The return of subscapularis strength after shoulder arthroplasty

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Background: During shoulder arthroplasty, the subscapularis tendon is released and repaired. Whether subscapularis strength subsequently returns to normal is poorly understood. This study’s purpose was to determine whether subscapularis strength returns to normal after shoulder replacement and whether any preoperative factors predict the return of strength postoperatively.

Methods: Sixty-four patients underwent unilateral shoulder arthroplasty. Subscapularis strength was compared between the surgical and contralateral (normal) limbs at baseline (preoperatively) and follow-up. In addition, operative arm subscapularis strength recovery was compared with ipsilateral supraspinatus strength recovery. Independent variables were assessed for their effect on subscapularis strength, including sex, age, dominant-side surgery, preoperative strength, preoperative external rotation, subscapularis management technique, and fatty infiltration.

Results: The mean subscapularis strength ratio at 24 months from baseline was 1.19 ± 2.23 (P = .0007). The normal side was significantly stronger than the operative side at all time points (P < .0001). The operative-side subscapularis mean strength ratio was 0.54 ± 0.28 of normal at baseline and 0.70 ± 0.24 at 24 months. Defining normal strength as 15%, 15% of patients were normal at baseline up to 22% at 24 months. At 24 months, the mean supraspinatus strength ratio from baseline (3.13 ± 6.11) was significantly greater than the subscapularis mean strength ratio (P = .0007). Multivariable regression analysis did not demonstrate any correlation (P > .05) between the independent variables studied and final subscapularis strength.

Discussion: Although significant strength improvement from baseline was observed at 2 years after shoulder arthroplasty, subscapularis strength returned to normal in only a minority of patients. Potential prognostic variables associated with final subscapularis strength remain elusive.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Shoulder; arthroplasty; subscapularis; strength; replacement; osteoarthritis
Shoulder arthroplasty is a means of managing advanced glenohumeral arthritic pain with favorable outcomes.\(^7\) To gain access to the glenohumeral joint, the subscapularis tendon may be released by a tenotomy, tendon elevation off bone ("peel"), or osteotomy of the lesser tuberosity.\(^30\) After implantation of the arthroplasty, the subscapularis is repaired for improved stability and function.\(^24\) Despite this, poor healing or rupture of a repaired subscapularis is not uncommon\(^14\) and can be associated with weakness, instability, and pain.\(^1,2,9\)

In addition to a tendon's intrinsic ability to heal, strength recovery of a muscle-tendon unit after its surgical release may be dependent on 3 separate factors: the method by which it is detached, the method by which it is repaired, and the effect of the underlying articular degenerative or inflammatory disease process on the tendon itself. In outcomes studies, the contralateral shoulder is frequently used as a marker of "normal" strength and range of motion, particularly in the setting of rotator cuff tears and trauma.\(^1,5,9,16,25\) To our knowledge, no previous studies have used this as a basis for evaluating recovery of subscapularis strength after shoulder arthroplasty. The primary objective of this study was to determine whether subscapularis strength returns to normal after shoulder arthroplasty by comparison to the normal, contralateral side. The secondary objectives were to compare the return of subscapularis strength with the return of supraspinatus strength in the operative arm and to determine whether any preoperative factors may predict the return of subscapularis strength after surgery.

Materials and methods

Patients

A retrospective analysis was undertaken in patients who were part of a larger multicenter, prospective, randomized clinical trial that assessed functional outcomes after lesser tuberosity osteotomy compared with subscapularis peel.\(^17\) Inclusion criteria for this study included failure of standard nonsurgical management for osteoarthritis or inflammatory arthritis. Patients with pain, stiffness, or arthroplasty on the contralateral, normal arm were excluded. The study cohort consisted of 64 patients (28 men) with a combined mean age of 67 (standard deviation [SD], 11; range, 38-90) years. Fifty-nine patients had a diagnosis of osteoarthritis, and 5 had rheumatoid arthritis. Surgery was carried out on the dominant arm in 22 patients (34%).

