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ARTHROSCOPY AND SPORTS MEDICINE

Pulley lesions in rotator cuff tears: prevalence, etiology, and concomitant pathologies

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Abstract

Purpose This study aimed to demonstrate the prevalence of lesions in the biceps pulley complex in a representative, consecutive series of rotator cuff tears and rotator cuff interval treatments. We also analyzed associated tear pattern of rotator cuff injuries and superior labrum anterior–posterior (SLAP) lesions. We evaluated the relationships of these lesions to traumatic genesis and the prevalence of pulley lesions in revision cases.

Methods This retrospective study analyzed all pre- and intra-operative documentation on arthroscopic rotator cuff reconstructions and isolated pulley lesion treatments performed by a single surgeon over 2 consecutive years. According to Habermeyer et al., we classified cases into four groups, based on the presence of additional or related complete or partial rotator cuff tears, SLAP lesions, trauma, and primary or revision surgery.

Results Among 382 patients with rotator cuff tears, 345 (90.3%) had an injured pulley system; 151 (43.8%) had partial tears of the rotator cuff; out of these, 106 (30.6%) were articular-sided. All of these articular-sided partial tears showed extension into the pulley complex. In 154 cases (44.6%), history of shoulder trauma was associated with the beginning of symptoms. In addition, concomitant SLAP lesions occurred in 25–62% of pulley lesions, correlating with the severity of pulley lesions. Among the 345 cases, there have been 32 (9.3%) revision cases where a pulley lesion was intra-operatively identified and addressed.

Conclusions Pulley complex lesions are present in 90.3% of surgically treated rotator cuff lesions, particularly in articular-sided injuries. In addition, we found a significant relationship between the incidence of SLAP lesions and the severity of pulley lesions. It seems reasonable to assume an important role of pulley system injuries in the pathogenesis of rotator cuff lesions.

Keywords Pulley lesion · Long head of biceps · Rotator cuff interval · LHB · Trauma · Rotator cuff lesion · Shoulder surgery · Arthroscopy

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Introduction

Pathologies of the long head of the biceps tendon (LHB) represent a unique entity, and they are a common source of shoulder pain. Several findings, such as medial dislocation, tendonitis, or partial tears, are reported in the literature [1–5].

More specifically, Walch et al. described the role of the reflection pulley of the LHB, formed by the superior glenohumeral ligament (SGHL) and the coracohumeral ligament (CHL), in stabilizing the intra-articular part of the LHB [6].

Previously, Werner et al. described the anatomic structures of the biceps pulley system, which consists of the CHL, the SGHL, and fibers of both, the supraspinatus and subscapularis tendons [7]. The superficial layer of the pulley system is created by the CHL, which originates at the medial aspect of the coracoid process, divides laterally into two parts, which insert at the greater and lesser tuberosities, respectively. The SGHL originates at the antero-superior aspect of the labrum and crosses the rotator interval on the articular side of the capsule [8]. Passing underneath the LHB, the SGHL forms a U shape, and inserts at the proximal aspect of the bicipital groove, above the insertion of the subscapularis tendon (Figs. 1, 2, 3, 4) [7].

Currently, pulley lesions are classified according to Habermeyer et al. into the following four patterns: [9].

Grade 1: Isolated lesion of the SGHL.

Grade 2: SGHL lesion accompanied by a partial, articular-sided, supraspinatus tendon tear (Fig. 5).

Grade 3: SGHL lesion accompanied by a deep surface tear in the subscapularis tendon (Fig. 6).

Grade 4: SGHL lesion accompanied by partial, articular-sided tears in both the supraspinatus and subscapularis tendons.

