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# The Destiny of the Subscapularis Tendon after Arthroscopic Supraspinatus Repair

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**Background:** The purpose of this study was to identify the changes in untreated subscapularis in patients who underwent supraspinatus repair and to evaluate the factors related to the changes in the subscapularis.

**Methods:** A cohort of patients who underwent isolated supraspinatus repair with preservation of the subscapularis was reviewed. Changes in the subscapularis, including any newly formed lesion and aggravation of an existing lesion, were evaluated 12 months postoperatively on magnetic resonance imaging along with an examination to identify causative factors after supraspinatus repair. Clinical scores were compared between patients with and without subscapularis changes.

**Results:** A total of 528 patients were reviewed. Changes in the subscapularis, including newly formed lesions and aggravation of an existing lesion, were shown in 90 patients (17.0%). Upon regression analysis, changes in the subscapularis were associated with the initial existence of a subscapularis lesion (grade I: $p = 0.042$, grade II: $p = 0.025$), an accompanying biceps lesion ($p = 0.038$), and a retear of the repaired supraspinatus ($p = 0.024$). No significant differences were shown in clinical scores between patients with and without subscapularis changes after supraspinatus repair.

**Conclusions:** Untreated asymptomatic subscapularis may undergo morphological changes even after repair of the torn supraspinatus. Preoperative subscapularis lesions, biceps long head pathology, and retears of the repaired supraspinatus were associated with subscapularis pathology in patients who underwent supraspinatus repair.

**Keywords:** *Rotator cuff, Subscapularis, Rotator cuff injuries*

The subscapularis is the largest of the rotator cuff muscles and is known for its main role as an internal rotator and adductor of the shoulder, while also contributing to the dynamic stability of the joint.[1,2] However, despite the importance of its anatomical role, problems regarding the condition of the subscapularis have received relatively little attention compared to that of the supraspinatus or infraspinatus.[3,4] Most of the research regarding rotator cuff problems is focused on the supraspinatus since the functional problems caused by the subscapularis may be less prominent than those associated with shoulder elevation or external rotation.[3,5-7] Due to the large size of the muscle and tendon itself, symptoms regarding the isolated subscapularis lesion may not develop without extensive or severe damage, showing high specificity and low sensitivity.[8,9]

Due to its anatomical location within the joint, lesions on the tendon portion of the subscapularis tend to be overlooked during the arthroscopic procedure.[10-13] Specifically, identification of the benign subscapularis lesions other than those in the upper border may not be easy, whereas the whole tendon portion of the supraspinatus and infraspinatus is easily accessible during the arthroscopic procedure. Poor detection of the lesion has led to speculation of a low incidence of subscapularis problems and consequent lack of strategy for subscapularis

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lesion treatment compared to that of the supraspinatus or infraspinatus. Even though the percentage of cases of isolated subscapularis tear is low, an accompanying subscapularis lesion was found in more than 50% of patients in combination with supraspinatus tear.[3,11]

Many studies have been published regarding the various factors associated with the pathophysiology of rotator cuff diseases.[14] However, in the majority of these studies, the so-called rotator cuff included only the supraspinatus; studies regarding only the subscapularis are rare, as isolated tears of the subscapularis remain relatively uncommon.[3,15,16] If we can predict the destiny of untreated subscapularis after repair of the torn supraspinatus and identify factors related to the pathologic changes in the subscapularis, it could aid in the detection of a concealed lesion or indications for voluntary treatment of the subscapularis along with supraspinatus repair.[17-19] The purpose of this study was to evaluate the changes in an untreated subscapularis tendon in patients who underwent repair of a full-thickness tear on the supraspinatus and to evaluate the factors related to these changes. We hypothesized that there would be overall changes in the preserved subscapularis after supraspinatus repair and that the preoperative condition of the subscapularis might have a correlation with postoperative changes in an untreated subscapularis.

## METHODS

This study was approved by the Institutional Review Board of Seoul St. Mary's Hospital, the Catholic University of Korea (IRB No. KC17OESI0118). As a retrospective review study, informed consent was waived.

