Original Research

Hidden Long Head of the Biceps Tendon Instability and Concealed Intratendinous Subscapularis Tears

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Background: Few studies have described the characteristics of a concealed intratendinous subscapularis tear (CIST), and there is a lack of research on the preoperative predictability of such lesions.

Purpose: To describe the characteristics of a CIST as seen on magnetic resonance imaging (MRI) and intraoperatively and to develop a scoring system for predicting such lesions.

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

Methods: Retrospectively, we identified 43 patients with CISTs among 442 consecutive patients who had undergone rotator cuff repair from July 2014 to June 2016. Range of motion, visual analog scale results for pain and function, and patient-reported outcome scores were evaluated preoperatively and at 1 and 2 years postoperatively. CISTs were classified arthroscopically as small (<5 mm), medium (5-10 mm), and large (>10 mm). We performed repair (≥50%) or debridement (<50%) depending on the total subscapularis tendon tear size including the CIST. Preoperative MRI findings were analyzed by 2 observers and were correlated with the arthroscopic findings. A 10-point scoring system was developed based on characteristics during the physical examination (anterior tenderness, bear hug sign), MRI (biceps tendon displacement and subluxation, subscapularis signal change just lateral to the lesser tuberosity), and arthroscopic surgery (medial biceps tendon lesion, combined subscapularis tendon tear), with a cutoff value of ≥7 predicting a CIST. After the retrospective study, we prospectively enrolled 95 patients to validate the 10-point CIST scoring system.

Results: All 43 patients diagnosed with a CIST during the retrospective study improved both range of motion and functional scores at 1 year postoperatively. The interrater agreement of the 2 observers was substantial for the evaluation of all parameters except for subscapularis tear classification, which was moderate. On arthroscopic surgery, 11 small, 19 medium, and 13 large CISTs were detected. The preliminary prospective study showed a sensitivity of 61.9%, specificity of 94.3%, positive predictive value of 89.0%, negative predictive value of 75.7%, and accuracy of 80.0% when the cutoff value was set at ≥7 on the CIST scoring system.

Conclusion: A CIST can be suspected using a combination of preoperative MRI and intra-articular diagnostic arthroscopic findings, but a definitive diagnosis requires an arthroscopic view. On the 10-point CIST scoring system, a score of ≥5 can be suggestive of a CIST, and a score of ≥7 is most likely to predict a CIST.

Keywords: shoulder; long head of the biceps tendon instability; subscapularis tear; concealed subscapularis tear

Anterior shoulder pain is a relatively common symptom, which is reported daily at outpatient clinics, especially in relatively younger patients with shoulder pain. Although a subscapularis tendon tear and/or biceps tendon lesion is a common cause of anterior shoulder pain, previously it was considered bicipital tendinitis in general and was treated nonoperatively with nonsteroidal anti-inflammatory drugs, physical therapy, and/or steroid injections into the bicipital groove around the biceps tendon.[4,23] The bear hug test is the most sensitive of all the physical examination tests; however, because it is only 60% sensitive and small-sized subscapularis tendon tears are frequently missed on magnetic resonance imaging (MRI), the diagnosis of upper one-quarter to one-third subscapularis tendon tears still remains a challenge.[1]

During some arthroscopic repair procedures of the rotator cuff, we found a subscapularis tendon tear that was not visible during intra-articular arthroscopic surgery. The rotator interval and medial biceps pulley were relatively intact with this concealed lesion. The lesion was found

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during the procedure of suprapectoral biceps tenodesis with the suture anchored from the bursal approach. It was more evident after slightly opening the transverse ligament over the bicipital groove to remove the remaining stump. These concealed subscapularis intratendinous (or midsubstance) tears were observed to be of various sizes and extent.

Hartzler and Burkhart[11] introduced the "occult" subscapularis tendon tear and an arthroscopic technique to visualize this tear. Neyton et al[17] used the term "hidden" for similar lesions. These lesions are easily missed during radiological and/or arthroscopic examinations and can lead to persistent pain after surgery. Denard and Burkhart[6] mentioned that occult tears of the subscapularis tendon are hidden by an intact medial sling and can be visualized on the articular side or in the bicipital groove and that the subscapularis footprint can be fully visualized only with a 70° arthroscope. Despite this information, there are few studies that describe the arthroscopic and radiological characteristics of this lesion. In addition, it would be beneficial if we can predict or suspect this lesion before or during surgery.

The purpose of this study was 2-fold: (1) to describe what we termed the concealed intratendinous subscapularis tear (CIST) and demonstrate the radiological and intraoperative findings of patients with this lesion and (2) to develop a preliminary scoring system that can predict the high probability of the presence of this hidden lesion. We hypothesized that a CIST can be predicted through clinical, radiological, and arthroscopic findings.

METHODS

The study consisted of 2 arms: (1) a retrospective study in which 43 consecutive patients who presented with CISTs during surgery were enrolled and (2) a prospective study of 95 different patients who had concomitant rotator cuff tears with the suspicion of biceps instability that required biceps tenotomy or tenodesis. We identified a CIST based on MRI, physical examination (positive sign on the bear hug test or anterior tenderness on the bicipital groove), and arthroscopic findings.

Retrospective Study Arm

Patient Selection

Our retrospective cohort study was approved by an institutional review board; the requirement for obtaining informed consent was waived for the patients involved in this study. From July 2014 to June 2016, a total of 442 patients underwent arthroscopic rotator cuff repair at our institution. When we suspected a CIST from any of the clinical, radiological, and intraoperative findings during arthroscopic rotator cuff repair, we opened the bicipital transverse ligament and a part of the rotator interval after the biceps procedure (biceps tenotomy or tenodesis) and inspected the subscapularis footprint in the subacromial arthroscopic view. The arthroscopic data of each patient were recorded electronically. Intra-articular arthroscopic recordings were reviewed retrospectively with the operative records of enrolled patients after surgery.