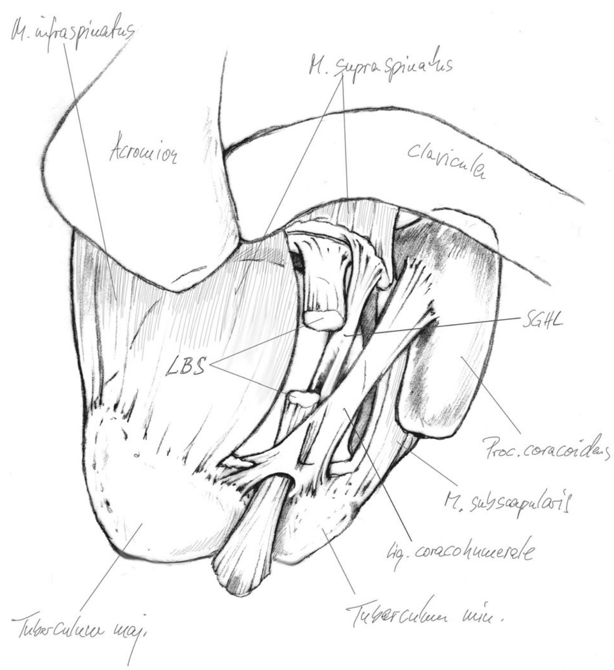

Fig. 1 Anatomical illustration of the pulley complex, surrounding structures and course of the long head of the biceps (LHB), view from above

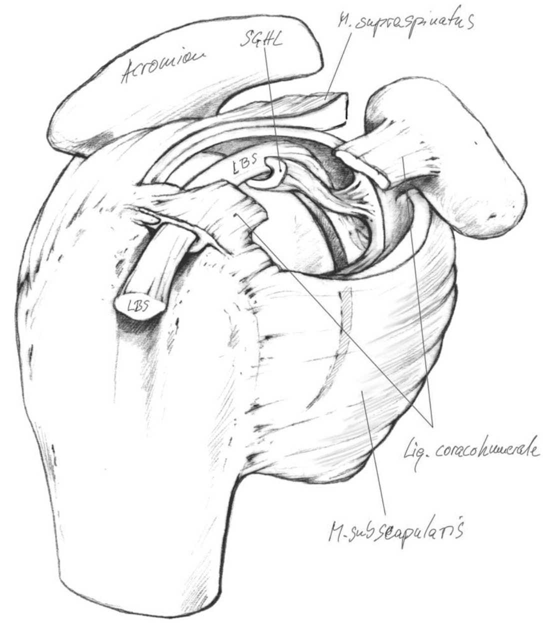

Fig. 2 Anatomical illustration of the pulley complex, surrounding structures and course of the long head of the biceps (LHB), view from anterolateral

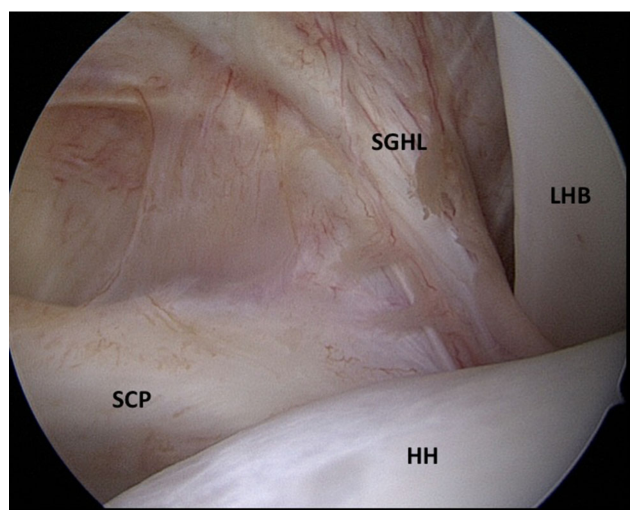

Fig. 3 Arthoscopic view from posterior portal showing an intact medial pulley system with the long head of the biceps tendon (LHB), humeral head (HH), subscapularis tendon (SCP), and superior glenohumeral ligament (SGHL)

In addition, those authors suggested a dynamic process, where grade 1 lesions may proceed to higher grade lesions.

Several authors have described pathological processes of the LHB due to instability [1–4, 10–12]. Baumann et al. provided epidemiologic data on pulley lesions acquired with diagnostic shoulder arthroscopy [13]. They reported a 7.1% prevalence of pulley lesions among patients without rotator cuff lesions or other relevant diagnoses. Baum et al. reported a 32% prevalence of pulley lesions, and they