We reviewed 656 patients who were diagnosed with isolated supraspinatus tears and underwent subsequent repair from March 2015 to February 2021. Preoperative diagnoses were based on magnetic resonance imaging (MRI), performed with a 3-T open-type scanner (Magnetom Vida, Siemens Healthineers). Oblique coronal, oblique sagittal, and axial FS T2-weighted spin-echo MRI scans were acquired for structural and qualitative assessments of the rotator cuff and adjacent structures. Also, the conditions of the tendons and adjacent structures were visually confirmed by arthroscopic procedures. Regardless of the radiologic grade of the subscapularis, any patients with symptoms attributable to subscapularis injury, including any positive or suspicious signs upon lift-off test, bear hug test, and belly press test, based on the preoperative medical records were excluded. There is a high probability of either an apparent or non-apparent pathological condition with a symptomatic subscapularis. Patients with a previous history of trauma confined to fracture or dislocation of the treated shoulder were not included in this evaluation. Also, supraspinatus tears associated with acute trauma were not included in the evaluation, as this study focused on the chronicity of tendon disease.

Eventually, a cohort of 528 patients who underwent sole repair of the supraspinatus without any additional treatments on the subscapularis was enrolled and evaluated. All surgical evaluations and procedures were performed via arthroscopy. The postoperative condition of the shoulder was evaluated by MRI at 12 months after the initial supraspinatus repair using the same MRI settings as those of the preoperative evaluation.

### Assessment

The postoperative condition of the subscapularis was evaluated and compared with the preoperative T2 axial view MRI. Existence of high-signal alteration and tendon fraying was considered grade I according to the classification by Pfirrmann et al.[20] Pfirmann grading system is known to have sensitivity and specificity of 91% and 86%, respectively. Evident partial tears were classified as grade II, whereas complete tears of the subscapularis were classified as grade III (Fig. 1).

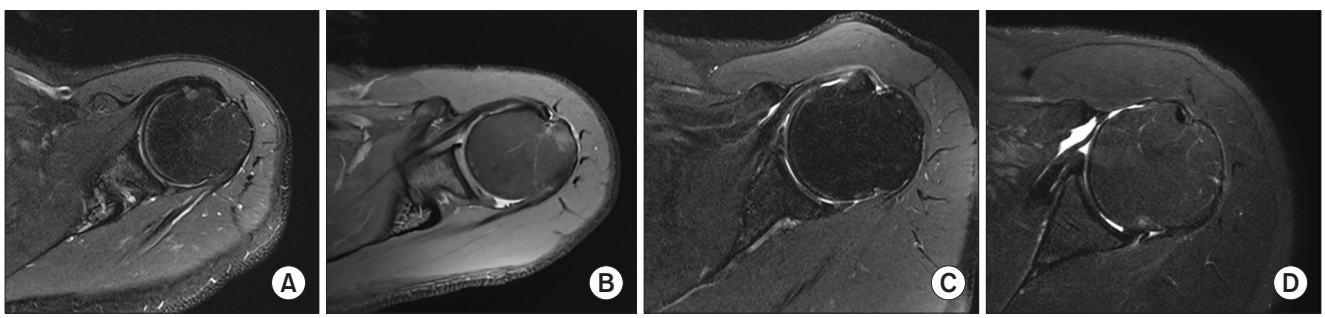


**Fig. 1.** Classification of subscapularis lesions on magnetic resonance imaging by Pfirrmann scale. (A) Grade 0: normal tendon. (B) Grade I: slight fraying and signal alteration in the cranial part. (C) Grade II: tear of the cranial ¾ of the subscapularis tendon. (D) Grade III: complete tear of the tendon.

Evaluation of changes in the subscapularis including a newly developed lesion, change from a preexisting intratendinous lesion, or progression of a preexisting subscapularis tear after supraspinatus repair on MRI was the primary outcome of this study. We also sought to determine which factors correlated with changes within the subscapularis tendon or with the development of new lesions. The MR images were independently evaluated by 2 authors (HJL and JHK).

