Original Article
Clinics in Orthopedic Surgery 2015;7:365-371 • http://dx.doi.org/10.4055/cios.2015.7.3.365

Arthroscopic Changes of the Biceps Pulley in Rotator Cuff Tear and Its Clinical Significance in Relation to Treatment

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Background: In the case of rotator cuff tears, the biceps pulley can be stressed by the unstable biceps tendon, and this can subsequently affect the stability of the subscapularis tendon. Therefore, it is important to distinguish between normal variations and lesions of the biceps pulley that affect anterosuperior lesions in cases of rotator cuff tears.

Methods: From January 2002 through November 2010, we observed biceps pulley and associated anterosuperior lesions in 589 of 634 cases (93%) of arthroscopic rotator cuff repair, including 72 cases (12.2%) of small tears, 219 cases (37.2%) of medium tears, 134 cases (22.8%) of large tears, and 164 cases (27.8%) of massive tears. We classified normal stretched biceps pulleys as type I, stretched biceps pulleys with mild changes as type II, those with a partial tear as type III, and torn pulleys as type IV.

Results: We were able to classify 589 cases of biceps pulleys as type I, II, III, or IV associated lesions in rotator cuff tears. Type I was seen in 91 cases (15.4%), type II in 216 cases (36.7%), type III in 157 cases (26.7%), and type IV in 101 cases (17.1%); unidentified cases numbered 24 (4.1%). Nearly three-quarters, 73.3%, of the cases (432/589) had associated anterosuperior lesions, and combined treatment for the associated lesions was administered in 29.2% (172/589) of cases.

Conclusions: Biceps pulley lesions with more than partial tears were identified in 48% of rotator cuff tear cases. The incidence and severity of pulley lesions were related to the rotator cuff tear size, the status of the long head of the biceps tendon and subscapularis tendon lesion, and the treatment methods.

Keywords: *Rotator cuff, Arthroscopy, Subscapularis tendon*

The biceps pulley is a capsuloligamentous complex that stabilizes the long head of the biceps (LHB) tendon in the bicipital groove[1] and opposes the anterior shearing stress in the rotator interval. Macroscopically, the superior glenohumeral ligament (SGHL) forms a U-shaped anterior suspension sling for the LHB tendon. Microscopically, fibers of the supraspinatus tendon join the posterosuperior part of the sling. Additionally, the SGHL, coracohumeral ligament (CHL) and posterior fibers of the subscapularis intermingle at the level of the entrance into the bicipital groove.[2,3] The pulley is built by fibers of the CHL, the SGHL, and the supraspinatus and subscapularis tendons.[4] Developmentally, variations of the biceps pulley may occur according to the degree of shoulder motion or the pathologic status. In the case of rotator cuff tear, the biceps pulley can be stressed by the unstable biceps tendon, and this can subsequently affect the stability of the subscapularis tendon. It is important to distinguish between normal variations and lesions of the biceps pulley that affect anterosuperior lesions in case of rotator cuff tear. The purpose of this study was to identify associated arthroscopic changes of the biceps pulley in rotator cuff tears and to evaluate their clinical significance.

Received March 13, 2015; Accepted June 18, 2015
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METHODS

Participants, Study Subjects

Five hundred and eighty-nine cases among 634 cases of arthroscopic rotator cuff repair from January 2002 to November 2010 that had preserved arthroscopic images of the glenohumeral joint and subacromial space were included in this study. Small tears were seen in 72 cases (12.2%), medium-sized tears in 219 cases (37.2%), large tears in 134 cases (22.8%), and massive tears in 164 cases (27.8%). All examinations were done by one surgeon with the patient in the beach chair position before arthroscopic treatment of the rotator cuff tear and associated lesions. There were 314 male patients and 275 female patients, and the mean age was 61 years (range, 39 to 84 years). We excluded revision cases, partial rotator cuff tear cases, and rotator cuff tear with combined instability cases.