We defined a CIST as follows: (1) a subscapularis tendon tear on the most lateral portion of the subscapularis footprint of the lesser tuberosity inside the transverse humeral ligament, (2) without definite intra-articular biceps pulley disruption and biceps tendon subluxations or dislocations, and (3) not visible in the glenohumeral arthroscopic view. All the interventions were performed by a single senior shoulder surgeon (J.C.Y.). Exclusion criteria were as follows: (1) a medial biceps pulley tear observed in the intra-articular arthroscopic view; (2) a definite sign of intra-articular subluxation or dislocation of the long head of the biceps tendon (LHBT) observed in the intra-articular arthroscopic view; (3) a history of shoulder surgery; (4) infection around the shoulder joint; (5) a ≥6-month interval between preoperative MRI and surgery; and (6) any other concomitant shoulder diseases such as rheumatoid arthritis, osteoarthritis, and systemic diseases (eg, systemic lupus erythematosus, ankylosing spondylitis). We reviewed the medical data that were prospectively recorded for all the subscapularis tendon tears and biceps tendon lesions. All the MRI scans were reviewed by 2 independent observers (M.J.K. and S.M.P.). All the patients who were diagnosed as having CISTs were retrospectively reviewed with the arthroscopic surgery videos for a second confirmation. Ultimately, 43 patients were enrolled in this part of the study.

MRI Protocol

MRI was performed using a 3.0-T scanner (Gyroscan Intera Achieva; Philips) with a dedicated receive-only shoulder coil. In selected patients, indirect or direct magnetic resonance arthrography (MRA) was performed. For indirect MRA, 0.1 mmol/kg of gadopentetate dimeglumine (Magnevist; Bayer) was intravenously injected as the contrast material, and the patients were instructed to perform shoulder exercises for 15 minutes. For direct MRA, MRI was performed within 1 hour of the injection of a mixture of normal saline, iohexol 300 mg/mL (Omnipaque; GE Healthcare), and Magnevist into the glenohumeral joint under routine fluoroscopic guidance.

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Ethical approval for this study was obtained from the Samsung Medical Center Institutional Review Board (No. 2018-01-159).

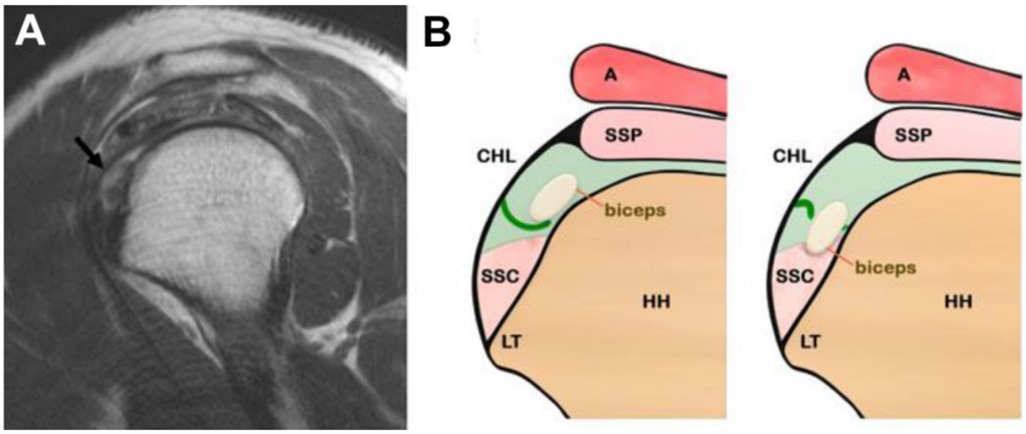

Figure 1. (A) Sagittal oblique T2-weighted magnetic resonance imaging of the left shoulder of a 49-year-old patient. The long head of the biceps tendon (LHBT; black arrow) was in direct contact with the subscapularis (SSC) tendon (displacement sign). Increased signal intensity and swelling of the biceps tendon were observed (biceps tendinopathy). (B) A schematic drawing indicating anterior displacement of the LHBT relative to the SSC tendon on a midsection through the lesser tuberosity (LT) of the humerus on sagittal oblique imaging. A, acromion; CHL, coracohumeral ligament; HH, humeral head; SSP, supraspinatus.

MRI Evaluation

Among the 43 patients, 41 underwent MRI at our institute: 26 underwent noncontrast MRI, 12 underwent indirect MRA, and 3 underwent direct MRA. The remaining 2 patients underwent noncontrast MRI and direct MRA at other hospitals. The difference in imaging modalities was because of the individual comorbidity of each patient. All the MRI scans were analyzed by 2 authors (M.J.K. and S.M.P.) who were in fellowship training in shoulder surgery and had access to all MRI sequences. They were blinded to each other's measurements as well as unaware of the arthroscopic results. The imaging material did not contain any patient information. The observers were instructed to evaluate the following 5 variables on each MRI scan.

(1) Integrity of the Subscapularis Tendon. We classified the subscapularis tendon tear according to the recently published classification of Yoo et al[26] based on the facet concept, although the classification is based on arthroscopic findings of a subscapularis tendon tear.[18] Through this classification, we wanted to know whether it is possible to create a CIST scoring system based on preoperative MRI findings only. A 5-category grading system was introduced, including the following: grade 0, no tear; grade I, fraying; grade IIA, a partial tear $\leq$50% of the first facet; grade IIB, a partial tear >50% of the first facet; grade III, a tear involving the entire first facet, and grade IV, a tear extending to the second facet.

(2) Tendinopathy of the LHBT. This was diagnosed if there were changes in the diameter, an increased signal intensity was reported, or irregular margins of the tendon were observed.[20] The proximal subacromial intra-articular portion of the LHBT from the biceps anchor to the rotator interval was best visualized on sagittal MRI (Figure 1A). The descending extra-articular portion in the intertubercular groove was best visualized on axial MRI.[4] A normal diameter of the biceps tendon ranged from 2 to 5 mm, had a typical round to ovoid appearance, and appeared homogeneously hypointense on cross-sectional imaging.

(3) Anterior Displacement of the LHBT. This was measured relative to the subscapularis tendon on a midsection through the lesser tuberosity of the humerus on sagittal oblique imaging. Schaeffeler et al[20] introduced the displacement sign and reported a high correlation between the positive findings of a biceps pulley lesion and a subscapularis tendon tear (Figure 1).