Outcome variables

The primary outcome measure was subscapularis strength in both the operative and contralateral (normal) arms as measured by a hand-held dynamometer (microFET2; Hoggan Health Industries, West Jordan, UT, USA) in the belly-press position\(^20\) preoperatively and at 3, 6, 12, and 24 months. Testing was carried out by use of a variation of the belly-press test described by Gerber et al\(^10\) with the dynamometer strapped to the patient’s hand; the hand was placed on the lower sternum with the elbow in line with but not posterior to the hand. The patient was asked to press the dynamometer into his or her sternum with a maximum force for a 5-second duration. The mean strength was calculated on the basis of 2 separate trials. The sensitivity of the belly-press test has been reported at 100% for detection of complete subscapularis tears,\(^26\) and the hand-held dynamometer has been validated for use in subscapularis evaluation.\(^20\) A spring scale was used to measure supraspinatus strength, taken as the mean of 3 separate measurements with the arm in the "scaption" position at 90° of elevation. All strength measurements were taken in the clinic setting at each center by the same trained research coordinator, who was not involved in the surgery.

In the absence of previously published values of dominant- vs nondominant-side subscapularis strength, reports on forearm and grip strength were used to estimate the range of asymmetry in upper limb strength. A previous report demonstrated that peak forearm torque strength in the nondominant arm was between 85% and 95% of the dominant extremity.\(^21\) In a review of 10 studies, dominant-side grip strength exceeded nondominant-side grip strength for mixed samples of right- and left-dominant subjects by a mean difference of 0% to 15.8%.\(^6\) Thus, operative-side strength was considered normal in the current study if the subscapularis strength values were within 15% of the contralateral, normal arm to account for this expected range of asymmetry.

Clinical outcome variables also included external rotation range of motion, measured with a goniometer with the arm in the adducted position, and a visual analog pain scale. Both were administered at baseline and 24 month postoperatively. The degree of preoperative subscapularis fatty infiltration was determined with computed tomography. The computed tomography protocol included 2-mm-thickness axial slices with 2-mm-thick coronal and sagittal reformations (with respect to the glenohumeral joint) in both bone and soft tissue algorithms. A musculoskeletal radiologist (K.R.) interpreted all scans. The fatty infiltration grade of the subscapularis was documented by the method described by Goutallier et al.\(^12\) The grading system is based on a 5-point scale: no fat, grade 0; fatty streaks within muscle, grade 1; fat content less than muscle content, grade 2; fat content equal to muscle content, grade 3; and fat content greater than 50%, grade 4.

Surgical technique

The surgical approach has been previously described.\(^17\) The deltopectoral approach was used in all patients. The long head of the biceps tendon, when present, underwent tenodesis to the pectoralis major in all cases. Two different means of managing the subscapularis were used, subscapularis peel (34 patients; 53%) and osteotomy of the lesser tuberosity (30 patients; 47%). For the peel group, the subscapularis tendon was peeled off the lesser tuberosity, beginning at the intertubercular groove and extending inferiorly to the humeral neck. The plane between the subscapularis and the conjoined tendon was developed with blunt dissection. The subscapularis muscle-tendon unit was then released superiorly at the rotator interval, anteriorly beneath the conjoined group, and mobilized off the anterior glenoid vault by a vertical capsulotomy. The entire anterior capsule was released, including the middle and inferior glenohumeral ligaments. Finally,
a limited release and mobilization deep to the subscapularis were completed with a curved Mayo scissors. An anterior glenoid neck retractor was then inserted. No further mobilization deep to the subscapularis beyond this was carried out. After mobilization of the subscapularis muscle-tendon unit, joint replacement was conducted with a press-fit humeral stem and a cemented, keeled glenoid component (Tornier SAS, Saint-Ismier, France). After arthroplasty, the subscapularis tendon was repaired to the lesser tuberosity with 3 nonabsorbable mattress transosseous sutures (No. 2 Hi-Fi; ConMed Linvatec, Largo, FL, USA) passed within the bicipital groove and tied over a miniplate placed on the lateral aspect of the greater tuberosity. The lesser tuberosity osteotomy was conducted as described by Gerber et al. A fragment of the lesser tuberosity (4-6 cm²) was elevated with a flexible osteotome along with the subscapularis tendon insertion. Tendon mobilization and subsequent repair were performed in a manner identical to the peel repair described before. Postoperatively, all patients received 24 hours of prophylactic antibiotic coverage. A shoulder sling was worn for the first 6 weeks. On the first postoperative day, patients were instructed to initiate self-assisted, passive forward elevation to 90° in the supine position and to limit external rotation to neutral for 6 weeks. Active elevation was allowed at 6 weeks, and gentle strengthening was begun 12 weeks postoperatively.

