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ORIGINAL ARTICLE

The "comma sign": an anatomical investigation (dissection of the rotator interval in 14 cadaveric shoulders)

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Abstract
Purpose The aim of the present study was to describe the precise anatomy of the so-called "Comma Sign" which has been observed during arthroscopy in retracted subscapularis (SSC) tears.
Methods Fourteen fresh cadaveric shoulders were prepared to obtain an articular view comparable to arthroscopic posterior portal view. A step-by-step dissection was carried out to verify the presence of any anatomic structure inserting directly on the lateral margin of the SSC tendon. A sequential detachment of the superior gleno-humeral ligament (SGHL), the coraco-humeral ligament (CHL), and the SSC tendon from their bony humeral insertions was performed. Under intra-articular and extra-articular view, the SSC and its connections with the supraspinatus (SS), the SGHL and the CHL were evaluated.
Results The detachment of the CHL and the SGHL from the humerus did not reveal any structure directly inserted on the superior-lateral margin of the SSC tendon. However, when the SSC tendon was excised from the lesser tuberosity and pulled medially, a bundle of fibers, which inserted directly onto its superior-lateral edge, was constantly observed.
Conclusions We constantly found an effective link between the superior-lateral corner of the SSC tendon and a bundle of fibers coming from SS and CHL. It became visible only after medial traction of the detached SSC. This structure yields the "Comma Sign" in subscapularis tendon tears.

Keywords Shoulder · Rotator cuff · Arthroscopy · Subscapularis · Comma sign

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Introduction

Isolated subscapularis (SSC) tendon tear repair represent about 5 % of the rotator cuff tear repair [4]. The incidence of the SSC lesion increases up to 30 %, with a majority of partial lesions, when considering association to supra and infraspinatus tear [4, 14]. Nowadays, the repair of the SSC tear is routinely done arthroscopically with reliable outcomes. During arthroscopic SSC repair, the identification of its superior tendon may be difficult from the posterior viewing portal, especially in case of retracted tear. Lo and Burkhart described the so-called "comma sign" during intra-articular assessment of retracted SSC tears [15]. It was described as a part of the superior gleno-humeral ligament (SGHL) and coraco-humeral ligament (CHL) complex, which seemed to be insert on the superior-lateral corner of the SSC tendon. However, the relationships between SGHL, CHL and SSC tendon are still discussed. On one side the bony insertions of these structures have been widely described; on the other hand, the anatomic connections between capsule, ligaments, and tendons are more controversial. When analyzing retracted SSC tears under arthroscopy, the continuity between SSC and SS tendons suggests a lateral bridge, which inserts on both

tendons rather than onto bone (comma sign). An anatomic study on fresh frozen cadavers was performed, creating a specimen view comparable to arthroscopic posterior portal view. Precise connections and insertions of the comma sign and its relationship with the SS and SSC tendons were investigated to compare arthroscopic and anatomic findings and attempt to explain the arthroscopic appearance.

Materials and methods

An anatomic study on 20 shoulders from 10 fresh frozen cadavers (8 male and 2 female, age range from 43 to 84 years) from the anatomy lab "Claude Bernard" in Lyon was carried out. All specimens came from deceased donors who provide consent for anatomical study. All shoulders were dissected through a wide delto-pectoral approach with complete proximal detachment of deltoid and partial lateral acromionectomy. The bursa and the coracoacromial ligament were excised, and the conjoint tendon was detached from the coracoid process. Once isolated the long head of biceps tendon (LHB) in the bicipital groove, the posterior cuff (infraspinatus and teres minor) was detached from its humeral insertion and excised. The SS tendon and the anterior structures were left in place. The humeral head was then resected at the anatomical neck with a saw blade and then removed. Thus, an articular view comparable to the arthroscopical posterior portal view was obtained (Fig. 1). Six out of the 20 shoulders presented full-thickness cuff tear and were excluded. The anatomic features on the SS tendon, LHB, SGHL, CHL, and the upper third of the SSC tendon were investigated to look for an anatomic structure inserting on the SSC tendon beyond the SGHL.