(4) Increased Signal Intensity of the Subscapularis Tendon. This was measured on the lateral portion of the lesser tuberosity, just medial to the intertubercular groove on axial MRI at the upper level of the bicipital groove (Figure 2A).

(5) Medial Displacement of the LHBT. This was measured relative to the entire course of the intertubercular groove on axial imaging. Several studies have suggested a correlation between biceps instability and subscapularis tendon tears.[1-3,10,17,24,25] A subluxation of the LHBT was defined as displacement over the inner rim of the groove while re-entering into the bony groove before disappearance of the groove (Figure 2B).[20,21,24]

Surgical Technique

All surgical procedures were performed under general anesthesia with the patients in the lateral decubitus position. Our standard arthroscopic examination methods were as follows: standard posterior and anterior portals were prepared for glenohumeral joint exploration. After a routine diagnostic examination, the LHBT was evaluated for any pathological change. Using a probe or grasper, the LHBT was drawn into the joint to allow an examination of the portion within the bicipital groove. The inferior or subscapularis side of the biceps tendon was examined carefully to confirm the presence of fraying or a partial tear. The upper portion of the subscapularis tendon was examined

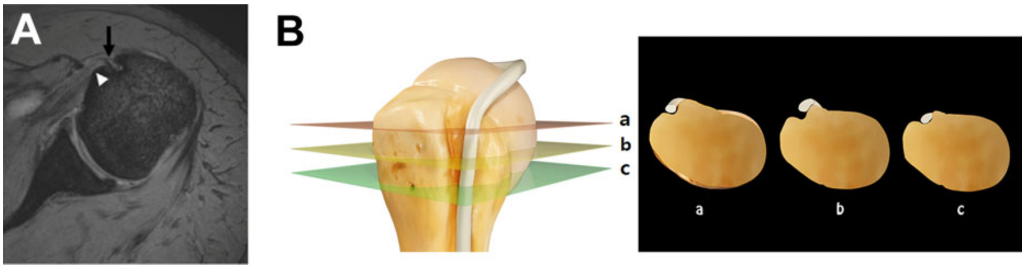

Figure 2. (A) Axial T2-weighted magnetic resonance imaging of the left shoulder showed a mild subluxation of the long head of the biceps tendon (LHBT; black arrow) and increased signal intensity of the subscapularis tendon on the lateral portion of the lesser tuberosity, just medial to the intertubercular groove (white arrowhead). (B) A schematic representation of the position of the LHBT relative to the entire course of the bicipital groove on axial imaging: subtle subluxation (*a*), definite subluxation (*b*), and biceps tendon re-entering the bony groove (*c*).

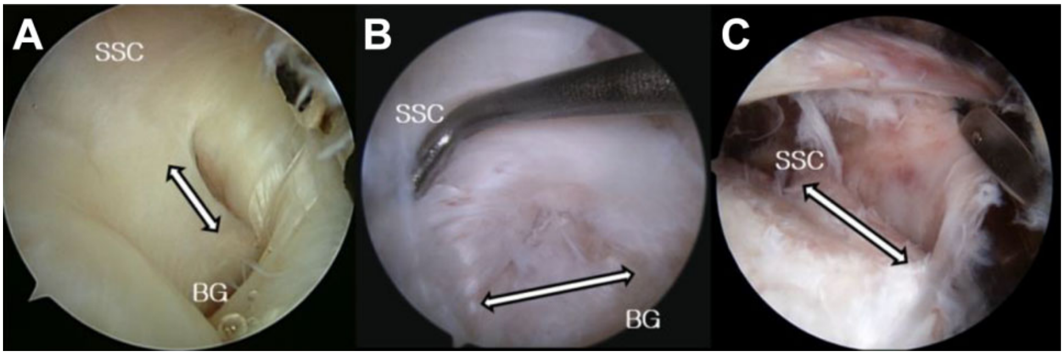

Figure 3. Classification according to the size of the concealed intratendinous subscapularis tear (CIST) (arrows) in the subacromial bursal-side arthroscopic view after cutting the rotator interval: (A) small (<5 mm), (B) medium (5-10 mm), and (C) large (>10 mm). BG, bicipital groove; SSC, subscapularis.

for a tear in a prospective manner using a 70° arthroscope, which was classified subsequently. The medial biceps pulley was also examined.

When we had a high suspicion of a CIST, which could be determined by instability of the biceps tendon on MRI and anterior tenderness on the bicipital groove or a positive bear hug test finding on physical examination, we performed biceps tenotomy or tenodesis as described in a previous study.[13] During that procedure, we opened the upper portion of the transverse humeral ligament and the superficial layer of the coracohumeral ligament (component of the rotator interval) laterally to inspect the upper lateral insertion of the subscapularis tendon. After opening the rotator interval and removing the remnant biceps tendon, we inspected the medial biceps pulley and the attachment of the subscapularis tendon. When we identified a CIST that could not be observed in the intra-articular arthroscopic view, we repaired (total detachment area ≥50% of the first facet) or debrided (total detachment area <50% of the first facet) according to the size of detachment from the subscapularis footprint (see the Supplementary Video online).

We classified a CIST according to the size: small (<5 mm), medium (5-10 mm), or large (>10 mm) because the width of the anatomic footprint of the subscapularis tendon is approximately 14 mm (Figure 3).[26] Additionally, we evaluated the following variables: (1) subluxations or dislocations of the LHBT; (2) any scuffing, fraying, abrasions, or tears of the medial biceps tendon, termed a sentinel sign by Sahu et al,[19] which indicated potential subscapularis tendon lesions (Figure 4); (3) biceps tendon integrity that was classified as being intact (grade 0), grade I (partial loss or erosion of <50% of the diameter of the tendon), or grade II (extensive loss or erosion of ≥50% of the diameter of the tendon) (Figure 5, A-C)[15]; and (4) because a partial or complete rupture of the medial biceps pulley was an exclusionary criterion in the evaluation of CISTs, we classified medial biceps pulley integrity as being intact or fraying (Figure 5, D and E).

Rehabilitation

After rotator cuff repair was performed in all 43 patients, routine postoperative rehabilitation was administered. Essentially, the patients underwent 4 weeks of immobilization with an abduction brace, followed by passive range of motion exercises for 8 weeks and muscle strengthening exercises for 12 weeks.

