (grade 2), partial-thickness cartilage loss with fibrillation (grade 3), and cartilage destruction with exposed subchondral bone (grade 4).

Through an additional anterolateral portal, the edge of the subscapularis tendon was tagged with sutures, and traction was applied to test the mobility of the tendon. For a retracted tendon edge, a gradual release was made. A 270° tendon release was performed by freeing the upper tendon margin from the scars to the pulley sling with an electrothermal device and the shaver, resecting anterior adhesions to the coracoid process, and also freeing the posterior aspect of the subscapularis from adhesions to the middle glenohumeral ligament and the scapular fossa, so that the tendon could be pulled tensionless to the lesser tuberosity.[14,15,33] The axillary nerve at the lower border of the subscapularis was left untouched. Through the anterior working portal the debridement and anchor placement

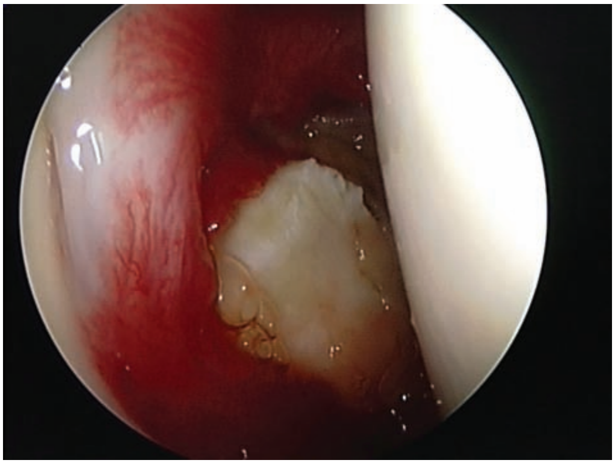

**Figure 3.** Visualization of a complete subscapularis tear in internal rotation of the shoulder.

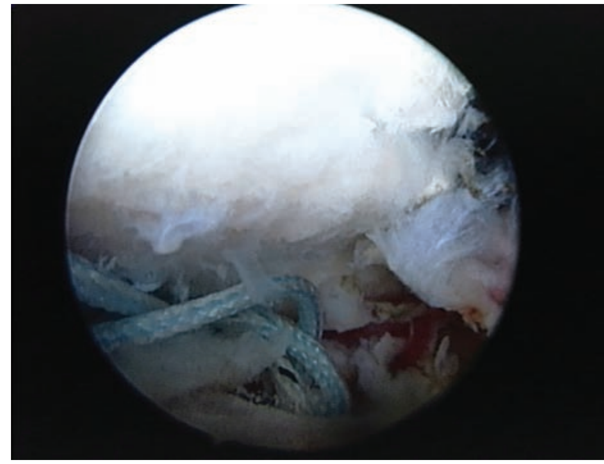

**Figure 4.** Anchor placement at the lesser tuberosity after lateral mobilization of the tendon stump (view through the anterolateral portal).

and the suture passage in a shuttle-relay technique was performed using cannulas. In all cases, we performed a suture anchor repair (Titancorkscrew 5 mm or Biocorkscrew 5 mm; Arthrex, Naples, Florida), double-loaded with number 2 braided nonabsorbable sutures (Fiberwire; Arthrex). Anchors were placed from inferior to superior at the lesser tuberosity in a single-row technique (Figure 4). Knots were tied with the arm in slight abduction and 20° of external rotation. Because most cases were traumatic tears, we did not perform a coracoplasty in this series. Depending on the patient's functional demand, a dislocated or partially torn long head of the biceps (LHB) was treated with a biceps tenodesis using a tenodesis screw or by tenotomy.

## Rehabilitation

Postoperatively, the shoulder was protected with use of an abduction pillow for 4 weeks. Overall external rotation was limited to 0° for 6 weeks. Also, no active internal rotation was allowed for 6 weeks. Passive mobilization of the shoulder with a pain-free forward flexion and external rotation to neutral was started on the first postoperative day under the supervision of a physiotherapist. Patients were not permitted to perform strenuous work for 3 months after the operation. Gradual return to sport activities was allowed after 6 months.

## Statistical Methods

Standard statistical software (SPSS version 18; SPSS, Inc, an IBM Company, Chicago, Illinois) was used to analyze the data. The mean, minimum, and maximum values were determined at each follow-up. The Wilcoxon test was used for analysis of paired data (eg, pre- and postoperative Constant score, subscapularis strength FMP values), and the Mann-Whitney test was used for unpaired groups. The level of significance was set at $P < .05$.