The anatomic analysis was achieved through a sequential step-by-step procedure:

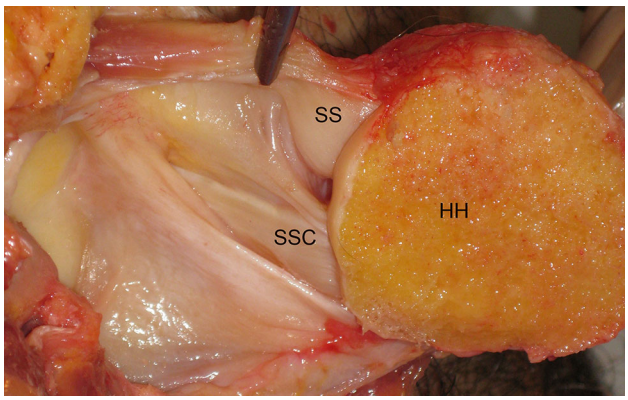

Fig. 1 Articular view after humeral head (HH) resection. *SSC* subscapularis tendon, *SS* supraspinatus tendon

1. The first step consisted in articular and extra-articular analysis of the aforementioned structures in a healthy condition that is: LHB and CHL/SGHL complex in place and intact SSC tendon.
2. The articular analysis was carried on after proximal tenotomy of LHB but with CHL/SGL complex in place and healthy SSC.
3. Third step consisted in further removal of CHL/SGHL complex insertion from the lesser tuberosity in the articular side, although the SSC was still intact.
4. Final step contemplated SSC tendon detachment from the lesser tuberosity in the articular side and medial traction. The rotator interval was opened at the level of the Weitbrecht foramen parallel to the SSC tendon. SS was left inserted during all the dissection.

Results

The SS tendon inserted onto the anterior most area of the highest impression on the greater tuberosity. The SSC tendon was formed by a superior part which inserted onto the uppermost margin of the lesser tuberosity, whereas the rest inserted onto the anteromedial portion of the lesser tuberosity. The cranial portion of the subscapularis tendon attachment was wider than the caudal portion and was in direct contact with the inferior side of the LHB at its corner, as shown by Arai et al. [1]. The LHB originated from the supraglenoid tuberosity and curved sharply to the intertubercular groove. At this point, soft-tissue structures retained the tendon within the groove. Those were formed by the lateral insertion of the upper third of the SCC, the SGHL, and the CHL. As described by Arai et al. [2], the SGHL has three basic types of origin: (1) the middle gleno-humeral ligament, LHB, and superior labrum; (2) the LHB and superior labrum; and (3) the LHB only. It inserted into the fovea capitis of the humerus. The origin of the CHL was the lateral aspect of the base of the coracoid process. According to the available literature, the main insertion of the CHL was the lateral rotator interval and the tuberosities [3, 9, 20], although another insertion into the supraspinatus or the subscapularis tendon was conceivable [21]. There was no clear boundary between the superior gleno-humeral and coraco-humeral ligament [2].

The step-by-step analysis showed the following findings:

1. No connections between the SSC and SS tendons emerged at a first intra and extra-articular examination.
2. The tenotomy of the LHB allowed articular exposure of SGHL–CHL complex forming the medial LHB pulley, but did not reveal any anatomic structure insertion on the supero-lateral corner of the SSC.

3. The resection of the SGHL/CHL complex at its humeral insertion exposed a more frontal thick tissue connecting supero-lateral corner of SSC and anterior margin of SS. Both tendons were still attached to humeral tuberosities. CHL was laterally detached from the bone but reached anteriorly that connection.
4. The disinsertion of the SSC tendon from the lesser tuberosity and its medial traction constantly revealed a steady connection at its supero-lateral corner with the anterior part of the SS, which was normally inserted. This connection has an arch shape and superior/posterior direction. In fact, further smooth split of the Weitbrecht foramen was easy medially, whereas it was impossible laterally (Figs. 2, 3). To confirm the anatomic position of this arch-shaped bundle, the cut surfaces have been properly marked. In this way, it was confirmed that in case of healthy SSC tendon and rotator interval ligaments, these vertical fibers joining the supero-lateral part of the SSC were hidden by the humeral head, LHB, CHL, and SGHL. The medial traction on the SSC tendon unmasked a vertical structure in the rotator interval and becomes the necessary condition required for exposure of the comma sign (Fig. 3).