Description of Experiment, Treatment, or Surgery

On arthroscopic examination, the biceps pulley was classified by 4 types according to morphologic differences when it was inserted into the medial attachment site of the bicipital groove. The normal stretch type (type I) was confined as the elastic feature of the pulley with no irritation signs. Minor changes (type II) with basically intact structural integrity were subclassified according to their reactive changes, including fraying (II-a), synovitis (II-b) and hypertrophy (II-c) of the medial pulley. We defined

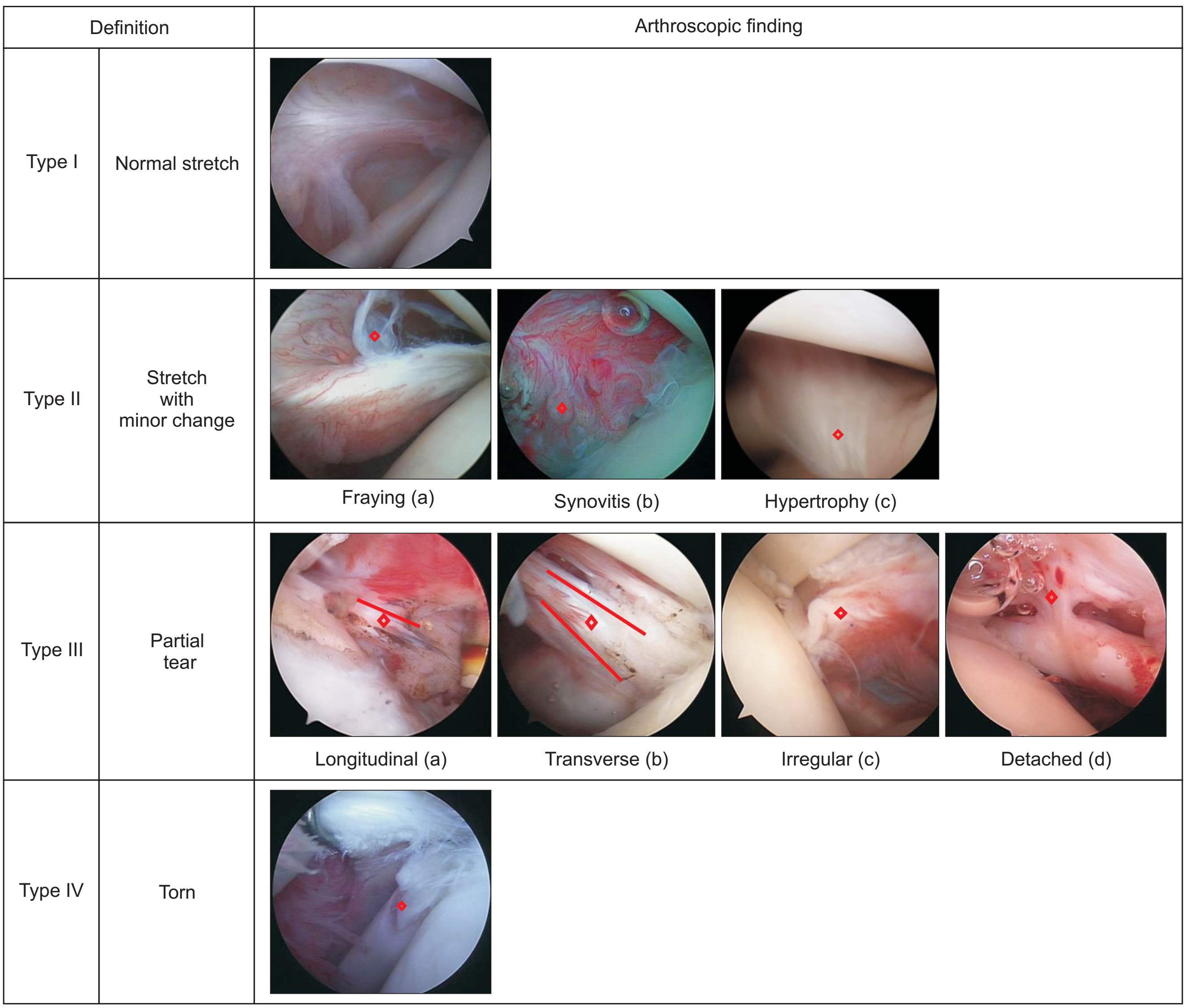

Fig. 1. The classification of the long head of the biceps pulley. Type I, II : normal or minor changes which preserve stability of the biceps pulley. Type III, IV : definite pathologic changes which influence stability of the biceps pulley.

pathologic changes rather than minor changes when the pulley structures were unstable with partial tears (type III). The patterns of partial tears were longitudinal type (III-a), transverse type (III-b), irregular type (III-c) and detached pulley (III-d). This classification was thought to have been developed according to the severity and duration of unstable biceps forces applied to the medial side of the bicipital groove because of the preexisting rotator cuff tear. Type IV was defined as when the whole attachment site of the pulley was disrupted, along with notable subscapularis tendon or biceps tendon lesions (Fig. 1).