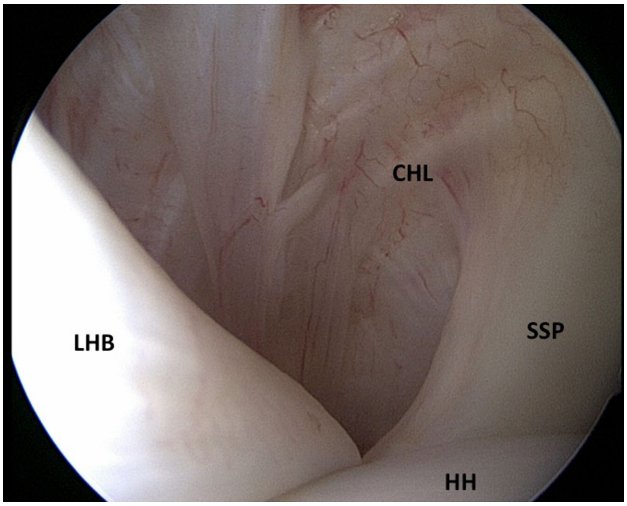

Fig. 4 Arthoscopic view from posterior portal showing an intact lateral pulley system with the long head of the biceps tendon (LHB), humeral head (HH), supraspinatus tendon (SSP), and coracohumeral ligament (CHL)

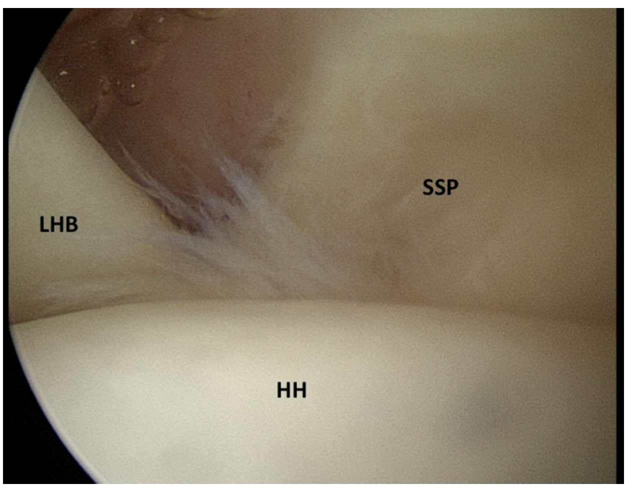

Fig. 5 Arthoscopic view from posterior portal showing pulley lesion grade 2 with partial tear of SSP

observed an association with superior labrum anterior–posterior (SLAP) lesions, in a prospective setting of different shoulder arthroscopy treatments with rotator cuff pathology, instability, osteoarthritis, and miscellaneous [14].

The present retrospective study aimed to evaluate the role of pulley lesions in arthroscopically treated rotator cuff tears and interval lesions. Furthermore, we evaluated whether untreated lesions of the LHB may have caused persistent pain in revision cases. In addition, we presumed an association with SLAP lesions, and we analyzed the potential association between a traumatic accident and the beginning of symptoms.

Hypothesis of this study was that lesions of the LHB pulley complex are very common and representative

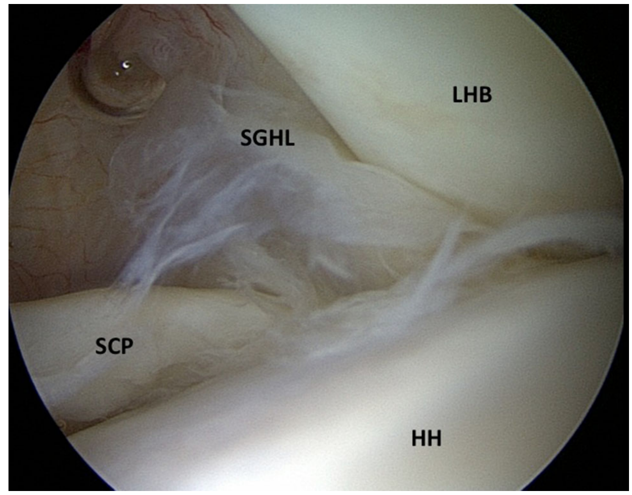

Fig. 6 Arthoscopic view from posterior portal showing pulley lesion grade 3 with partial tear of SCP

lesions in both primary and revision rotator cuff treatments. In addition, an association to SLAP lesions and traumatic accidents was presumed.

Methods

We retrospectively reviewed the charts of all patients that underwent shoulder arthroscopy at our institution between 2014 and 2015 for rotator cuff pathologies. The study included all patients that underwent arthroscopic rotator cuff repair or interval surgery. No open repair was performed in this period and all patients with chronic irreparable, antero-superior, or postero-superior massive tears undergoing muscle transfer procedures had diagnostic arthroscopy before and were included, as well. Patients were excluded when they had other pathologies, like shoulder instability, calcifying tendonitis, or chondral procedures. All procedures were performed by a single, shoulder-trained surgeon (senior author).