# RESULTS

Arthroscopic evaluation showed the following tear extent according to the Fox and Romeo[9] classification: in 4 shoulders, the tear involved the upper 25% of the tendon (type II); 10 tears involved the superior 50% of the tendon (type III); and 7 tears were large tears (type IV) and involved the whole craniocaudal tendon diameter.

Eight shoulders showed a grade 1 tendon retraction, 8 shoulders a grade 2 tendon retraction, and 5 shoulders a grade 3 tendon retraction.

The status of the LHB tendon was classified as ruptured in 2 cases, 6 shoulders had a normal LHB, the LHB was subluxated in 6 cases, the LHB was dislocated medially in the joint in 3 cases, and a partial tear was present in 7 cases. In 16 cases, no glenohumeral chondromalacia was found; a grade 1 (4 cases) and a focal grade 2 (1 case) chondromalacia was detected during arthroscopy. An average of 2.2 anchors (range, 1-4) was used for tendon fixation. A biceps tenodesis was performed in 9 cases, a tenotomy in 1 case, and recentering of the LHB in 2 cases.[22]

At the time of the final follow-up at an average of 27 months (range, 24-36 months) after the operation, 13 patients rated their result as excellent, 6 had a good result, 1 patient was satisfied, and 1 patient was not satisfied.

The mean Constant score improved significantly from 50.3 points (range, 39-62 points) preoperatively to 82.4 points (range, 65-98 points) postoperatively, with a significant gain in all subcategories (Table 1).

Preoperatively, all patients could perform the belly-press test, and 19 patients showed a positive belly-press test. The lift-off test was positive in 16 patients and could not be performed in 5 patients (24%) because of pain or restricted internal rotation. Postoperatively, most positive preoperative belly-press tests were reversed by surgery, with 16 negative belly-press tests and 5 (24%) remaining positive belly-press tests. Postoperatively, the lift-off test was negative in 19 shoulders, weak in 1 shoulder, and positive in 1 shoulder.

TABLE 1
Pre- and Postoperative Constant Scores[a]

| | Pain, Points | ADL, Points | ROM, Points | Strength, Points | Constant Score, Points | Age- and Gender-Adjusted Constant Score, % |
|---|---|---|---|---|---|---|
| Preoperative | 4.4 | 8.7 | 29.1 | 8.1 | 50.3 | 59.1 |
| Postoperative | 13.3 | 17.4 | 36.4 | 15.3 | 82.4 | 93.8 |

[a]ADL, activities of daily living; ROM, range of motion. Preoperative vs postoperative, all significant at $P < .01$.

Among the 5 patients with a positive belly-press test, postoperatively only 1 patient had a rerupture of the upper half of the subscapularis tendon as confirmed by MRI. Preoperatively, this patient had a type IV lesion, a moderate fatty infiltration (FIG 2) of the subscapularis muscle, and a time interval of 11 months from injury to surgery. The other 4 patients showed an intact tendon on MRI but insufficiency of the upper subscapularis muscle. All 4 patients had a negative lift-off test, indicating an intact lower subscapularis muscle. Patients with a positive postoperative belly-press test and present atrophy of the upper subscapularis muscle did not have lower Constant scores compared with patients with a negative test ($P > .05$). The postoperative Constant score for patients with a negative belly-press test averaged 83 points, and for patients with a positive belly-press test, the average Constant score was 80 points.

Postoperatively, 14 patients showed symmetric postoperative external rotation as compared with the contralateral side, 6 patients had a small external rotation deficit ranging from 0° to 10°, and 1 patient with a longstanding rupture had an external rotation deficit of 15°. Overall, active external rotation with the arm at the side (preoperative average 42° and postoperative average 58°; $P < .05$) and internal rotation behind the back (preoperative average level: iliosacral joint; postoperative average level: L1; $P < .05$) were significantly improved by surgery.

Active forward flexion improved from 134.2° preoperatively to 171.2° postoperatively ($P < .05$). The SST increased from a preoperative average of 6.3 points (range, 3-11 points) to a postoperative average of 11.2 points (range, 7-12 points) ($P < .01$).

Complications included 1 subscapularis tendon rerupture confirmed by MRI, 1 rupture of a suture-anchor biceps tenodesis due to trauma, and 1 temporary shoulder stiffness that could be managed with physiotherapy. The patient who had a rerupture was quite satisfied with the result and refused to undergo revision surgery. We had no cases of infection, no neurovascular injuries (especially no lesions of the axillary nerve), and no hardware failure or complex regional pain syndrome.