Age, sex, grade of a subscapularis tear evaluated on preoperative MRI, tear size (length of maximum retraction measured during the arthroscopic procedure) of the supraspinatus, preoperative condition of the long head of the biceps tendon, type of acromion, and existence of accompanying lesions were evaluated with preoperative MRI and during the arthroscopic procedure. The condition of the biceps long head tendon (LHBT) was subdivided as in the study of Lee et al.[21] The existence of intra-tendinous signal change, dislocation, and partial rupture was considered pathologic LHBT.

The method of supraspinatus repair and accompanying treatments were also evaluated. In patients with shoulder stiffness, anterior and inferior capsular release was performed. The single-row method and the transosseous equivalent method were utilized for the repair of the torn supraspinatus. Acromioplasty was performed in type II and III acromions. At the postoperative MRI at 12 months after the operation, the existence of retears was analyzed according to the classification by Sugaya et al.[22]

Clinical scores including the American Shoulder and Elbow Surgeons (ASES) score, Constant score, and visual analog scale (VAS) score for pain were compared between patients with and without subscapularis changes after supraspinatus repair. Outcomes were also compared based on the range of motion, including forward flexion, external rotation, and internal rotation. Internal rotation was evaluated by the tip of the thumb reaching the vertebral level. Internal rotation up to the level of the sacrum was designated as 0 point, and 1 point was added for each level up. The assessment was performed by 2 authors (HJL and YSK).

**Table 1.** Demographic Data of the Patients

| Variable | Value (n = 528) |
|---|---|
| Age (yr), mean ± SD | 63.42 ± 7.19 |
| Sex (male : female) | 273 : 255 |
| Dominant : non-dominant | 284 : 244 |

SD: standard deviation.

**Statistical Analysis**

The primary outcome variable of interest was a change in the condition of the subscapularis after repair of a torn supraspinatus. Univariate and multivariate analyses using logistic regression were performed to evaluate variables related to changes in the subscapularis. Clinical and VAS scores for pain were compared using the Mann-Whitney *U*-test. The level of significance was set at $p$-value < 0.05. The SPSS software version 19 (IBM Corp.) was used for statistical analysis.

## RESULTS

The demographic data of the enrolled patients are shown in Table 1. Among the evaluated patients (n = 528), 289 were grade 0 according to Pfirrmann's classification, with no apparent preoperative subscapularis lesion. Despite the enrollment of patients with no symptoms, 239 (45.2%) showed at least grade I or II lesions on the subscapularis. There were no patients with a grade III subscapularis tear, and none of the patients underwent subscapularis repair. Postoperative results are described in Table 2.

Change of the untreated subscapularis was shown in 90 of the enrolled patients (17.0%), with 22 (22/289,

**Table 2.** Post-arthroscopic Results with Supraspinatus Repair

| Supraspinatus | Value |
|---|---|
| Tear size (mm), mean ± SD | |
| Retraction | 14 ± 3.83 |
| Anterior to posterior | 12 ± 4.19 |
| Repair method | |
| Single row suture | 172 |
| Suture bridge | 143 |
| Footprint coverage | |
| Full | 308 |
| Partial | 7 |
| Capsulectomy | 46 |
| Acromion | |
| Type I | 74 |
| Type II | 212 |
| Type III | 29 |
| Acromioplasty | 102 |

SD: standard deviation.

7.6%) developing a new lesion of grade I. Intratendinous changes in grade I patients were shown in 54 patients (54/201, 26.9%), while 8 patients experienced aggravation from grade I to grade II (8/201, 4.0%). An increase in the existing lesion size was shown in 6 patients (6/38, 15.8%). There were no patients whose lesions proceeded to grade III (Fig. 2).