The study was approved by the Ethics Commission.

Arthroscopic procedure

Surgery was performed with the patient in a beach-chair position. Before arthroscopy, all patients received a standardized examination under general anesthesia to evaluate passive range of motion and glenohumeral instability. An arthroscope with 30° was used in all cases. Diagnostic views of the joint were performed through the standard posterior and anterior portals. Visualization of the LHB was performed at the level of the bicipital groove, by flexing the elbow, elevating the shoulder, and using a probe to pull out the LHB. Internal rotation allowed evaluation of the medial pulley system and the adjacent subscapularis tendon. After intra-

Table 1 Distribution and characteristics of pulley lesions ($n = 345$, 90.3% of all included shoulders)

	Grade 1	Grade 2	Grade 3	Grade 4	p value
n	48 (13.9%[a])	126 (36.5%[a])	20 (5.8%[a])	151 (43.8%[a])	
Trauma	7 (14.6%[b])	81 (64.3%[b])	9 (45%[b])	57 (37.7%[b])	<0.001
SLAP	12 (25%[b])	46 (36.5%[b])	11 (55%[b])	94 (62.3%[b])	<0.001
Revision	12 (25%[b])	9 (7.1%[b])	3 (15%[b])	8 (5.3%[b])	<0.001
Rotator cuff injury pattern	16 (33.3%[b]) bursal-sided SSP	48 (38.1%[b]) articular-sided SSP, 15 cases bi-focal bursal-sided	19 (95%[b]) articular-sided SCP, 4 cases bi-focal bursal-sided SSP	39 (25.8%[b]) articular-sided SSP, 10 cases bi-focal bursal-sided SSP	<0.001
		78 (62.7%[b]) complete SSP	1 (5%[b]) complete SCP	112 (74.2%[b]) complete SSP	
				3 (2%[b]) complete SCP	

A p value <0.001 shows a significant difference in the distribution of grade 1–4 pulley lesions within the trauma, SLAP, revision, and rotator cuff injury group. Pearson's Chi-square test was used

[a] Out of all pulley lesion cases

[b] Out of all pulley lesion cases of the corresponding subtype

articular viewing, the scope was switched into the subacromial space and a bursoscopy was performed to evaluate the presence of subacromial pathologies and to assess the presence and size of rotator cuff tears. This was done with the scope through an anterolateral portal. The extent of a partial thickness tear in the subscapularis tendon was quantified according to the classification described by Fox and Romeo [15]. Tears of the supraspinatus tendon were classified according to Habermeyer et al., for articular-sided lesions; according to Snyder et al., for bursal-sided lesions; and according to Bateman for complete tears [16–19]. The SLAP complex was evaluated and classified according to Snyder et al. [20].

All intra-operative findings were documented in a standardized fashion with a shoulder documentation sheet in our shoulder data system. All pulley lesions were treated with either a tenodesis or a tenotomy, in standard fashion. The choice of treatment was made individually and based on informed consent and intra-operative findings.

Subjective history of shoulder trauma associated with the beginning of symptoms was recorded before surgery and analyzed after by chart review.

Statistical analysis

Categorical variables are described as frequencies with percentages. Differences between groups were evaluated with Pearson's Chi-square. A p value ≤ 0.05 (two-tailed) was considered statistically significant. All data were analyzed with SPSS (SPSS 22.0, IBM Inc., Somers, NY, USA).

Results

We evaluated 382 cases of arthroscopic treatments for rotator cuff disease or isolated pulley lesions. Primary indication for surgery was based on pain, dysfunction, failed non-operative treatment, symptom duration, and radiological findings.

The patients (238 males and 144 females) had a mean age of 58.5 ± 12 years at the time of surgery. In 345 cases (90.3%), we identified a pulley lesion of the LHB. 32 patients had undergone revision surgery, after primary treatment at another institution.

Table 1 and Fig. 7 show the distributions of associated pathologies among the different grades of pulley lesions ($p < 0.001$, Table 1; Fig. 7).

Grade 1 pulley lesions

Among the 345 pulley lesions, 48 cases (13.9%) were classified as grade 1 pulley lesions [9]. In 7 cases (14.6%), the patients associated a traumatic accident with the beginning of symptoms. In 12 cases (25%), there was a concomitant SLAP lesion ($n = 7$, type 1 and $n = 5$, type 2 according to Snyder). Twelve cases (25%) were revision surgeries.