**Statistical methods**

The mean, standard deviation, and range were reported for the outcome variables in the operative and normal side at each time point. A longitudinal analysis, mixed-effect model, using patients as random effects, assessed whether the strength improved significantly over time on the operative side, and 2-sided t tests were used to compare this outcome between the operative and normal sides and between operative-side subscapularis strength and operative-side supraspinatus strength at baseline, 6 months, 1 year, and 2 years after surgery. Strength on the operative side was expressed as a ratio with comparison to the normal-side strength. Associations between external rotation and subscapularis strength and between pain and subscapularis strength were determined with a Spearman correlation coefficient. A univariate regression model was used with sex, age, surgery on the dominant arm, baseline strength, baseline external rotation, subscapularis management technique, and subscapularis fatty infiltration variables to determine associations with final subscapularis strength. A multivariable regression model was then used to control for each variable independently.

**Results**

Strength data for the operative and contralateral (normal) arms are summarized in Table I and Figure 1. Operative shoulder subscapularis strength increased from 3.4 kg (SD, 2.3) at baseline to 4.6 kg (SD, 2.5) at 24 months, representing a mean increase of 1.2 kg (P = .0007). The ratio of subscapularis strength for the operative arm vs baseline strength was 0.87 (SD, 2.43) at 3 months, 0.24 (SD, 2.44) at 6 months, 0.32 (SD, 2.65) at 12 months, and 1.19 (SD, 2.23) at 24 months. Subscapularis strength in the normal, contralateral arm was 6.6 kg (SD, 3.1) at baseline and 7.2 kg (SD, 3.5) at 24 months. The differences between the operative-side and normal-side strength were significant at all time points (P < .0001). The mean ratio of operative-side strength to normal-side strength was 0.54 (SD, 0.28) at baseline and increased to 0.70 (SD, 0.24) at 24 months (Table II). With operative-side strength within 15% of contralateral-side strength being considered normal, 15% of patients were normal at baseline, with an increase to 22% at 24 months (Table III).

Mean external rotation range of motion was 19° ± 18° at baseline and 43° ± 20° at 24 months. The mean pain visual analog scale score was 6.9 (SD, 2.2) at baseline and 0.8 (SD, 1.6) at 24 months.

An association between baseline pain and baseline subscapularis strength was observed (r = −0.35; P = .005). However, no such association was found at 24 months of follow-up (r = −0.22; P = .09). Similarly, no associations were detected between external rotation and subscapularis strength at baseline (r = 0.13; P = .3) or at 24 months of follow-up (r = 0.05; P = .67).

A comparison of the ratios of operative-side subscapularis strength to baseline strength with the ratios of operative-side supraspinatus strength to baseline strength is summarized in Table IV and Figure 2. No differences were observed at 3 months (P = .099) or 6 months (P = .5812), but significant differences were identified at 12 months (P = .0052) and 24 months (P = .0007).

The univariate regression analysis identified the association of 2 factors with final subscapularis strength, sex (P < .0001) and baseline strength (P < .0001). Multivariable regression analysis did not identify any predictors of final subscapularis strength with the following independent variables: sex (P = .134), age (P = .589), surgery on the dominant arm (P = .536), baseline strength (P = .194), baseline external rotation (P = .302), subscapularis management technique (P = .673), or baseline subscapularis fatty infiltration (P = .47).

**Discussion**

During shoulder arthroplasty, to gain access to the joint for implant insertion, the subscapularis tendon is released with a tenotomy, peel, or osteotomy of the lesser tuberosity and is subsequently repaired. Whether subscapularis strength returns to normal after these approaches is not well understood. The results of this study indicate that subscapularis strength increases postoperatively over time. However, at all time points, the strength on the operative side was significantly lower than on the contralateral (normal) side, and only a minority of patients (22%) reached normal strength by 24 months. A negative association was identified between baseline pain and subscapularis strength, indicating that more severe pain was correlated with poorer subscapularis strength. However, no other correlations were observed between either pain or
external rotation and subscapularis strength at other time points. Comparison of the ratios of operative-side strength recovery of the subscapularis to the supraspinatus revealed significantly lower ratios in the subscapularis strength at 12 and 24 months. This finding is interesting as it demonstrates differential rates of recovery in the rotator cuff muscles, with the supraspinatus starting at a lower ratio and progressing more rapidly (Fig. 2). To determine if any independent factors were predictive of subscapularis strength recovery, a multivariable regression analysis was done. Unfortunately, no factors were found to be predictors of final strength.