Variables, Outcome Measures, Data Sources, and Bias

In order to ascertain intraobserver correlations in their classification, arthroscopic findings about pulley type were evaluated two times for the 309 cases from January 2002 to 2007 and the 280 cases from 2007 to 2010 over a 3-year interval. Interobserver correlation was evaluated by three shoulder fellows. Our hypothesis was that the pulley types in rotator cuff tears were related to the severity of the associated pathology at the anterosuperior region, including the LHB tendon and the subscapularis tendon. Correlations between pulley type and associated lesions or treatment methods were evaluated.

Statistical Analysis and IRB approval

The subjects' clinicopathologic characteristics were summarized using descriptive analysis, particularly, the values of frequency and percent for qualitative variables by category. The chi-square test was used to determine the intraobserver correlation with a kappa value. The Spearman test was used to figure out the interclass correlation coefficient by classification method. The chi-square test was used to determine the correlation between pulley type according to tear size, pulley type according to associated lesion, and treatment according to pulley type with a lambda value. All tests were two-sided, and p-value less than 0.05 was considered to indicate statistical significance; IBM SPSS ver. 19.0 (IBM Co., Armonk, NY, USA) was used for the analyses. The protocols that were used adhere to the principles of the Declaration of Helsinki and were approved by the Institutional Review Board (IRB) of Daegu Catholic University Hospital (CR-11-102-PRO-001-R).

RESULTS

Intraobserver Correlations Regarding the Classification

Intraobserver agreement was 0.678 using cross tabulation (Table 1). Type I showed normal findings, and type II lesions were considered to be minimal changes relating to the rotator cuff tear. Type III and type IV were considered major changes that affected the stability of adjoining structures, including the LHB, the subscapularis tendon, and the supraspinatus tendon.

Interobserver Correlations Regarding the Classification

Interobserver agreement between inspectors 1 and 3 was 0.565 ($p < 0.005$); between 1 and 2, it was 0.493; and between 2 and 3, it was 0.481 (Table 2). That is, observers 1 and 2 classified the pulley the same way in 49.3% of cases; observers 2 and 3 agreed on 48.1% of cases; and observers 1 and 3 agreed on 56.5% of cases.

There was discrepancy in the correlations between the intraobserver correlations done by the operator and the interobserver correlation done by fellow surgeons, owing to differences in the understanding of this classifica-

Table 1. Intraobserver Correlations

First observation	Second observation					Total
	Stretch	Stretch with minor change	Partial tear	Torn pulley	Unidentified	
Stretch	64 (71.9)	21 (23.6)	3 (3.4)	0	1 (1.1)	89
Stretch with minor change	5 (5.6)	76 (84.4)	5 (5.6)	4 (4.4)	0	90
Partial tear	2 (4.2)	13 (27.1)	29 (60.4)	4 (8.3)	0	48
Torn pulley	0	5 (8.9)	5 (8.9)	44 (78.6)	2 (3.6)	56
Unidentified	0	2 (7.7)	0	4 (15.4)	20 (76.9)	26
Total	71 (23.0)	117 (37.9)	42 (13.6)	56 (18.1)	23 (7.4)	309

Values are presented as number (%).
Kappa value, 0.678; $p < 0.001$.

tion system, experiences in arthroscopic image interpretation, and limited capture images rather than video images.