In this group, no patient had a subscapularis tendon tear, either complete or partial. In 16 cases (33.3%), there was an additional bursal-sided partial tear of the supraspinatus tendon (Snyder B1 to B3 [17]), accompanied by a mechanical outlet impingement.

Grade 2 pulley lesions

Among the 345 pulley lesions, 126 cases (36.5%) were classified as grade 2 pulley lesions [9]. In 81 cases (64.3%), a traumatic accident was associated with the beginning of symptoms. In 46 cases (36.5%), there was a concomitant SLAP lesion ($n = 27$, type 1 and $n = 19$, type 2 according to Snyder). Nine cases (7.1%) were revision surgeries, due to persistent pain after a previous surgery.

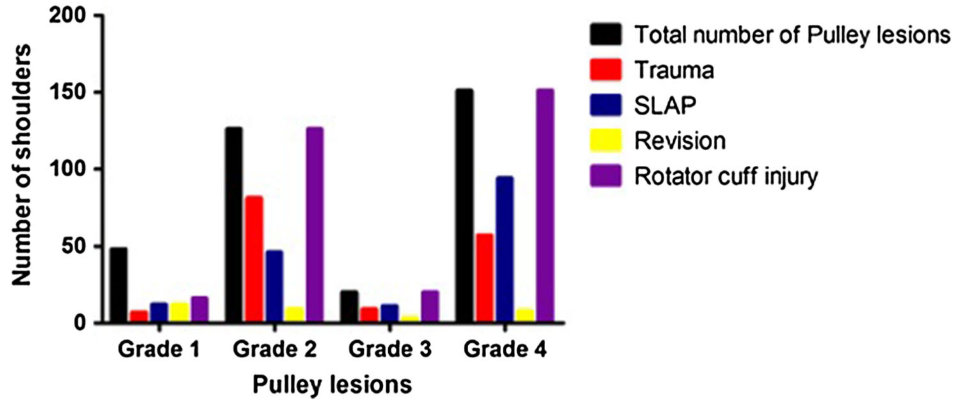

Fig. 7 Distribution of pathologies associated with the different grades of pulley lesions; ($p < 0.001$)

In this group, no patient had a subscapularis tendon tear. However, 48 patients (38.1%) had a partial tear in the supraspinatus tendon related to the pulley lesion (16 in zone A, 10 in zone B, and 22 in zone C [16, 18]). Out of these 48 patients, 15 had bi-focal lesions, where an articular-sided partial tear (A–C [16]) was combined with a bursal-sided partial tear (B1–B3 [17]). A mechanical outlet impingement accompanied all bursal-sided partial tears. In 78 cases (62.7%), a complete tear was present in the supraspinatus tendon, and 18 of these patients had massive postero-superior rotator cuff tears.

Grade 3 pulley lesions

Among the 345 pulley lesions, 20 (5.8%) were classified as grade 3. In 9 cases (45%), a traumatic accident was associated with the beginning of symptoms. In 11 cases (55%), there was a concomitant SLAP lesion ($n = 6$, type 1 and $n = 5$, type 2 according to Snyder). This cohort included three revision cases (15%).

A partial tear in the subscapularis tendon, classified according to Fox and Romeo (grade I to grade III), was observed in 19 cases (95%) [15]. In one case, there was a complete tear (Fox and Romeo Grade IV). In four cases, an additional bursal-sided partial tear was present in the supraspinatus tendon (B1–B3 [17]), accompanied by a mechanical outlet impingement.

Grade 4 pulley lesions [9]

Among the 345 pulley lesions, 151 (43.8%) were classified as grade 4. In 57 cases (37.7%), a trauma was associated with the beginning of symptoms. In 94 cases (62.3%), there was a concomitant SLAP lesion ($n = 76$, type 1; $n = 13$, type 2; $n = 4$, type 3; and $n = 1$, type 4 according to Snyder). This cohort included eight revision cases (5.3%).

A partial tear in the subscapularis tendon was observed in all cases, except three, which had complete tears (2%) [15]. In 112 patients (74.2%), a complete tear was present in the supraspinatus tendon, and 35 of these were massive rotator cuff tears. Thirty-nine patients (25.8%) had an articular-sided partial tear of the supraspinatus tendon (10 in zone A, 5 in zone B, and 24 in zone C [16]). In 10 cases, a bi-focal, bursal-sided, and articular-sided partial tear was detected (B1–B3 [17]), accompanied by a mechanical outlet impingement.