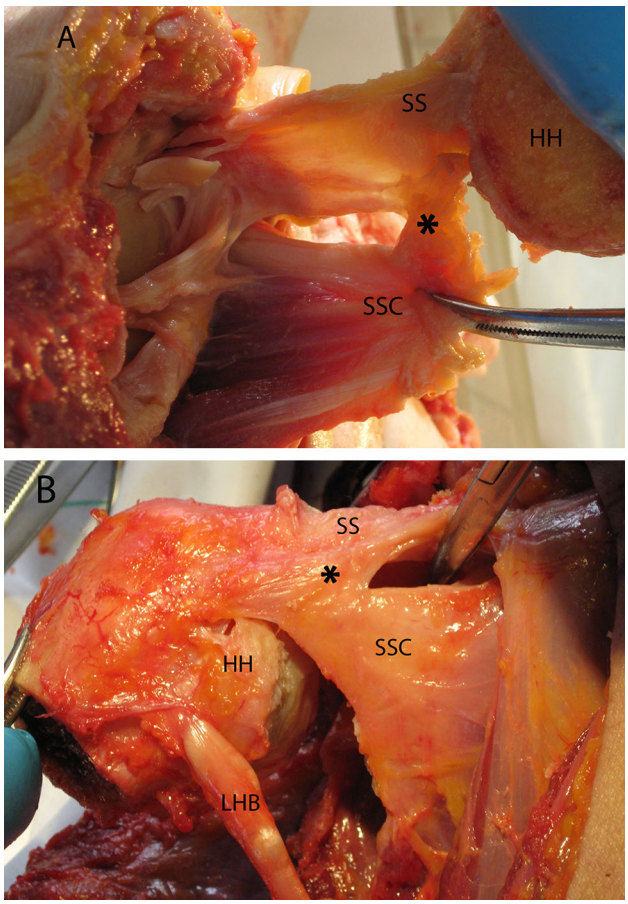

Fig. 2 The excision of the SSC tendon from the lesser tuberosity and its medial traction constantly revealed a steady connection (*asterisk*) at its supero-lateral corner. Articular view (**a**) and extra-articular view (**b**)

Discussion

A literature analysis concerning the anatomy of the rotator interval was carried out to investigate the relationship between CHL and SGHL and cuff tendons. There was general consensus regarding the bony insertions of the aforementioned ligaments. However, their shape, direction, and relationship with surrounding anatomic structures were more controversial. Some authors reported strict connections between CHL and SGHL at their lateral portion, but no tendinous insertions [3, 4, 6, 8–10, 12, 17, 19–21].

In anatomy textbooks, Paturet alone described a reinforcing structure that could correspond to our results. It originated from the anterior part of the SS tendon (SS expansion for the lesser tuberosity) crossing the upper part of the bicipital groove and inserting on the supero-lateral portion of the lesser tuberosity in conjunction with the SSC tendon [17]. Multiple studies of gross and microscopic dissection showed different shapes for the anterior capsule and cuff insertions [1, 2, 5, 8–10, 11, 16, 21]. Clark described a common insertion of the rotator cuff tendons by means of "interdigitating fibers" and similar connections between tendons, capsule, CHL, and SGHL. Among there connections, there was a capsular band oblique to the cuff tendons, including CHL. It formed part of the roof of the bicipital groove until the lesser tuberosity and joined bony (glenoid and humerus) and tendinous (SSC, SS, and partially IS) structures. SS and SSC tendons formed a bridge-shaped complex at the uppermost part of the bicipital groove [8, 9]. Boon [5] confirmed the existence of a continuous, highly dense, collagen band extending across the bicipital groove. Gleason [11] described in the same location a transverse humeral ligament formed by fibers of the subscapularis tendon with contributions from the supraspinatus tendon and the coraco-humeral ligament. CHL was found, by Yang [21], as a reinforcement of the anterior capsule with similar histologic features. This could correspond to what described by Cooper [10], who reported CHL and capsule in a same layer, which protruded at the rotator interval where the cuff sheath was interrupted. Mochizuki reported then again a long intramuscular tendinous portion located in the anterior half of the supraspinatus inserting into the most superior area of the lesser tuberosity in 21 % of 113 specimens. This tendinous portion was defined as "the comma sign" [16].