Subscapularis strength assessment has been carried out after shoulder arthroplasty by several authors. 17,19,27 Scalise et al 27 compared shoulder arthroplasty patients who underwent either lesser tuberosity osteotomy or subscapularis peel. No differences between groups were observed in internal rotation strength with the arm in the adducted position in neutral rotation when controlling for sex. The authors observed superior Penn scores in the osteotomy group. Jackson et al 15 studied patients who underwent subscapularis tenotomy and noted a poor correlation between the belly-press and lift-off tests and assessment of tendon integrity by ultrasound. Dynamometer strength testing in the bear-hug position demonstrated a significant correlation with tendon integrity. Patients with

| Table I  Subscapularis strength in operative and contralateral (normal) arms, tabular representation  |
| Follow-up Time | Operative, mean kg (SD) | Contralateral, mean kg (SD) | P value |
| Baseline | 3.4 (2.3) | 6.6 (3.1) | <.0001 |
| 3 months | 2.7 (1.7) | 6.6 (3.0) | <.0001 |
| 6 months | 3.6 (2.3) | 7.2 (3.3) | <.0001 |
| 12 months | 3.8 (2.0) | 7.2 (3.4) | <.0001 |
| 24 months | 4.6 (2.5) | 7.2 (3.5) | <.0001 |

SD, standard deviation.

| Table II  Ratio of operative vs contralateral arm subscapularis strength including interquartile ranges over time  |
| Follow-up Time | Mean (SD) | Median (IQR) |
| Baseline | 0.54 (0.28) | 0.5 (0.33, 0.73) |
| 3 months | 0.43 (0.22) | 0.46 (0.25, 0.58) |
| 6 months | 0.53 (0.31) | 0.5 (0.3, 0.75) |
| 12 months | 0.61 (0.30) | 0.54 (0.41, 0.8) |
| 24 months | 0.70 (0.24) | 0.75 (0.57, 0.82) |

SD, standard deviation; IQR, interquartile range.

| Table III  Number of patients with normal operative-arm subscapularis strength (within 15% of contralateral-arm subscapularis strength) over time  |
| Follow-up Time | N (%) |
| Baseline | 8 (15.38%) |
| 3 months | 1 (1.82%) |
| 6 months | 7 (14.29) |
| 12 months | 9 (16.36) |
| 24 months | 11 (21.57) |

SD, standard deviation.

| Table IV  Comparison of ratios of operative-side subscapularis strength to baseline vs supraspinatus strength to baseline over time  |
| Time | Operative-side subscapularis strength ratio (SD) | Operative-side supraspinatus strength ratio (SD) | P value |
| 3 months/baseline | -0.87 (2.43) | -2.12 (6.25) | .099 |
| 6 months/baseline | 0.24 (2.44) | 0.33 (5.86) | .5812 |
| 12 months/baseline | 0.32 (2.65) | 2.54 (6.07) | .0052 |
| 24 months/baseline | 1.19 (2.23) | 3.13 (6.11) | .0007 |

SD, standard deviation.

Figure 1  Subscapularis strength in operative and contralateral (normal) arms, graphical representation.

Figure 2  Operative-side ratio of subscapularis strength to baseline strength, compared with ratio of supraspinatus strength to baseline strength over time. mo, months; bl, baseline; 3 mo./bl, ratio of strength at 3 months to baseline strength; 6 mo./bl, ratio of strength at 6 months to baseline strength; 12 mo./bl, ratio of strength at 12 months to baseline strength; 24 mo./bl, ratio of strength at 24 months to baseline strength. *P = .0052. **P = .0007.
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Liem et al carried out strength evaluation in the lift-off position in patients who underwent subscapularis tenotomy; mean strength postoperatively was 3.8 kg. The inability to tuck in one’s shirt and a positive lift-off test result were both correlated with poorer functional outcome measures. At postoperative follow-up, 30% of patients in the series had partial subscapularis tears on ultrasound, although the tendon integrity was not correlated with clinical outcomes. In a comparison of subscapularis peeling and release techniques, no differences in subscapularis strength, healing rates, or tendon integrity were found between groups.