Development of CIST Scoring System

If we can predict a high possibility of the existence of this lesion, then it would be feasible to look for it during

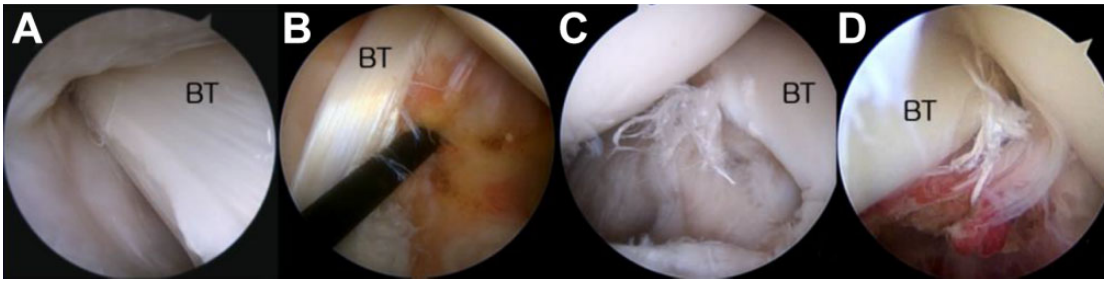

Figure 4. Medial biceps tendon lesion (sentinel sign). Intra-articular arthroscopic view: (A) scuffing of the medial part, (B) fraying of the medial part, (C) abrasion of the medial part, and (D) partial tear of the medial part. BT, biceps tendon.

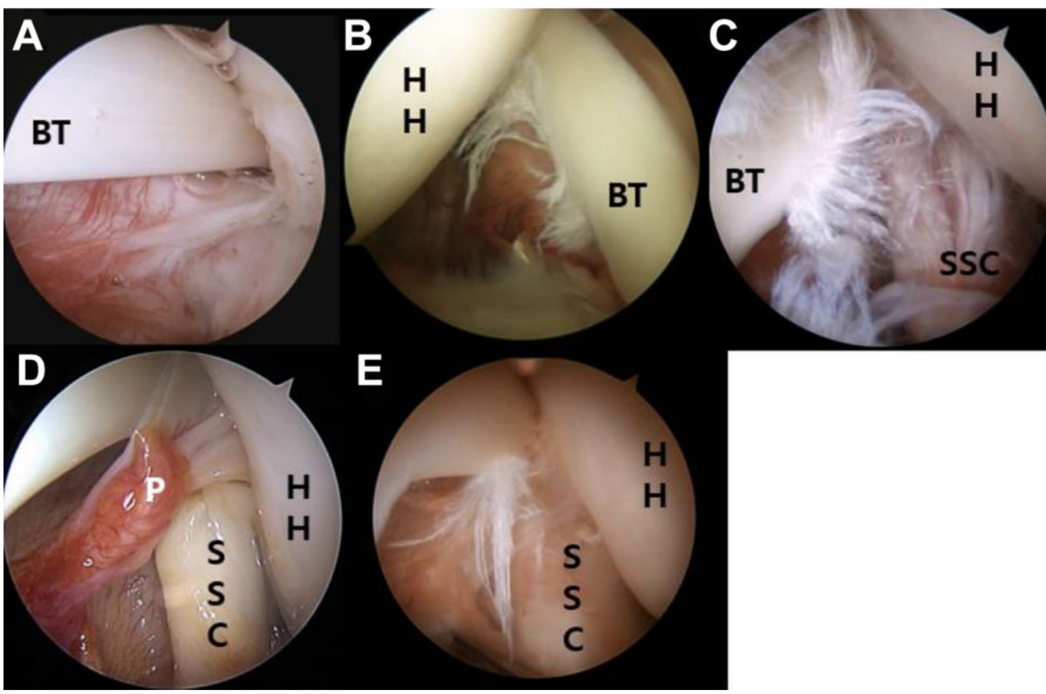

Figure 5. Biceps tendon tear grade and medial pulley integrity. Intra-articular arthroscopic view: (A) tendon grade 0 (intact), (B) tendon grade I (<50%), (C) tendon grade II (≥50%), (D) medial pulley intact, and (E) medial pulley fraying. BT, biceps tendon; HH, humeral head; P, biceps pulley; SSC, subscapularis.

arthroscopic surgery. Hence, based on the retrospective observations, we examined the preoperative and intraoperative findings that could predict a CIST and developed a scoring system of 10 points consisting of 3 categories: physical examination, preoperative MRI, and intra-articular arthroscopic findings. Detailed characteristics of the scoring system are described in Table 1.

Prospective Study Arm

Patient Selection

From May 2017 to August 2018, we prospectively enrolled 166 patients who underwent arthroscopic rotator cuff repair, for whom there was also a suspicion of biceps instability (on MRI) or the presence of anterior tenderness on the bicipital groove or a positive bear hug test finding on a physical examination. These patients were advised to undergo biceps tenotomy or tenodesis. Exclusion criteria included the following: (1) a definite sign of a medial biceps pulley tear or intra-articular dislocation or absence of the LHBT observed in the intra-articular arthroscopic view; (2) a definite sign of a subscapularis tendon tear on MRI or arthroscopically that needed to be repaired rather than debrided; (3) a history of shoulder surgery including biceps tenotomy or tenodesis; (4) infections around the shoulder joint; (5) a ≥6-month interval between preoperative MRI and surgery; and (6) any other concomitant shoulder diseases such as rheumatoid arthritis, osteoarthritis, and systemic diseases (eg, systemic lupus erythematosus, ankylosing spondylitis). Overall, 71 patients were excluded, and we ultimately enrolled 95 consecutive patients for the prospective

TABLE 1
CIST Scoring System[a]

	Score
Physical examination findings	
Anterior tenderness	No = 0; yes = 1
Bear hug sign	No = 0; yes = 1
MRI findings	
Biceps tendon displacement on sagittal oblique imaging	No = 0; yes = 1
Biceps tendon subluxation on axial imaging	No = 0; subtle = 1; definite = 2
Subscapularis signal change just lateral to the lesser tuberosity	No = 0; yes = 1
Intra-articular arthroscopic findings	
Medial biceps tendon lesion	No = 0; fraying = 1; definite = 2
Subscapularis tear classification[b]	Intact = 0; type I = 1; type II = 2
Total possible score	10

[a]CIST, concealed intratendinous subscapularis tear; MRI, magnetic resonance imaging.
[b]According to Yoo et al.[26]

study arm. All surgical procedures were performed by a single senior orthopaedic surgeon (J.C.Y.). According to the policy of the Korean Health Insurance Review and Assessment Service, biceps tenodesis was performed in patients aged <60 years, and biceps tenotomy was performed in those aged ≥60 years.