Univariate regression analysis showed that postoperative changes on the subscapularis were related to the initial subscapularis lesion on preoperative MRI and retear of the repaired supraspinatus (Table 3). Upon multivariate regression, postoperative changes of the subscapularis were related to accompanying LHBL ($p$ = 0.027), initial subscapularis lesion ($p$ = 0.044), and retear of the repaired supraspinatus ($p$ = 0.033). Higher functional scores including pain VAS were shown in patients with no changes

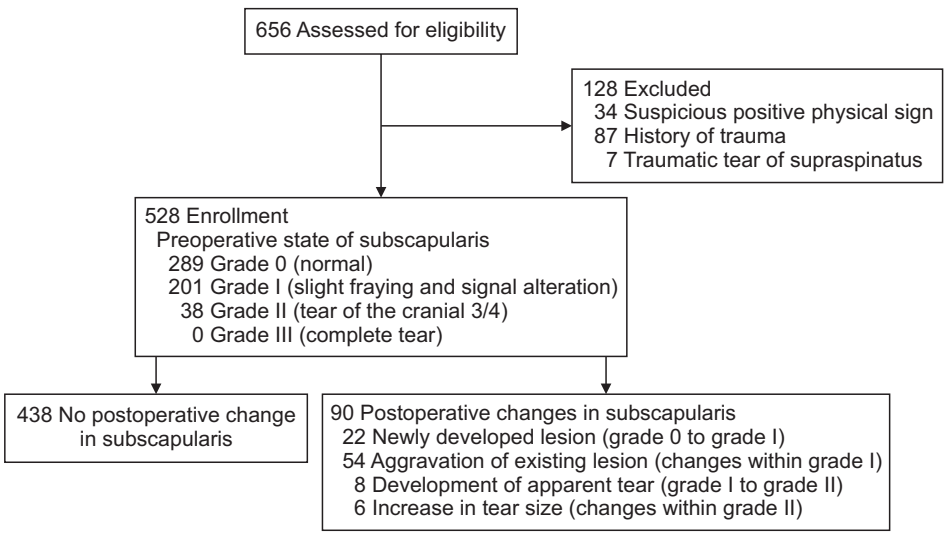


**Fig. 2.** Flowchart of patient enrollment.

**Table 3.** Univariate Analysis Showing Variables Affecting Changes in Subscapularis

| Characteristics | Odds ratio | 95% CI | *p*-value |
|---|---|---|---|
| Age | - | - | 0.724 |
| Sex | - | - | 0.694 |
| Comorbidity | | | |
| Diabetes mellitus | - | - | 0.743 |
| HBP | - | - | 0.959 |
| Thyroid | - | - | 0.887 |
| Supraspinatus | | | |
| Tear size | | | |
| Anterior to posterior | - | - | 0.173 |
| Retraction | - | - | 0.220 |
| Repair method | | | |
| Single row suture | - | - | 0.817 |
| Double row suture bridge | - | - | 0.541 |
| Footprint coverage | - | - | 0.212 |
| Retear | 1.114 | 1.010–1.084 | 0.024* |

**Table 3.** Continued

| Characteristics | Odds ratio | 95% CI | *p*-value |
|---|---|---|---|
| Preoperative state of subscapularis | | | |
| Grade 0 | | | 0.613 |
| Grade I | 1.881 | 1.175–1.228 | 0.042* |
| Grade II | 2.617 | 1.414–1.717 | 0.025* |
| Existence of biceps long head lesion | 1.722 | 1.238–1.885 | 0.038* |
| Acromion | | | |
| Type 1 | - | - | 0.489 |
| Type 2 | - | - | 0.657 |
| Type 3 | - | - | 0.294 |
| Acromioplasty | - | - | 0.088 |
| Capsulectomy (existence of shoulder stiffness) | - | - | 0.076 |

CI: confidence interval, HBP: high blood pressure.
*$p < 0.05$, statistically significant.