The injury patterns of the remaining 37 patients [$n = 382$ (total cases), $n = 345$ (cases with pulley lesions)] were as follows: 16 were revisions after LHB tenodesis or tenotomy; 9 were isolated, bursal-sided, partial tears of the supraspinatus tendon; 5 were bony avulsions of the rotator cuff after trauma; and 7 were massive rotator cuff tears with chronic LHB tears.

The pulley lesions were significantly correlated to rotator cuff pathologies ($p < 0.001$). Figure 8 shows the distribution of rotator cuff pathologies associated with pulley lesions. For clarity reasons, the bursal-sided tears were excluded from the pulley grade 2–4 lesions in Fig. 8.

Discussion

This study could show that in all cases with articular-sided partial tears, the pulley system was injured. Bi-focal lesions with concomitant bursal-sided partial tears were accompanied by a mechanical outlet impingement. We could observe that pulley lesions were highly related to SLAP lesions and to traumatic accidents. In all revision surgeries with not addressed LHB in primary surgery, a pulley lesion was documented and treated in the revision procedure.

Lesions in the pulley system of the LHB are a unique entity and a common source of anterior shoulder pain [21, 22]. Several authors have described associations with rotator cuff tears, acute trauma, repetitive microtrauma, superior anterior–posterior lesions, and soft tissue degeneration [3, 4, 6, 13, 14, 23–27]. Furthermore, several authors have described and assumed that a dynamic process of progression occurred, starting with an injury of the

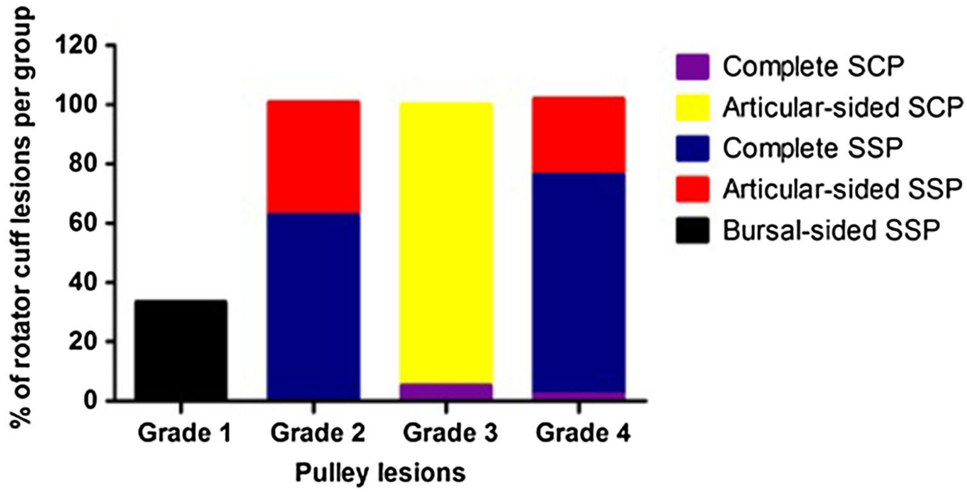

Fig. 8 Rotator cuff pathologies associated with pulley lesions; for clarity reasons, the bursal-sided tears were excluded from the pulley grade 2–4 lesions; ($p < 0.001$)

pulley system of the LHB, which led to partial tears in the adjacent rotator cuff, and subsequently, to a complete tear [9, 13]. Recently, Godeneche et al. published results after analyzing 218 cases of primary arthroscopic repair of a subscapularis tear. In approximately 75% of the cases, the authors could show that the SGHL/CHL complex was pathologically changed. They concluded, that in cases of prevalence of a subscapularis tendon tear with a lesion of the SGHL/CHL complex, the LHB is nearly always affected [28].

Nevertheless, a few studies have investigated the epidemiology and concomitant injuries related to lesions in the pulley system.

Classifications of injuries in the biceps pulley system were described by Bennett et al. and Habermeyer et al. [9, 29]. Our institution commonly employs the classification system of Habermeyer et al.; therefore, it was used in the present study.