Validation of CIST Scoring System

Through the preliminary prospective study, we tried to validate our scoring system. The CIST scores of 95 consecutive patients who needed biceps tenodesis or tenotomy were checked according to the scoring system. By performing univariate logistic regression analysis, we measured the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy with respect to cutoff values that were determined by the statistical analysis below.

Statistical Analysis

Statistical analysis was performed using SAS version 9.4 (SAS Institute). The Cohen kappa coefficient was used to determine the interrater reliability (agreement) among the categorical variables reported by the 2 observers. Regarding analysis of the changes according to time, the Wilcoxon rank-sum test was used to compare the 1-year changes between the preoperative and postoperative parameters as well as the 2-year changes between the preoperative and postoperative parameters.

Regarding the prospective study, power analysis revealed that a sample of 59 patients was required to detect the effect of each predictor on the existence of a CIST, with an odds ratio of 2.5, significance level of 5% (alpha of .05; 2-tailed test), and power of 80%.[7]

TABLE 2
Patient Demographics and Procedures Performed[a]

	Retrospective Arm	Prospective Arm
Sex, male/female	37/6	40/55
Age, mean (range), y	56.9 (43-77)	60.8 (38-80)
History of trauma	13	17
Dominant arm involved	36	72
Time between preoperative MRI and surgery, mean (range), d	31 (0-147)	56 (1-170)
Biceps procedures		
Biceps tenotomy	6	56
Biceps tenodesis	37	39
Subscapularis procedures		
Debridement	16	89
Repair	27	6

[a]Data are shown as No. of patients unless otherwise indicated. MRI, magnetic resonance imaging.

Univariate logistic regression analysis was performed to estimate the independent risk factors that could affect the probability of the existence of a CIST. A regression model was performed through the maximum likelihood method. A cutoff value was set to maximize the Youden index. $P < .05$ was considered a statistically significant difference.

RESULTS

Patient Demographics in Retrospective Study Arm

The 43 study patients in this arm consisted of 37 males and 6 females, with a mean age of 56.9 years (range, 43-77 years). A history of trauma was noted in 13 patients (30.2%), and 36 patients (83.7%) underwent surgery on the dominant arm. Moreover, 37 patients underwent biceps tenodesis, and 6 underwent biceps tenotomy. Before surgery, all patients underwent at least 3 months of nonoperative management such as physical therapy, steroid injections, and rehabilitation exercises but showed no response.

For subscapularis tendon tears, we performed debridement in 16 patients and repair in 27 patients. The mean interval between preoperative MRI and surgery was 31 days (range, 0-147 days) (Table 2).

Patient Demographics in Prospective Study Arm

The 95 study patients in this arm consisted of 40 males and 55 females, with a mean age of 60.8 years (range, 38-80 years). A history of trauma was noted in 17 patients (17.9%), and 72 patients (75.8%) underwent surgery on the dominant arm. There were 39 patients who underwent biceps tenodesis, and 56 patients underwent biceps tenotomy. For subscapularis tendon tears, we performed debridement in 89 patients and repair in 6 patients. The mean interval between preoperative MRI and surgery was 56 days (range, 1-170 days) (Table 2).

TABLE 3
Clinical Outcomes[a]

	Preoperative	1 y Postoperative		2 y Postoperative	
	Mean ± SD	Mean ± SD	*P* Value	Mean ± SD	*P* Value
Forward elevation	148.60 ± 29.16	155.24 ± 16.92	.599	156.00 ± 32.69	.26
External rotation at side	49.06 ± 20.21	54.76 ± 13.65	.420	56.67 ± 17.99	.44
Internal rotation	7.44 ± 2.32	8.27 ± 1.45	.358	8.29 ± 2.12	.34
Abduction	135.95 ± 37.79	152.38 ± 21.19	.039[b]	156.33 ± 30.15	.02[b]
VAS for pain	4.93 ± 2.16	1.43 ± 1.44	<.001[b]	1.11 ± 1.40	<.001[b]
VAS for function	4.79 ± 4.13	7.86 ± 1.35	.005[b]	8.26 ± 1.81	<.001[b]
ASES score	49.60 ± 18.24	78.00 ± 16.69	<.001[b]	83.74 ± 15.26	<.001[b]
Constant score	54.19 ± 16.33	71.86 ± 13.90	.003[b]	74.67 ± 15.73	.01[b]
SST	5.38 ± 3.04	8.94 ± 2.06	.003[b]	9.00 ± 2.48	.008[b]
KSS	56.38 ± 16.81	82.36 ± 12.03	<.001[b]	81.40 ± 16.94	.003[b]
Internal rotation index	0.84 ± 0.25	0.90 ± 0.13	.071	0.94 ± 0.21	.46
Belly press index	0.75 ± 0.20	0.86 ± 0.25	.08	0.95 ± 0.30	.03[b]
Liftoff index	0.66 ± 0.52	0.83 ± 0.45	.016[b]	0.94 ± 0.50	.03[b]

[a]ASES, American Shoulder and Elbow Surgeons; KSS, Korean Shoulder Score; SST, Simple Shoulder Test; VAS, visual analog scale.
[b]Statistically significant compared with preoperative value ($P < .05$).