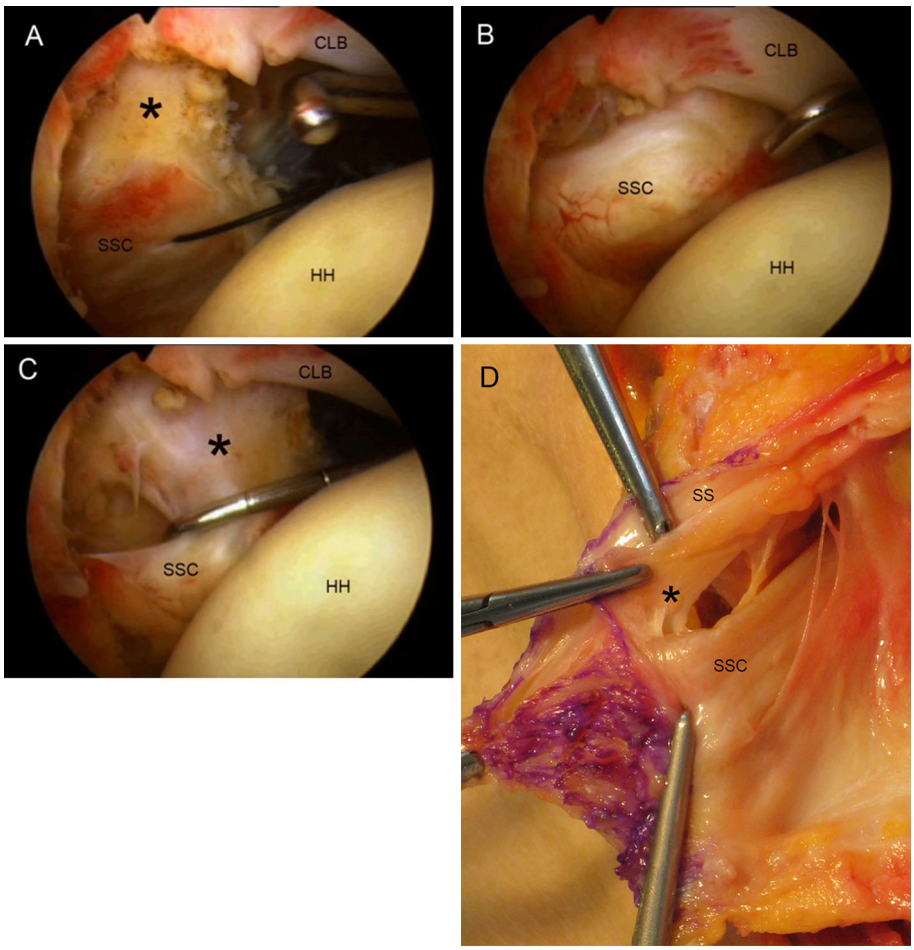

Fig. 3 **a–c** Posterior portal view: after debridement, lateral reduction of SSC with probe on "Comma Sign" (*asterisk*). **d** Posterior view of the connection between rotators interval, SS and SSC tendon (*asterisk*). Bony insertions are marked in *violet* (colour figure online)

Anatomic operative features of the rotator interval were reported in a few studies. Walch [20] in an open cuff repair study on 116 shoulders affected by SS tendon ruptures and found that the CHL joined like a bridge the anterior aspect of the SS at the supero-lateral edge of the SSC. These findings were similar to those of Clark [8, 9]. Moreover, the CHL and the SGHL had a convergence toward the tuberosities. Although these data suggested a sort of continuity between the SSC tendon and CHL, the author excluded a precise connection. In 2003, Lo and Burkhart [15] first described the "Comma Sign" as a part of the superior gleno-humeral ligament (SGHL) and coraco-humeral ligament (CHL) complex, which seemed to be insert on the superior-lateral corner of the torn SSC tendon. Rotator interval features were recorded by Bennett [3, 4] during arthroscopic SSC repair. He identified medial and lateral aspects of the CHL. He found that, on its upper portion, the CHL had some connections with the SGHL (CHL/SGHL complex), articular capsule and SSC tendon. The CHL was superficial to the SGHL. Moreover, he found some anatomic differences between the CHL/SGHL complex insertion and SSC insertion even if they seemed to be connected with some crossing fibers (interdigitating fibers). The same author performed a retrospective study on the prevalence of rotator interval lesions in case of rotator cuff ruptures [4]. He reported that 47 % of subscapularis ruptures had an associated lesion of the CHL/SGHL complex. At the level of its bony insertion, the fibers of the SSC tendon were in continuity with the medial wall of the bicipital groove (CHL/SGHL complex). Interestingly, CHL/SGHL complex could be damaged even in case of healthy SSC. However, he demonstrated that capsular lesions were more frequent in case of multiple tendon ruptures. Finally, he confirmed that CHL had some connections with the anterior surface of the SSC close to its bony insertion.

According to the available literature, there is a general agreement concerning medial and lateral insertions of the structures that form the rotator interval. However, several differences exist on the connections among these structures. An anatomic study recently described a tendinous insertion of the CHL [21]. Furthermore the cadaver study by Clark [8, 9] and the arthroscopic analysis by Bennett [3, 4] revealed close connections (interdigitating fibers) between these