Pulley Type according to Tear Size

Of the 589 cases of rotator cuff tear, the most common findings were type II lesions involving minor changes, which occurred in 36.7% of the cases (216 cases), and normal stretched type, which occurred in 15.4% of the cases (91 cases); type I and II could be considered lesions with intact pulleys that did not affect the stability of the biceps or subscapularis tendons. Nearly half, 47.9%, of the cases (282/589) had pulley lesions that were higher than type III, and in these cases, the integrity of the pulley was affected. Type III (partial tear) lesions were seen in 26.7% (157) of cases, type IV (complete tear) in 17.1% (101 cases), and unidentified pulley due to humeral head migration or severe capsular changes in 4.1% (24 cases). In 72 cases of small tears of the rotator cuff, 30 cases had minor changes of the pulley, 22 had normal stretch of the pulley, 19 had partial tears of the pulley, and 1 had a complete tear of the pulley. Pulley types higher than type III, which represent structural defects, were seen in 27.8% of the cases (20 cases). In 219 cases of medium-sized tears, the pulley type showed minor change in 98 cases, 44 cases had normal stretch, 59 cases had partial tears, and 14 cases had complete tears. Pulley types that were higher than type III were seen in 35.2% of the cases (77 cases), including 4 cases of unidentified pulley. In 134 cases of large tears, a pulley type with minor changes was seen in 44 cases, 21 cases had normal stretch, 36 cases had partial tears, and 27 cases had complete tears. Just over half, 51.5%, of cases were higher than type III (134 cases), including 6 cases of unidentified pulley. In 164 cases of massive tears, a pulley type with minor changes was seen in 44 cases, 4 cases had normal stretch, 43 cases had partial tears, and 59 cases had complete tears. Pulley types higher than type III were seen in 70.7% of the cases (116 cases), including 14 cases of unidentified pulley. The degree of pulley type was related to the size of the tear ($p < 0.001$) (Table 3).

Table 2. Interclass Correlation Coefficients by Classification

Classification	Observer 3	Observer 1	Observer 2
Observer			
3	1	-	-
1	0.565 (< 0.001)*	1	-
2	0.481 (< 0.001)*	0.493 (< 0.001)*	1

*Statistically significant ($p < 0.05$).

Associated Lesions according to Pulley Type

Among the 589 cases of rotator cuff tear, associated anterosuperior lesions were identified in 73.3% (432/589) of cases, of which 49.3% (213/432) were subscapularis and biceps lesions, 41.7% (180/432) were isolated subscapularis lesions, and 9.0% (39/432) were isolated biceps lesions. Of the 91 cases of type I (normal stretch type) pulley, associated anterosuperior lesions were identified in 27.5% (25/91). Most of the lesions (20/25) were partial isolated subscapularis tears. Of the 216 cases of type II pulley (stretch with minor change), associated anterosuperior lesions were identified in 70.8% (153) of cases. The most common lesions were partial isolated subscapularis tears (54.9%; 84/153), combined subscapularis and biceps lesions (30.7%; 47/153), and isolated biceps lesions (13.7%; 21/153). There was one complete subscapularis tear. Of the 157 cases of type III pulley (partial tear), an associated anterosuperior lesion was identified in 84.7% (133/157) of cases. There was an increased tendency for subscapularis tendon lesions to be present; 49.6% (66/133) of cases had partial isolated tears of the subscapularis tendon, and

Table 3. Pulley Type according to Tear Size

Variable	Stretch	Stretch with minor change	Partial tear	Torn pulley	Unidentified	Total
Small	22 (30.6)	30 (41.7)	19 (26.4)	1 (1.4)	0	72
Medium	44 (20.1)	98 (44.7)	59 (26.9)	14 (6.4)	4 (1.8)	219
Large	21 (15.7)	44 (32.8)	36 (26.9)	27 (20.1)	6 (4.5)	134
Massive	4 (2.5)	44 (27.0)	43 (26.4)	59 (35.9)	14 (8.6)	164
Total	91 (15.4)	216 (36.7)	157 (26.7)	101 (17.1)	24 (4.1)	589

Values are presented as number (%).
Lambda value, 0.092; $p < 0.001$.

48.9% (65/133) had combined subscapularis and biceps lesions. Isolated biceps lesions were seen in 2 cases. Of the 101 cases of type IV pulley (complete tear), associated anterosuperior lesions were identified in 99% (100/101) of cases. The most common lesion was the combined subscapularis and biceps type (88%; 88/100). Subscapularis (SCC)-isolated lesions were prevalent with minor changes and partial tears of the pulley, but LHB-isolated lesions were dominant with minor changes, and the prevalence of combined lesions was related to the degree of the pulley type ($p < 0.001$). The lesion involvement of the SCC tendon was more prevalent than that of the LHB tendon regardless of pulley type ($p < 0.001$) (Table 4).