Clinical Outcomes

At the 1-year follow-up, all clinical scores were observed to have improved significantly compared with their respective preoperative values. Range of motion increased in all patients at the 1-year follow-up compared with preoperatively; however, only the improvement in abduction was statistically significant. The muscle power index increased in all patients at the 1-year follow-up compared with their respective preoperative values; however, only the improvement in the liftoff index was statistically significant. At the 2-year follow-up, significant improvement in all the clinical scores was maintained. Range of motion increased in all patients at the 2-year follow-up compared with preoperatively and 1-year follow-up; however, only the improvement in abduction was statistically significant. The muscle power index increased more at the 2-year follow-up compared with their respective preoperative and 1-year follow-up values. The belly press index and liftoff index improved significantly at the 2-year follow-up compared with their respective preoperative values. However, the internal rotation index showed no significant improvement compared to the preoperative value (Table 3).

MRI Findings

Regarding the subscapularis tear classification, no subscapularis tendon was observed to be grade 0 (intact) or I (fraying) in all 43 patients, as reported by both observers. Observer A reported a type IIA tear in 22 of 43 patients (51.2%), while observer B reported a type IIA tear in 28 of 43 patients (65.1%). On the other hand, a type IIB tear was reported in 18 of 43 patients (41.9%) by observer A, while observer B reported a type IIB tear in 15 of 43 patients (34.9%). Observer A reported a type III tear in 3 of 43 patients (7.0%), while observer B did not report a type III tear in any of the patients (0.0%).

TABLE 4
Interrater Reliability of Preoperative MRI[a]

	Interrater Reliability (Kappa)
Subscapularis tear classification[b]	0.509
Subscapularis signal change just lateral to the lesser tuberosity	0.812
Biceps tendinopathy	0.728
Biceps tendon subluxation	0.687
Biceps tendon displacement	0.694

[a]MRI, magnetic resonance imaging.
[b]According to Yoo et al.[26]

Observer A reported a subscapularis signal change in 34 of 43 patients (79.1%), just lateral to the lesser tuberosity on axial imaging at the upper bicipital groove, while observer B reported the same in 31 of 43 patients (72.1%). Observer A reported biceps tendinopathy in 36 of 43 patients (83.7%), while observer B reported the same in 37 of 43 patients (86.0%). Observer A reported a subluxation of the biceps tendon on axial imaging in 34 of 43 patients (79.1%), while observer B reported the same in 31 of 43 patients (72.1%). Regarding anterior displacement of the biceps tendon relative to the subscapularis tendon on sagittal oblique imaging (displacement sign), observer A reported a displacement sign in 34 of 43 patients (79.1%), while observer B reported the same in 36 of 43 patients (83.7%).

The Cohen kappa coefficient to determine interrater reliability was interpreted to be substantial for the evaluation of all parameters except for subscapularis tear classification, for which it was interpreted to be moderate (Table 4).

TABLE 5
Classification of Intra-articular Arthroscopic Findings[a]

	No. of Patients
Subscapularis tear classification[b]	
0	0
I	3
IIA	30
IIB	10
III	0
Size of CIST	
Small	11
Medium	19
Large	13
Biceps tendon integrity	
Intact	2
Grade I	31
Grade II	10
Medial biceps tendon lesion (sentinel sign)	34/43
Medial biceps pulley integrity	
Intact	9
Fraying	34

[a]CIST, concealed intratendinous subscapularis tear.
[b]According to Yoo et al.[26]

Arthroscopic Findings

The intra-articular arthroscopic findings of all 43 patients were classified (Table 5). Among them, a type IIA subscapularis tendon tear was the most common finding (30 patients; 69.8%). Type I and type IIB tears were found in 3 patients (7.0%) and 10 patients (23.3%), respectively. The sizes of the CIST were small in 11 patients (25.6%), medium in 19 patients (44.2%), and large in 13 patients (30.2%). No obvious biceps tendon subluxation or dislocation was seen in the intra-articular arthroscopic view. An intact biceps tendon was observed in 2 patients (4.7%), whereas 31 patients (72.1%) showed grade I biceps tendon lesions (<50% of the biceps tendon diameter), and 10 patients (23.3%) showed grade II biceps tendon lesions (≥50% of the biceps tendon diameter). In 34 patients, medial biceps tendon lesions (sentinel sign) were identified. The medial biceps pulley was intact in 9 patients (20.9%).

Of the 43 patients, 27 underwent subscapularis repair, and 16 underwent debridement. In 19 patients who had undergone arthroscopic surgery, the subscapularis tendon tear size was <50% of the first facet as inspected including CISTs in the subacromial arthroscopic view, and debridement seemed sufficient. However, after inspecting the rotator interval in the subacromial arthroscopic view and identifying detachment of ≥50% of the first facet, we performed repair.

Cutoff Values of CIST Scoring System

After performing univariate logistic regression analysis, the CIST scoring system revealed a sensitivity of 97%, specificity of 45%, PPV of 58%, NPV of 96%, and accuracy of 68% when we set the cutoff value to ≥5. When we set the cutoff value to ≥7, it showed a sensitivity of 61.9%, specificity of 94.3%, PPV of 89.0%, NPV of 75.7%, and accuracy of 80.0% that predicted the existence of a CIST.

The sensitivity, specificity, PPV, and NPV of individual characteristics are detailed in Table 6. Among all of the characteristics evaluated in the study, a biceps tendon subluxation on axial imaging was the most independent risk factor for predicting a CIST and showed an odds ratio of 5.57. Both a biceps tendon subluxation on axial imaging and a medial biceps tendon lesion on intra-articular arthroscopic surgery, respectively, revealed a moderate diagnostic accuracy (66% and 70%), with a balanced sensitivity (83% and 69%), specificity (53% and 70%), PPV (58% and 64%), and NPV (80% and 74%).

DISCUSSION

The subscapularis tendon plays an essential role in shoulder function and in maintaining normal glenohumeral biomechanics in the shoulder joint.[12,22] Previous studies have reported the importance of combined preoperative physical examination and diagnostic imaging in achieving an accurate diagnosis of lesions of anterior shoulder structures.[5,8] In this study, we found hidden lesions in the form of biceps tendon subluxations and subscapularis intratendinous tears (CISTs) and tried to characterize them. In all 43 patients who underwent arthroscopic rotator cuff repair at our institution, the biceps pulley was found to be intact in 9 patients, and fraying was observed in 34 patients; however, pulley continuity and tension were maintained. We thought that the CISTs were usually located at the upper lateral insertion of the subscapularis footprint, just medial to the biceps tendon entering the intertubercular groove. Despite the absence of obvious subluxations of the biceps tendon observed in the intra-articular arthroscopic view, a CIST was found during subacromial arthroscopic surgery. This lesion was distinct from the articular-side subscapularis tendon tear, while in some cases, it was connected to the articular-side subscapularis tendon tear (see the Supplementary Video online).