In the operated shoulder, subscapularis strength in the belly-press position averaged 65.2 N (range, 18-119 N) compared with 86.6 N (range, 34-151 N) on the contralateral side ($P < .05$). In the lift-off position, the operated shoulder generated an average of 44.1 N (range, 16-125 N) compared with 68.4 N (range, 32-142 N) on the contralateral side ($P < .05$) (see Table 2). In both specific subscapularis testing positions, a significant subscapularis muscle strength deficit persisted in the postoperative course. Patients with a positive belly-press test generated lower average force values (58 vs 69 N) compared with patients with a negative test, but numbers were too small for statistical analysis.

TABLE 2
Subscapularis Muscle Strength Measurement[a]

| | Operated Shoulder | Contralateral Shoulder | P Value |
|---|---|---|---|
| Strength (N): belly-press position | 65.2 | 86.6 | <.05 |
| Strength (N): lift-off position | 44.1 | 68.4 | <.05 |

[a]Strength values in Newtons (N) are given as the average.

Grading of postoperative MRI scans revealed 20 intact subscapularis repairs (Figure 5) and 1 complete subscapularis rerupture (1/21 [5%]) of the upper tendon half with persistent atrophy of the upper subscapularis muscle and an increasing FIG from stage 2 to stage 3 in the postoperative course. In one other case, thinning of the upper part of the repaired subscapularis tendon was detected on axial planes, indicating an articular-sided partial tear, but showing no gap formation between the tendon and the lesser tuberosity. Analysis of the muscle FIG on pre- and postoperative axial scans did not show a significant progression of fatty infiltration of the subscapularis ($P > .05$) or other rotator cuff muscles.

In the operated shoulder, the CRTD averaged 24.8 mm (range, 15-37 mm), and the CATD averaged 29.5 mm (range, 16-44 mm). In the healthy control group, the CRTD averaged 32.8 mm (range, 24-42 mm), and the CATD averaged 36.1 mm (range, 27-45 mm), representing significant larger diameters compared with the operative group (each $P < .05$). There was a trend for a lower postoperative CRTD in patients with positive belly-press tests indicative for atrophy of the upper subscapularis muscle (Figure 6), whereas these patients did not show a higher corresponding pre- or postoperative subscapularis muscle FIG. The postoperative CATD was not smaller in patients with positive belly-press tests compared with patients with a negative test.

Operated shoulders showed a significantly smaller average subscapularis CSA of 1970 $mm^2$ (range, 950-2870 $mm^2$) compared with an average subscapularis CSA of 2380 $mm^2$ (range, 1120-3040 $mm^2$) in the control group. Strength values in the belly-press position correlated positively with subscapularis muscle CSA ($P < .001$).

Analysis of conventional radiographs showed no significant progression of osteoarthritis after a mean follow-up of

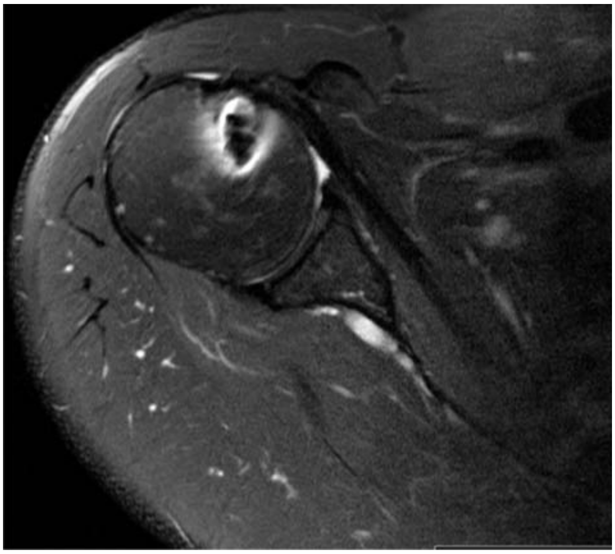

**Figure 5.** Postoperative MRI in the axial plane showing an intact subscapularis tendon repair.

27 months. On radiographs, no significant glenohumeral osteoarthritis was found in 20 cases and a grade 1 osteoarthritis in 1 case.

No case of hardware failure or anchor loosening was observed.

## DISCUSSION

The present study represents the largest series to date in patients with isolated subscapularis tendon tears that have been treated with an all-arthroscopic subscapularis tendon repair. To our knowledge, it is the only study in which subscapularis strength was quantified with use of an electronic force measurement plate, and structural integrity of the repair was assessed with a standardized postoperative MRI.