Treatment Methods according to Pulley Type and Tear Size

Of the 589 cases of rotator cuff tear, isolated rotator cuff repair was done in 31.2% (184) of cases and rotator cuff repair and acromioplasty were done in 38.4% (226) of cases. Combined treatments for the associated lesions independent of the acromioplasty were 29.2%(172/589) of cases, comprising subscapularis repair in 8.0% (47) of cases, biceps tenotomy or tenodesis in 14.6% (86), and subscapularis tendon repair and biceps treatment together in 6.6% (39). Debridement only was done in 1% (7) of cases as the treatment. Of the 91 cases of the type I (normal stretch type) pulley, the main treatment was isolated rotator cuff repair (34.1%; 31cases) and rotator cuff repair with acromioplasty (64.8%; 59 cases). For anterosuperior lesions, the biceps was treated in only 1 case. Of the 216 cases of type II pulley (stretch with minor change), combined treatment for the associated lesion was performed in 21.3% (46/216) of cases, comprising 29 cases of biceps treatment, 12 cases of subscapularis repair, and 5 cases of both types of treatment. Of the 157 cases of type III pulley (partial tear), combined treatment for the associated lesion was performed in 42.0% (66/157) of cases, comprising 33 cases of biceps treatment, 22 cases of subscapularis

Table 4. Pulley Type according to Associated Lesion

Variable	Stretch	Stretch with minor change	Partial tear	Torn pulley	Unidentified	Total
None	66 (41.7)	63 (40.4)	24 (15.4)	1 (0.6)	3 (1.9)	157
SCC-isolated	20 (11.1)	85 (47.2)	66 (36.7)	8 (4.4)	1 (0.6)	180
LHB-isolated	2 (5.1)	21 (53.8)	2 (5.1)	4 (10.3)	10 (25.6)	39
SCC + LHB	3 (1.4)	47 (21.8)	65 (30.8)	88 (41.2)	10 (4.7)	213
Total	91 (15.4)	216 (36.7)	157 (26.7)	101 (17.1)	24 (4.1)	589

Values are presented as number (%).
Lambda value 0.194; $p < 0.001$.
SCC: subscapularis, LHB: long head of the biceps.

Table 5. Treatment according to Pulley Type

Variable	Stretch	Stretch with minor change	Partial tear	Torn pulley	Unidentified	Total
RCR	31 (16.4)	74 (40.4)	46 (25.1)	24 (13.1)	9 (4.9)	184
RCR + ACP	59 (26.1)	94 (46.1)	45 (19.9)	18 (8.0)	10 (4.4)	226
RCR + SCC	0	12 (25.5)	22 (46.8)	13 (27.7)	0	47
RCR + LHB	1 (1.2)	29 (32.9)	33 (38.8)	18 (21.2)	5 (5.9)	86
RCR + SCC + LHB	0	5 (12.8)	11 (28.2)	23 (59)	0	39
Debridement	0	2 (33.3)	0	5 (66.7)	0	7
Total	91 (15.4)	216 (36.7)	157 (26.7)	101 (17.1)	24 (4.1)	589

Values are presented as number (%).
Lambda value, 0.057; $p < 0.001$.
RCR: rotator cuff repair, ACP: acromioplasty, SCC: subscapularis repair, LHB: long head of the biceps treatment.

repair, and 11 cases of both treatments. Of the 101 cases of type IV pulley (complete tear), combined treatment for the associated lesion was done in 53.5% (54/101) of cases, comprising 23 cases of both biceps treatment and subscapularis repair, 18 cases of biceps treatment, and 13 cases of subscapularis repair. Treatment for the associated lesions depended on the degree of pulley type ($p < 0.001$), and it was more focused on the biceps lesions even though the subscapularis tendon was more frequently involved ($p < 0.001$) (Tables 4 and 5).