In the preoperative MRI review, a higher percentage of patients were suspected of having a subluxation of the biceps tendon (observer A: 79.1%; observer B: 72.1%). A signal intensity change in the lateral part of the subscapularis footprint was observed in 79.1% of patients by observer A and 72.1% of patients by observer B. In the intra-articular arthroscopic view, lesions of the medial side of the biceps tendon were observed in 79.1% of the patients. This suggests that high-resolution preoperative MRI and intra-articular examinations of the biceps tendon can help in predicting a concealed tear of the subscapularis tendon on the superolateral part of the lesser tuberosity, which is not seen during intra-articular arthroscopic surgery alone.

In addition, 19 patients of the retrospective study arm showed more severe tears of the subscapularis tendon when inspected in the subacromial arthroscopic view than expected in the intra-articular arthroscopic view. This means that both the intra-articular and subacromial arthroscopic views may be required to assess subscapularis tendon tears, and our CIST scoring system can help to

TABLE 6
Sensitivity, Specificity, PPV, and NPV of CIST Scoring System Variables[a]

	Odds Ratio (95% CI)	Sensitivity	Specificity	PPV	NPV	Accuracy	*P* Value
Anterior tenderness	1.71 (0.71-4.14)	0.738	0.377	0.484	0.645	0.537	.235
Bear hug sign	2.91 (1.26-6.72)	0.619	0.642	0.578	0.680	0.631	.013[b]
Biceps tendon displacement on sagittal oblique imaging	1.59 (0.66-3.82)	0.714	0.415	0.492	0.647	0.547	.301
Biceps tendon subluxation on axial imaging	5.57 (2.08-14.92)	0.833	0.528	0.583	0.800	0.663	.0006[b]
Subscapularis signal change just lateral to the lesser tuberosity	0.80 (0.33-1.96)	0.310	0.736	0.482	0.574	0.547	.623
Medial biceps tendon lesion	5.29 (2.14-13.08)	0.691	0.698	0.644	0.740	0.695	.0003[b]
Subscapularis tear classification[c]	3.60 (0.59-21.92)	0.810	0.425	0.423	0.733	0.800	.165

[a]CIST, concealed intratendinous subscapularis tear; NPV, negative predictive value; PPV, positive predictive value.
[b]Statistically significant.
[c]According to Yoo et al.[26]

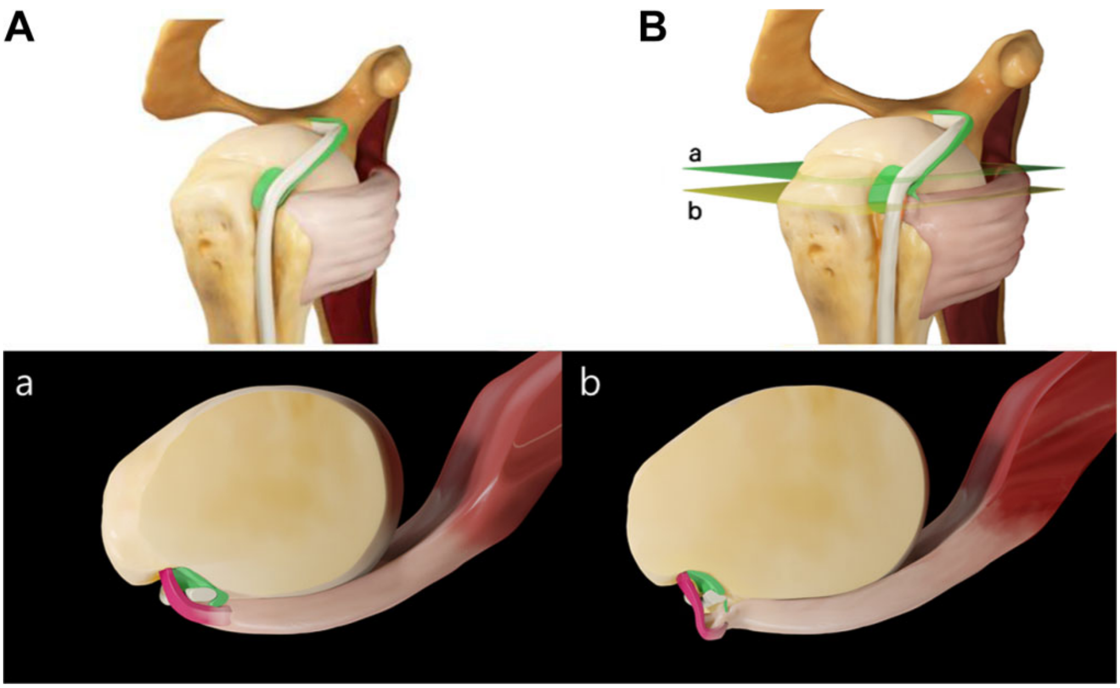

Figure 6. Schematic representation of a concealed intratendinous subscapularis tear (CIST). (A) An intact medial biceps pulley with no subluxation of the biceps tendon into the first facet of the subscapularis footprint. (B) A disrupted medial biceps pulley led to a subluxation of the biceps tendon into the first facet of the footprint, which caused the development of a CIST: the medial biceps pulley looked intact at the proximal portion, masking the CIST on intra-articular arthroscopic surgery (*a*); and a disrupted medial biceps pulley at the distal portion caused a medial subluxation of the biceps tendon and the eventual development of a CIST (*b*).

inspect subscapularis tendon tears from the subacromial side in the rotator interval.