Several authors have reported on clinical outcomes after open repair of isolated subscapularis tendon tears.[1,2,6-8,11,12,20] We identified only 3 studies reporting the results of arthroscopic repair of isolated subscapularis tendon tears. Bennett[3] published a series of 8 patients with a 2-year follow-up after arthroscopic repair of isolated subscapularis tendon tears. The postoperative Constant score was 74 points, but no information was given about postoperative clinical subscapularis tests or structural integrity of the repair. Adams et al[1] reported excellent results after arthroscopic repair of isolated subscapularis tears in 7 patients after a minimum follow-up of 3 years. Lafosse et al[21] studied 17 patients, the first series with detailed information on the postoperative results of arthroscopic subscapularis repair for isolated tears. They found good clinical results with a postoperative Constant score of 84 points in 17 patients after a follow-up of 29 months, a rerupture rate of 12% evaluated by computed tomographic arthrograms, and a rate of persistent positive or weakened belly-press tests in 24% of the patients.

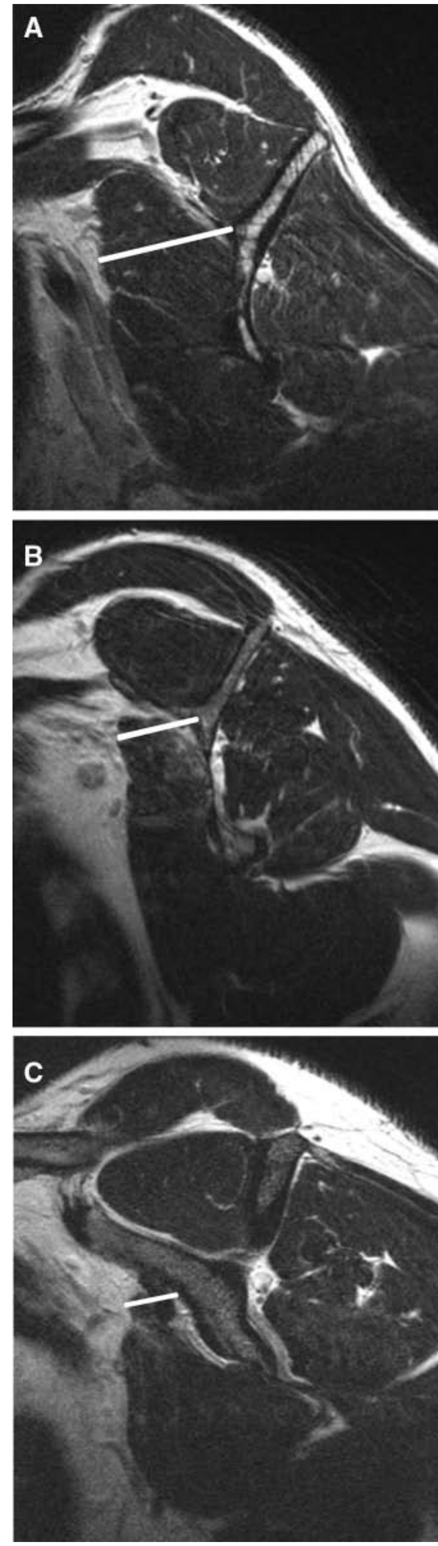


**Figure 6.** Postoperative subscapularis muscle atrophy. A, Intact muscle belly without cranial atrophy. B, Partial atrophy of the upper subscapularis muscle portion. C, Advanced atrophy of the upper subscapularis muscle portion with markedly reduced cranial-transversal diameter. This patient had a positive belly-press test.

In a multicenter study, Edwards et al[7] reported on the results of open repair in 84 isolated subscapularis tendon tears. The Constant score averaged 79.5 points after 45 months. Marked fatty infiltration of the subscapularis muscle negatively influenced the postoperative belly-press test, but the postoperative Constant score was not influenced by fatty degeneration. Additional tenodesis or tenotomy of the LHB had a significant positive influence on the outcome. The rerupture rate was assumed to be 13% based on clinical and radiographic findings.

Gerber and colleagues[11] reported on 16 patients with an average follow-up of 43 months and a score of 82% in the age- and gender-matched Constant score after open repair of an isolated subscapularis tear. Gerber et al[11] and Edwards et al[7] each reported persistent positive lift-off and belly-press tests in the postoperative course, representing a partial subscapularis muscle insufficiency at a rate of 31% and 20%, respectively. It was shown that positive postoperative subscapularis tests were not indicative of a poor clinical outcome, as these patients did not achieve lower Constant scores, but Edwards et al[7] stated that the commonly used shoulder scores do not adequately reflect subscapularis muscle strength.