To verify and confirm the relationship between an injured pulley system and rotator cuff tears, we analyzed all exclusively rotator cuff tears treated at our institution between 2014 and 2015 ($n = 382$). To focus our analysis on specific parts of the pulley system, we sub-divided the cases into groups of complete and partial tears ($n = 106$, articular-sided; $n = 45$, bursal-sided). In addition, we investigated potential trauma mechanisms and concomitant injuries, particularly SLAP lesions. We also analyzed the revision cases to identify persistent pulley lesions. This approach contrasted with those typically employed in other studies, which either selected patients with more restrictive criteria or included all patients with arthroscopic treatments [13, 14].

Our results revealed that, among all patients, 90.3% had an injured pulley system; moreover, all patients with articular-sided partial tears ($n = 106$) had an injured pulley system. Our results showed a wide distribution of pulley lesion severities: 13.9% were grade 1, 36.5% were grade 2, 5.8% were grade 3, and 43.8% were grade 4. Both the prevalence and the distribution of lesions contrasted with findings described in the previous studies [9, 13, 14]. We ascribe this difference mainly to the different inclusion criteria. To ensure that we provided valuable epidemiological data, we included all patients with solid pulley lesions or rotator cuff tears that were treated over 2 years; thus, the cohort included 382 cases.

We classified articular-sided partial tears of the supraspinatus and subscapularis tendons according to Habermeyer et al. and Fox and Romeo et al., respectively [15, 18]. Our results showed a significant distribution of articular-sided partial supraspinatus tendon tears in zones A to C (Habermeyer classification) and subscapularis tears in grades 1–3 (Fox and Romeo classification). These results indicated that these injuries affected more than the immediate surroundings of the pulley system; furthermore, our results supported the theory of a dynamic process, where the rotator cuff tear started with an injury of the biceps pulley system (Fig. 9).

Several different aspects of our study supported this theory. First, our cohort did not include patients with an articular-sided partial tear that had an intact pulley system. In addition, in all cases, partial tears were located directly next to the pulley system. Therefore, we deliberately did not use the classification ‘partial articular supraspinatus tendon avulsion tears (PASTA)’, because we assumed that these were not a separate articular-sided rotator cuff pathology; rather, they were more likely injuries that extended from the pulley system. In addition, the high incidence of a trauma history (14.6–64.3%) as begin of symptoms seems reasonable to assume a direct relationship between traumatic lesion of the pulley system and following friction injury of the adjacent anterior or posterior aspects of the rotator cuff. Obviously, pre-existing degenerative changes cannot be excluded.

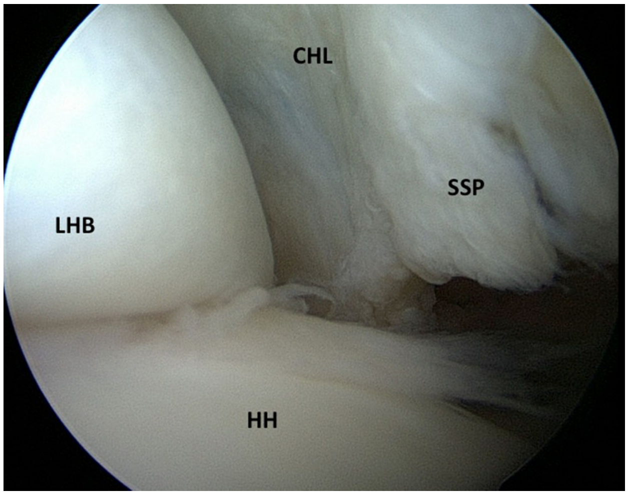

Fig. 9 Arthoscopic view from posterior portal showing pulley lesion grade 2 with complete tear of SSP

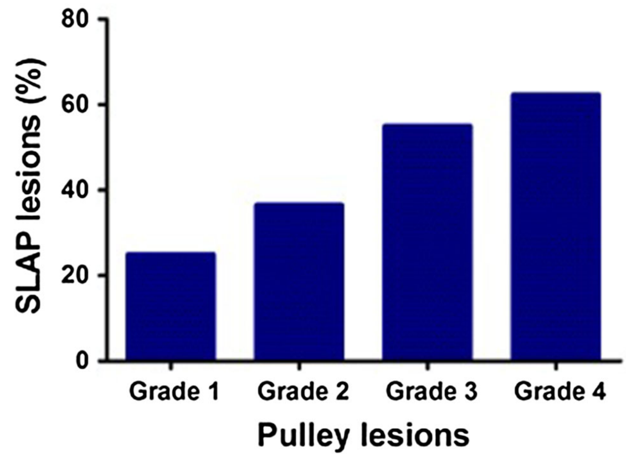

Fig. 10 Prevalence of superior labrum anterior-posterior lesions increased with the severity of the pulley lesion

Braun et al. discussed and described shear forces that affected and could lead to injuries in the pulley system [30]. In case of injured pulley systems, those same shear forces remain present and could, theoretically, also lead to rotator cuff injuries. Nevertheless, because our data were retrospectively collected, we could not confirm this theory entirely.