The LHBT courses through the rotator interval obliquely and makes about a 40° turn along the anterior surface of the humeral head. The fibers of the superior glenohumeral ligament and coracohumeral ligament combine to form the medial pulley of the biceps tendon and stabilize the LHBT in its intra-articular course.[4,10] The medial biceps pulley lies on the subscapularis tendon, forming the surface, and a CIST appears to occur on the lateral inferior surface of the medial biceps pulley. Therefore, even if the medial superior surface of the medial biceps pulley is intact, a subluxation of the biceps tendon occurs on the lateral inferior surface of the pulley, leading to friction of the lateral surface of the pulley and the superolateral part of the subscapularis tendon, resulting in a CIST (Figure 6). In this process, the biceps tendon may either detach the subscapularis tendon from the bone or split the subscapularis tendon into superficial and deep layers. To relieve pain due to this lesion, a biceps procedure should be performed in combination with repair or debridement of the subscapularis tendon.

Habermeyer et al[10] classified intra-articular lesions occurring at the rotator interval according to the presence of a superior glenohumeral ligament lesion and rotator cuff tear and reported an association between intra-articular lesions and anterior superior impingement. We considered the role of the medial biceps pulley to be important in predicting concealed tears of the subscapularis tendon. The classification systems to describe the integrity of the medial biceps pulley reported thus far were insufficient. We therefore classified the integrity of the medial biceps pulley as intact, fraying, partial tears, and complete tears according to intra-articular arthroscopic findings. Subsequently, partial and complete tears were excluded from this study because we believe that when a subluxation of the biceps tendon is certain, we should perform a procedure to definitively treat the lesion. The purpose of our study was to find the occult lesion.

Koo and Burkhart[14] reported that tears at the distal portion of the subscapularis tendon can be observed in the intra-articular arthroscopic view using a 70° arthroscope and manipulation. However, because the CISTs that we found were more inferior and distal to the medial pulley attachment site, there might be a part that cannot be seen in the intra-articular arthroscopic view even with a 70° arthroscope either in flexion or internal rotation. Additionally, it is difficult to assess the relationship of the subscapularis tendon tear on the intra-articular side to the medial wall of the bicipital groove. The rotator interval opening in the subacromial arthroscopic view makes it much easier to assess the detachment size of the subscapularis tendon. We performed debridement in the case of small lesions and performed repair with anchors to the lesser tuberosity in the case of large lesions, especially those that tended to be much larger subscapularis tendon tears.

Neyton et al[17] revisited the report of Walch et al[25] and emphasized that the clinical suspicion of a hidden subscapularis tendon tear and rotator interval opening needs careful consideration. Our surgical technique was not much different from their technique, except for the detailed arthroscopic portal position. However, we tried to find a method that may help in predicting concealed subscapularis tendon tears. The strength of our study is the attempt to predict CISTs based on preoperative MRI and intra-articular arthroscopic findings.

The clinical impact of this lesion other than pain is not yet clear. We expect that a biceps procedure will relieve anterior shoulder pain; however, whether it will aid in repairing the subscapularis tendon tear is not clear, especially in older patients with combined supraspinatus and infraspinatus tendon tears. According to the classification of Yoo et al,[26] most of the subscapularis tendon tears were type IIA ($\leq$50% of the first facet of the lesser tuberosity). However, whether to repair these small upper one-quarter subscapularis tendon tears still remains a controversy.[16]

Our study has several limitations. First, the study bears the inherent weakness of a retrospective design and had a relatively small sample size, despite meeting the required sample size in the power analysis. However, the aim of this study was to describe the preoperative radiological and intraoperative findings of a CIST so that we could predict its presence. Second, the preoperative MRI reviewers, who were both orthopaedic surgeons, reached just moderate agreement on the subscapularis tear classifications. Both the observers were blinded, and hence, they were aware of neither the CIST-existing specific cases nor the findings of each other. We assume that in spite of their being orthopaedic specialists, there was a difference of opinion in determining type IIA or IIB tears because the first facet had a relatively smaller area[26] (13.8×13.5 mm) and there might have been difficulties in determining whether the tear area exceeded 50% or not. This is closely related to the reason why we included intra-articular findings in our scoring system, not preoperative findings of MRI-based subscapularis tear classification.

A third limitation is that we might have caused iatrogenic damage to the rotator interval structures. Hartzler and Burkhart[11] and Godeneche et al[9] emphasized that medial biceps sling takedown should only be performed if proximal biceps tenotomy or tenodesis is required as a concomitant procedure because the medial sling is otherwise necessary to maintain the stability of the intra-articular biceps tendon. We performed rotator interval opening only after performing the planned biceps procedure in all 43 patients. Procedures were performed by a highly experienced senior orthopaedic surgeon, and we could not find any evidence of iatrogenic injuries while reviewing the arthroscopic surgery videos. Moreover, there was no report of any postoperative complications in the patient data that were recorded at the outpatient clinic. Fourth, in the retrospective arm, we did not routinely open the rotator interval to find a CIST. We retrospectively examined MRI and intra-articular arthroscopic findings of those who turned out to have CISTs intraoperatively. Thus, it is possible that similar features of MRI findings might be found in patients who have no CIST, as we found in our prospective study.

Finally, in some cases of the prospective arm, although the score was over 7 points, we could not find a CIST after partial distal cutting of the rotator interval, and we did not repair the interval after inspection because the rotator interval is commonly released in rotator cuff surgery. It could be an unnecessary procedure for patients without CISTs. To address this question, we are currently performing a preliminary level 1 trial with CISTs that may require rotator interval opening, followed by repair or debridement. We believe that this prospective study will provide a detailed guideline to determine whether there is a need to investigate hidden subscapularis tendon tears, especially as an approach to address the complaint of unexplained anterior shoulder pain preoperatively. Further study with large-volume research should be conducted to approach this condition.

CONCLUSION

A CIST can be suspected using a combination of preoperative MRI and intra-articular diagnostic arthroscopic findings, but a definitive diagnosis requires opening the biceps pulley and viewing in the subacromial arthroscopic view. We have developed a 10-point scoring system; a score of 5 can be suggestive, and a score of 7 is most likely to predict the existence of this lesion. Therefore, we recommend inspecting CISTs in the subacromial arthroscopic view when the CIST score is ≥ 7.

A Video Supplement for this article is available at http://journals.sagepub.com/doi/suppl/10.1177/2325967119898123

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