The current study did not demonstrate full recovery of strength in the operative arm, with only 22% of patients achieving normal subscapularis strength by 24 months. The reasons for this poor strength recovery are not entirely clear. Possible associations with the degree of external rotation, as a measure of tendon excursion, and pain were investigated. Other than an association between baseline pain and subscapularis strength, no other correlations were identified, indicating that these factors are unlikely to influence the recovery of subscapularis strength.

It is possible that the subscapularis muscle and tendon in the setting of advanced shoulder arthritis may limit the amount of strength recovered postoperatively. In addition, in the postoperative shoulder, the relationships in the joint, including humeral head height and joint line position, may be altered from their preoperative positions. These additional factors may alter the function of the subscapularis through changes in the length of the musculotendinous unit and possibly through alterations in the direction of its action. To investigate the possible effects of the disease process and arthroplasty on the degree of subscapularis strength recovery, a comparison was made between subscapularis strength recovery and supraspinatus strength recovery in the ipsilateral shoulder. Supraspinatus strength was chosen as a comparator, given that it was also subjected to the same disease process, lack of excursion, and arthroplasty, but it did not undergo a surgical release and repair as did the subscapularis. Thus, differences identified in strength recovery between subscapularis and supraspinatus may be attributable to the process of surgical release and repair and not to the underlying arthritic process or joint reconstruction. Our observations that subscapularis strength recovery was significantly lower than supraspinatus recovery appear to demonstrate that the surgical release and repair in part accounts for the poorer recovery ratio. Further study into methods of subscapularis release and repair is required in hopes of improving the results of this aspect of shoulder arthroplasty.

Gerber et al observed an association between subscapularis fatty infiltration grade and a positive belly-press test result. In an analysis of factors associated with functional outcome after shoulder arthroplasty, Edwards et al reported that subscapularis fatty infiltration was often associated with infraspinatus fatty infiltration. Subscapularis fatty infiltration, however, did not influence postoperative functional outcomes. In the current study, several factors were analyzed for association with subscapularis strength and functional outcome measures. No associations were identified among factors including sex, age, surgery on the dominant arm, baseline strength, baseline external rotation, subscapularis management technique, and fatty infiltration.

The results of this study may be viewed in the light of certain limitations. Patients were screened to determine if they had evidence of joint degeneration in the contralateral arm, by way of history and physical examination. Any patients who described or demonstrated contralateral symptoms or signs were excluded from the analysis, as were patients who had a contralateral shoulder arthroplasty. If this did introduce an element of bias, it would favor patients with a normal contralateral arm; in this way, patients included in the analysis would represent the worst-case scenario in terms of strength comparison. Hughes et al observed small but significant differences in internal rotation strength in normal subjects in certain arm positions. It was expected that hand dominance may have affected the results of the current study. For this reason, this variable was included in the multivariable regression model. In addition, the definition of normal was subscapularis strength that fell within 15% of the contralateral side; hence, the asymmetry that is known to occur between dominant and nondominant sides was accounted for. Finally, the study was underpowered to detect statistically significant associations with multivariable regression analysis. A total of 280 observations would have been required to achieve 80% power for this particular analysis.

**Conclusion**

Significant differences in subscapularis strength were observed between the operative and normal shoulders at all time points. Only 22% of patients reached normal strength at 24 months of follow-up. Subscapularis strength recovery was significantly poorer than supraspinatus strength recovery, indicating that the surgical release and repair may negatively affect subscapularis recovery more so than the arthritic disease process or joint reconstruction. Multivariable regression analysis of variables including sex, age, surgery on the dominant arm, baseline strength, baseline external rotation, subscapularis management technique, and fatty infiltration did not demonstrate that any of these factors were significant predictors of final subscapularis strength after shoulder arthroplasty.
References