**Table 4.** Comparison of Postoperative Clinical Scores between Patients with Changes in Subscapularis and No Change in Subscapularis at Postoperative 12 Months

| Characteristics | Patients with changes in subscapularis | Patients with no change in subscapularis | *p*-value |
|---|---|---|---|
| Pain VAS score | 2.4 | 2.0 | 0.08 |
| ASES score | 25.4 | 26.8 | 0.15 |
| Constant score | 88.5 | 90.6 | 0.32 |
| Forward flexion (°) | 140.7 | 144.4 | 0.41 |
| External rotation (°) | 78.2 | 75.9 | 0.18 |
| Internal rotation (°)* | 4.3 | 4.4 | 0.54 |

VAS: visual analog scale, ASES: American Shoulder and Elbow Score.
*Internal rotation measured based on the level of vertebrae. The vertebral level was numbered serially as follows: 0 for any level below the sacral region and 1 additional point for each level higher than the sacrum.

in subscapularis, but no statistical significance was found. There were no differences in the range of motion (Table 4).

## DISCUSSION

The results of the study showed that about 20% of the untreated subscapularis tendons experienced intra-tendinous signal changes during the first 12 months after repair of the torn supraspinatus. Rather than newly developed lesions, changes were mostly noted at the preexisting subscapularis lesion. Among the evaluated factors, the preexistence of a subscapularis lesion, the existence of concomitant LHBT pathology, and the retear of a repaired supraspinatus were associated with further changes in the subscapularis. However, these changes did not reflect the functional outcomes.

Identification and recognition of subscapularis problems have increased with the improvement of arthroscopic techniques and imaging modalities.[11,23-25] Since the subscapularis lesion detection has been improved and subscapularis tears occur more frequently as a concomitant lesion than an isolated lesion, the relationships between adjacent structures and the pathophysiology of subscapularis tears have been analyzed in several studies. Among the structures, LHBT is associated as a vicious cycle with the subscapularis. It is more likely that the LHBT will be displaced or unstable with a subscapularis tear, which indicates a sentinel sign because attachment of the subscapularis to the lesser tuberosity extends to the transverse ligament and assists in forming the biceps pulley that stabilizes the biceps tendon itself.[26-29] On the other hand, kinking of a displaced LHBT within the torn subscapularis tendon not only interferes with tendon healing but may apply further stress to the subscapularis. The result of this study, which showed a correlation between changes in subscapularis and the existence of LHBT pathology, clearly added clinical evidence for the intimate relationship between pathologic LHBT and the subscapularis. Surgeons should not only be aware of the sentinel sign on concealed

LHBT lesions but of the need for meticulous observation of the subscapularis to detect pathologic LHBT.[30] However, as the cohort of this study did not include patients who had undergone a biceps procedure, the result might have been different with the treatment of an existing biceps lesion.

Another tendon that cannot be excluded when explaining subscapularis lesions is the supraspinatus. The subscapularis and anterior portion of the supraspinatus together are categorized as the anterosuperior rotator cuff, which is responsible for supporting and balancing forces on the horizontal plane.[6,31] The high prevalence of concomitant subscapularis and supraspinatus clearly explains the clinical intimacy between the 2 tendons. Even though these results cannot confirm the causal relationship between supraspinatus retear and subscapularis, they add objectivity to the relationship of the tendons.[32] It can be speculated that the structural collapse of a repaired supraspinatus may sequentially affect the force couple and the untreated subscapularis. According to a computer simulation test by Gausden et al., the existence of a supraspinatus tear significantly increased the subscapularis load.[33]

As the LHBT is a well-known pain source of the shoulder joint and factors related to aggravation of the LHBT are relatively well-revealed, the clinical algorithm for simultaneous treatment of LHBT along with supraspinatus repair is well established.[29,34] Also, symptoms regarding LHBT pathology and the outcome of treatment of LHBT are pretty straightforward. However, different from the clinical results derived from LHBT, morphologic changes on subscapularis did not lead to clinical outcomes regarding this study. As the physical signs specific to subscapularis lesions do not often develop unless the structures of the tendon collapse enough to develop mechanical problems, it is not always easy to determine the sole outcome from subscapularis.[8,9,15] Aggravation of the subscapularis lesion was confined to either grade I or II in this study, and the clinical scores might have shown significant differences with postoperative changes comparable to grade III subscapularis lesions. Also, clinical barometers utilized for the outcome evaluation in this study can only reflect the general condition of the shoulder and may have definite limitations on specifically reflecting the subscapularis status.