DISCUSSION

To stabilize the LHB tendon, the SGHL, and CHL evolved into a pulley system.[5] If the pulley becomes detached, the effective intra-articular length of the LHB tendon becomes shortened, which hinders the normal peel-back mechanism of the superior labrum and causes pulley impingement on the posterosuperior labrum.[6] However, the more important function of the biceps pulley is believed to be its protection of the LHB tendon against anterior shearing stress. Kim et al.[7] reported that the region approximately 15 mm posterior to the LHB may be where rotator cuff tears most commonly initiate and that altered mechanics may influence the stability of the LHB tendon, which causes stress on the biceps pulley, resulting in subscapularis lesions.[4] Gerber and Sebesta[8] described pulley lesions that result from repetitive, forceful internal rotations above the horizontal plane. This type of rotation causes anterosuperior impingement (ASI), through the undersurface of the reflexion pulley, and subscapularis impingement against the anterosuperior glenoid rim. Habermeyer et al.[5] also reported ASI of the shoulder as a result of pulley lesions, and they described four types of biceps pulley lesion. The authors suggested that a lesion in the pulley system that leads to instability of LHB causes a partial articular side subscapularis tear and that the subluxated LHB with concomitant decentralization of the humeral head results in a process that reinforces the ASI. Braun et al.[4] stated that tears in the subscapularis tendon were significantly associated with tears in the pulley. In our study, an associated subscapularis lesion was more frequently identified with an LHB pulley tear lesion ($p < 0.001$). Complete subscapularis tears were related to complete pulley tears.[9] Although in this study, the frequency of a subscapularis lesion correlated with the type of pulley lesion, many subscapularis lesions were found with the pulleys intact. Hence, it is more reasonable to consider that it is the difference in elasticity between the pulley and the subscapularis that causes more damage to the subcapularis tendon, which is less elastic. On arthroscopic examination of rotator cuff tears, we could classify 4 types of biceps pulley with 0.678 intraobserver agreement. Interobserver reliability was also evaluated in this study. The biceps pulley type was classified by three shoulder fellows, and the interobserver reliability values between surgeons 1 and 2, 2 and 3, 3 and 1 were 0.493, 0.481, and 0.565, respectively. The discrepancies between the intraobserver and interobserver reliability values could be explained by the proficiency of the surgeons and their understanding of the classification system. Reliability could be improved with more arthroscopic information including video images and a more simplified approach to the classification system. The Habermeyer classification includes pulley lesions and SCC and LHB lesions, with no particular criteria in terms of the pulley lesion.[5] In our study, the pulley lesions were classified primarily according to changes in the pulley, and we also considered the associated lesions of the SCC and LHB tendons. Hence, the pulley lesions could be used as an indirect sign to determine the treatment regimen for the accompanying lesions during arthroscopic surgery of the rotator cuff tear.

In our study, the degree of the pulley type was related to the tear size ($p < 0.001$) (Table 3)—the higher the degree, the larger the tear size. The type and prevalence of associated lesions were related to the type of pulley lesion ($p < 0.001$), but the main involvement was focused on the SCC tendon rather than the LHB tendon regardless of pulley type (Table 4). Treatment for the associated lesions depended on the degree of pulley type ($p < 0.001$), and it was more focused on the biceps lesions even though the subscapularis tendon was more frequently involved ($p < 0.001$) (Tables 4 and 5).

Our study confirmed that accompanying SCC lesions were found at a high frequency compared with LHB lesions related to the pulley lesions in a rotator cuff tear, and thus, a pulley lesion could be regarded as an indirect sign of an SCC lesion regardless of its necessity for treatment.

Our study has limitations. First, this was a retrospective case series study, and thus, the level of evidence is low. Moreover, we cannot rule out bias regarding the arthroscopic images taken by one observer using capture images rather than video. This is the reason for the relatively low interobserver correlations compared with the intraobserver agreement. Thus, the value of this classification system might rest more with shoulder specialists, who need to understand these anatomic changes in order to correlate clinical relevance. Second, this study did not look at clinical outcomes. However, for the first time, pulley lesions were classified based on arthroscopic findings, and this can help determine the direction of treatment for the associated lesions during rotator cuff repair. Third, we could not check the contralateral side (normal shoulder) because of ethical challenges, and so we could not conclude whether biceps pulley lesions were pathological or not. To our knowledge, this study represents one of the largest published series of patients with pulley lesions. In the future, controlled studies that include the clinical results will be needed.

In conclusion, biceps pulley lesions with more than partial tears were identified in 48% of rotator cuff tear cases. The configuration of the biceps pulley lesion as identified through arthroscopic examination may be closely related to the tear size, the status of LHB tendon and subscapularis tendon lesions, and their treatment

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported

ACKNOWLEDGEMENTS

We thank Prof Im-Hee Shin of the Medical Statistics Department for her advice and guidance on the statistical analysis.

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