Still it is not clarified whether longer treatment delays cause muscle atrophy and fatty infiltration of the subscapularis muscle that cannot be fully reversed by surgery or if a possible denervation during the release of the musculotendinous unit, elongation of the repair, or a combination of these factors causes subscapularis muscle dysfunction despite an intact tendon.[11,28]

All of the patients in the present study showed a significant increase in active forward flexion, external rotation, and internal rotation. The Constant score, with all subcategories, could be improved significantly by surgery. The majority of positive preoperative belly-press tests and lift-off tests could be reversed, with only 5 remaining positive belly-press tests (24%) and 1 positive and 1 weakened lift-off test (10%) after surgery. Patients with a positive postoperative belly-press test did not score significantly lower Constant scores. We assume that this lack of association between a positive belly-press test and a lower outcome score is found frequently because subscapularis function is not reflected adequately by the Constant score and all other shoulder scoring systems.[7] Therefore, we developed the force measurement plate to assess the often overlooked subscapularis muscle function.

Postoperative magnetic resonance findings revealed a rerupture in 1 case (5%) and an intact subscapularis repair in 20 shoulders, including 1 case with a markedly thinned upper subscapularis tendon. The CRTD, CATD, and subscapularis muscle CSA were significantly reduced in the operated group compared with the age-, gender-, and BMI-matched control group.

With the force measurement plate, which was designed for the evaluation of postoperative subscapularis function in this study, we could quantify subscapularis muscle strength in the subscapularis-specific internal rotation position, with a reproducible and specific method. In the postoperative course, overall subscapularis strength in the operated shoulder was significantly reduced in the belly-press and lift-off test position compared with the contralateral shoulder. The subpopulation of patients with a positive postoperative belly-press test generated less average power in the FMP testing compared with patients with a negative test, but patient numbers were too small for statistical comparison. Postoperative subscapularis strength in the lift-off test position was significantly reduced compared with the contralateral shoulder but with only 1 positive and 1 weakened lift-off test. Our clinical and MRI findings show that in most cases, a positive belly-press test is associated with an atrophy of the upper subscapularis muscle portion and a reduced cranial-transversal muscle diameter. The lift-off test was negative in 4 of 5 of these patients, and on MRI scans, there was no significant atrophy or a reduced CATD, indicative of an intact lower muscle portion of the subscapularis. We think that this is a common finding, as most tears affect only the upper part of the subscapularis tendon. Our findings are in line with an electromyographic study by Tokish et al,[30] who reported that the belly-press test mainly reflects the function of the upper subscapularis and the lift-off test mainly activates the lower portion of the subscapularis. The majority of shoulders were operated on after a short symptomatic time interval, and we did not find a significant progression of fatty infiltration of the subscapularis muscle or other rotator cuff muscles on postoperative magnetic resonance images. Because of this finding, we could only find a trend for better functional results and less postoperative subscapularis muscle atrophy on MRI in patients with a shorter delay between injury and surgery but no statistical significance. Patients with type IV tears did not have lower scores compared with patients with type II and type III tears. We suspect that this finding is due to an early repair in all type IV tears without apparent fatty muscle degeneration. It seems that an intact function of the lower subscapularis muscle portion is sufficient to achieve centering of the humeral head and good clinical shoulder scores, but greater study populations are necessary to prove this hypothesis.[7,11,12,21]

We think that arthroscopic subscapularis repair helps to minimize the soft tissue trauma around the shoulder, resulting in a lower postoperative shoulder stiffness rate and a lower rate of significant external rotation deficits compared with open repair studies.[11] Early results of arthroscopic repair after a mean follow-up of 27 months are promising, but a long-term follow-up is needed to show if subscapularis muscle insufficiency is progressing, rerupture rate is increasing over time, and arthroscopic repair of isolated subscapularis tears achieves equal results compared with open repair.

## CONCLUSION

Our findings show that arthroscopic subscapularis repair achieves a significant functional improvement, with a low rerupture rate based on MRI findings, and restores subscapularis function in the majority of patients.

Subscapularis strength is reduced after surgical repair compared with the contralateral shoulder and can be quantified with the use of the electronic force measurement plate. Insufficiency of the upper subscapularis portion can be detected with specific clinical tests, and muscle atrophy can be revealed on parasagittal magnetic resonance planes (Y-shaped view). The majority of these postoperative partial subscapularis insufficiencies are subclinical and do not alter patient satisfaction or shoulder scoring systems.

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