There is no controversy on the repair of a subscapularis tear with functional deficit or symptoms commensurate with lesion severity, but repairing a relatively benign subscapularis lesion has a concern of limited external rotation or postoperative stiffness.[3,35,36] In fact, there is no definite cut-off limit for treating a partial subscapularis tear. To clinically validate the purpose and result of this study, the influence of a partial subscapularis tear should be considered and a logical rationale for repairing subscapularis should be discussed. According to Kedgley et al.,[37] tear size of an anterosuperior rotator cuff tear was proportional to posterior translation of the humeral head. Also, Su et al. claimed that the effect of an anterosuperior rotator cuff defect was far greater in anterior translation than superior translation.[38] A recent biomechanical cadaveric study has reported that additional repair of the partially torn subscapularis did not affect either external rotation or the glenohumeral kinematics.[39] These previous reports demonstrate the benefits and necessity of active treatment for apparent subscapularis lesions.

Even though the result of this study cannot confirm the causal relationship between a subscapularis lesion and revealed factors, we strongly believe that the findings of this study validate the recent trend toward expanding treatment for subscapularis lesions along with reinforcing the diagnosis and classification. As mentioned in the first paragraph, most changes within the tendon were aggravated by a preexisting lesion. The percentage of the population with changes was about 17%, while that of changes in patients with preexisting lesions was higher at 28%. We conclude that subscapularis lesions should be actively searched and repaired, especially in patients with a high risk of retear. Also, the existence of a neglected subscapularis lesion exceeding grade I is a possible risk factor for further deterioration, and active treatment should be carefully considered regardless of its symptoms.

This study included the largest population of patients presented in any of the recent studies regarding the condition of subscapularis. Also, this study focused on "concealed" asymptomatic lesions, which is unique from previous studies. It identified risk factors for the progression of subscapularis tears and provided risk factors that recommend surgeons to fix partial subscapularis tears. The result of this study may help initiate an algorithm for the management of partial subscapularis tears. We hope this study may have the potential to make a clinical impact on surgeons' decision-making.

Our study has some limitations. First, evaluation of the relationship between postoperative changes in subscapularis and clinical outcomes could have been more objective if the postoperative clinical evaluations had been confined to subscapularis function. The relationship of subscapularis morphological changes with clinical symptoms was analyzed by comparing clinical shoulder scores and pain severity among the patients. The ASES score, Constant score, and VAS for pain cannot fully distinguish between patients with and without subscapularis lesions.

For the same reason, there may have been no significant differences regarding clinical scores between the patients with or without aggravation of subscapularis. Second, the patient cohort related to postoperative subscapularis pathology was not large, which may have resulted in failure to identify contributing factors. Third, there was a limitation in defining intratendinous signal change in the subscapularis as MRI was the only modality for the determination of changes. Even though some degree of objectiveness regarding the detection of subscapularis lesions on MRI is guaranteed in several studies, it is still true that the diagnosis accuracy on subscapularis injury is relatively low compared to that of overall rotator cuff tears.[40] Also, while the MRI classification that was used for evaluation is capable of reflecting the extent of lesions, it has limitations on reflecting the 3-dimensional structure of the subscapularis. Also, Pfirrmann grading system of subscapularis is based on the MR arthrogram, whereas the evaluation of subscapularis in this study was based on MRI without arthrogram. Fourth, the only aspect of the surgical technique considered was the method of repair of the supraspinatus tear. Factors such as the number of anchors, material, or suture configurations might have an impact on the postoperative results and be considered potential confounders.

Untreated asymptomatic subscapularis underwent morphological changes even after rotator cuff repair. Preoperatively existing subscapularis lesions, biceps long head pathology, and retear of the repaired supraspinatus were associated with subscapularis pathology in patients who underwent supraspinatus repair.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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