ligaments and the tendons of the rotator cuff. The transversal band described by Clark, as well as the fibers of the CHL on the anterior surface of the SSC, supports our findings. Our study confirms that humeral insertions of CHL and SGHL corresponded to those that have been previously described in literature. We found in all fourteen dissections close connections between the lateral portions of the CHL and SGHL, which seemed to be blended in a single and not separable structure on their most lateral part. Moreover, we found an anatomic continuity between tendon fibers of the SSC and SS and ligaments. In clinical features, retraction of the torn SSC tendon is needed to expose the comma sign [18]. Similarly in dissected specimens, only the medial traction on the SSC constantly revealed a portion of the complex SS tendon–CHL–SGHL, which was inserted on the supero-lateral corner of the SSC tendon. It connected the tendons with an opposite course, forming a perpendicular bridge between SS and SSC tendons. Its insertion on the SSC tendon was rather anterior, suggesting an origin from the SS tendon and CHL rather than from the SGHL [3, 4, 16]. This hypothesis was confirmed by the extra-articular section of the transverse ligament at the top of the bicipital groove. After this manoeuver, the identification of the aforementioned complex was no more possible (Fig. 4). Thus, some findings support a tendinous nature, whereas others suggest a ligamentous part of the bundle. Some authors reported an effective tendinous link between SS and SSC [8, 9, 16, 17], others a blended insertion of tendons and rotator interval ligaments [3, 4, 8, 9]. Only Yang [21] described a CHL entirely inserted onto rotator interval, SS and SSC tendons. This diverges from a traditional ligament course, which is from bone to bone. However, nor the intra-articular inspection, neither extra-articular approach clarified the precise course and composition of this structure. A histological study could better define its origins and characteristics.

This anatomic structure has an important relevance during arthroscopic SSC repair since it delimitates the superior-lateral corner of the retracted tendon [7, 16]. Its arthroscopic identification is crucial, since preoperative imaging is usually not able to detect this structure [13]. Its preservation has several additional positive effects. It avoids the "cut-through" effect [7], and the postoperative structural failure and it restore the SS function in anterior–superior cuff lesions [16]. We believe it is important to recognize it, since it can be easily confounded with other structures such as LHB.

Conclusion

In this anatomic study, a close connection between SSC and SS tendons and the ligaments of the rotator interval (CHL and SGHL) was constantly found. It seems that some of the lateral fibers originating from the complex CHL–SGHL and from the SS constantly inserted on the superior-lateral aspect of the SSC tendon rather than to bone. This is an uncommon finding for a ligamentous structure but more histologic studies are needed. Those fibers are not visible in an intact shoulder, but are clearly visible only in case of retracted lesions of the SSC tendon. They represent the Comma Sign described arthroscopically by Lo and Burkhart [15]. The Comma Sign is a useful landmark for retracted SSC tear recognition and then reconstruction. A radiological assessment of this fibrous structure could be interesting for a study to come.

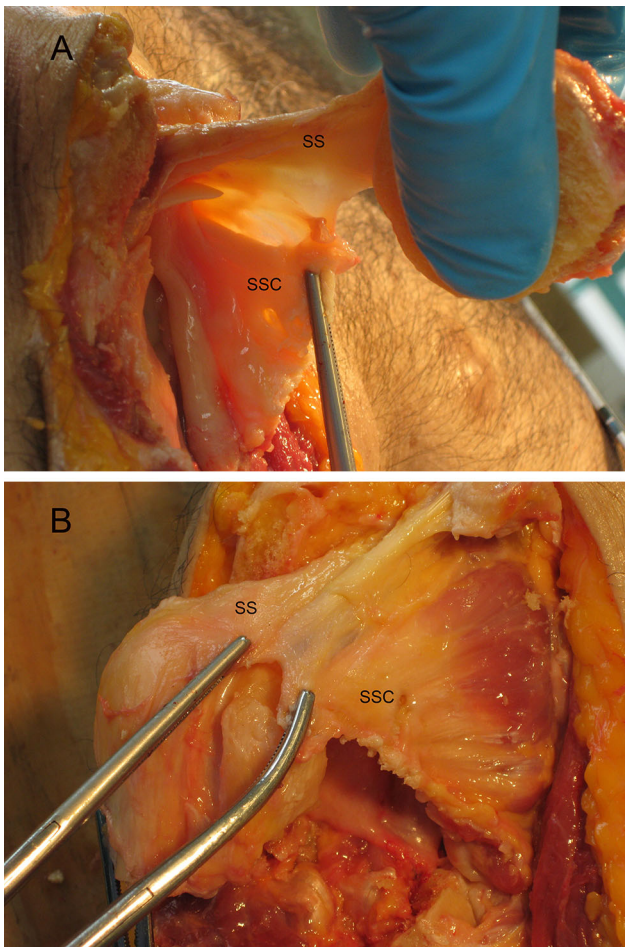

Fig. 4 The section of the transverse ligament at the top of the bicipital groove. After this manoeuver, the identification of the steady connection between SSC and SS was no more possible. Articular view (**a**) and extra-articular view (**b**)

The experiments comply with the current laws of the country in which they were performed.

Conflict of interest The authors declare that they have no conflict of interest.

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