Another aspect of this study was that bursal-sided tears were not common in our cohort; we identified only 45 cases. All of these cases were associated with a relevant mechanical outlet impingement, which was treated in the same procedure. This finding was consistent with other findings reported in the literature [31–33]. However, articular-sided partial tears were observed far more often, which indicates that pulley lesions might be of crucial importance in the pathomechanism of rotator cuff lesions.

In our cohort, 163 cases (47.2%) had a concomitant SLAP lesion. In addition, we observed that the prevalence of SLAP lesions increased from 25 to 62.3% with increases in pulley lesion severity, from grade 1–4. Braun et al. described a prevalence of 56.2% SLAP lesions in their cohort [14]. However, it should be taken into consideration that the inclusion criteria differed between these studies. Moreover, our study design did not allow a determination of which injury pattern occurred first. In addition, SLAP lesions are very common lesions in this age group. Nevertheless, we could confirm a relevant association between these two injury patterns (Fig. 10).

Pulley lesions can be caused by both traumatic and non-traumatic events. However, the role of traumatic etiology has not been thoroughly investigated and documented. In this study, 154 patients (44.6%) reported an association with a corresponding trauma that occurred at the beginning of symptoms. In addition, Baumann et al. found a history of trauma in 43% of pulley lesions [13]. However, these findings did not prove that the pulley lesion pathology arose from a traumatic accident; rather, they suggested that symptoms often start after a traumatic accident, due to possibly pre-existing pathology. It was not possible to distinguish whether the trauma caused the pulley system injury or simply aggravated a (presumably) pre-existing partial rotator cuff tear, similar to the acute-on-chronic model observed for massive rotator cuff tears.

Our cohort included 32 cases (9.3%) that required revision due to persistent pain after a previous arthroscopic cuff repair procedure. In all revision surgeries with not addressed LHB, a pulley lesion was documented and treated in the revision procedure. This finding emphasized the clinical importance of pulley lesions; not treating this kind of lesion might cause persistent pain, which would result in an unsatisfactory outcome.

How to treat lesions of the LHB, respectively, pulley lesions is controversially discussed in literature and was not the focus of this study [34–37]. All pulley lesions were treated with either a tenodesis or a tenotomy, in standard fashion.

In general, we believe that rotator cuff interval pathologies continue to be underestimated, and they are often untreated. The lack of treatment leads to persistent pain and further rotator cuff injury.

We present a retrospective study describing the prevalence of different pathologies, which supports our opinion that rotator cuff lesions are a dynamic process based on a lesion of the pulley complex. However, further studies are needed to investigate the relationship and interaction of the different types of pathologies.

The study has some limitations. It should be emphasized that only the senior author performed all diagnoses, surgical procedures, and documentation of intra-operative findings. Although it is a shoulder-trained surgeon with more than 500 shoulder surgeries a year, no interobserver analysis was included. In addition, this study analyzed the data in a retrospective manner.

Conclusions

In conclusion, this study showed that injuries in the pulley system of the LHB are very common, but unfortunately in many cases, they remain underestimated and untreated. We observed that in all cases with articular-sided partial tears, the pulley system was injured. This strongly supports our opinion that a major proportion of cuff lesions originate from pulley lesions that dynamically progress over time, from partial to complete tears. Bi-focal lesions with concomitant bursal-sided partial tears, due to a mechanical outlet impingement, can also occur, which attests to the multi-factorial genesis of rotator cuff pathologies. In all revision surgeries with not addressed LHB in primary surgery, a pulley lesion was documented and treated in the revision procedure. In addition, we found that pulley lesions were highly related to SLAP lesions and to traumatic accidents.

Compliance with ethical standards

Conflict of interest The authors do not declare any conflict of interest related to the content of this article.

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