MENTORS IN ORTHOPEDICS

CONCEPT OF THE "BICEPS BOX": A TOOL TO IMPROVE UNDERSTANDING OF ANTEROSUPERIOR IMPINGEMENT OF THE SHOULDER WHEN THE INTRA-ARTICULAR BICEPS IS NORMAL

https://doi.org/10.71165/yqud-b86b

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SUMMARY

Background: Anterior shoulder pain is frequently attributed to pathology of the long head of the biceps tendon (LHBT), leading to the common surgical practice of tenotomy or tenodesis during rotator cuff repair. However, the routine sacrifice of a macroscopically normal LHBT remains controversial due to potential postoperative complications and a lack of consensus regarding the precise nosological origin of pain when intrinsic tendon damage is absent.

Objective: This article describes the "biceps box" concept, a functional geometric model designed to map the anatomical environment of the LHBT and differentiate between intrinsic tendon lesions and extrinsic damage to adjacent stabilizing structures.

Key Points: The LHBT is modeled within a rectangular cuboid representing the rotator interval. The posterior wall comprises the five-layered supraspinatus tendon, while the superior wall consists of the coracohumeral complex and superior glenohumeral ligament (SGHL). The subscapularis and SGHL form the anterior wall, and the lateral wall is defined by the biceps pulley and semicircular humeral ligament. This tissue continuum maintains LHBT stability through interconnected structures, including the fasciculus obliquus and rotator cable. Clinical studies indicate that interobserver reliability in diagnosing LHBT instability is often low, potentially leading to unnecessary surgical intervention. Furthermore, the model accounts for sensory innervation of the rotator interval by the lateral pectoral nerve, suggesting that anterosuperior humeral head decentering may result in nerve entrapment and referred pain.

Conclusion: The biceps box model provides a framework for identifying anterior shoulder pain arising from extrinsic structural or neurological involvement. This approach encourages conservative management, such as dynamic humeral centering and targeted nerve blocks, when the LHBT appears healthy.

KEYWORDS

Shoulder Joint; Rotator Cuff Injuries; Arthroscopy; Tenodesis; Tendon Injuries

INTRODUCTION

A classic topographical presentation in shoulder pain is projection towards the front [1],[2]. The nosological origin is not well established although it is recognised that the intra-articular portion of the biceps (the long head of biceps tendon, LHBT) is one possible explanation [3]. In line with this hypothesis, routinely sacrificing the LHBT in arthroscopic rotator cuff repairs or shoulder arthroplasty would seem to be justified [4]. The “biceps killer” approach is very widespread in France, yet it is not the consensus worldwide [5], mainly because of complications like the Popeye sign after tenotomy ± tenodesis of the LHBT [6]. Some authors have suggested the possibility of anterosuperior impingement that could be due to involvement of structures around the LHBT, in particular the biceps pulley, which would remove suspicion from LHBT itself as the cause [7].

The development of new surgical techniques using the intra-articular portion of the biceps, or LHBT, as an autologous graft, such as dynamic anterior stabilisation [8] or superior capsular reconstruction using the biceps in situ [9], prompt us to be more inclined to preserve the biceps.

The controversy over routine tenotomy ± tenodesis of the LHBT becomes even more relevant when investigation finds the biceps to be normal, i.e., with no tear, fissure, separation of layers, medial or lateral instability, and with no concomitant SLAP injury.

The SFA Biceps Group has carried out a multicentre clinical study under the aegis of the Francophone Arthroscopy Society, looking at approaches to managing the normal long head of biceps in isolated grade 1 supraspinatus tendon tears [10].

This work led the group to ask what is the origin of anterior pain when the LHBT is normal and to consider the role played by adjacent structures. Since the LHBT is entirely enclosed we mapped the environment of the biceps in the form of a rectangular cuboid and we called this the “biceps box” [11].

This perspective prompted us to rethink how LHBT injuries are described, separating intrinsic damage, affecting the biceps, from extrinsic damage, affecting the adjacent structures, or, in other words, the walls of the biceps box [12].

The objective of this article is to present the concept of the biceps box and to describe the different sides of the box.

DESCRIPTION OF THE WALLS OF THE BICEPS BOX

The intra-articular portion of the biceps is located within the rotator interval, forming the centre within the other structures that appear to wrap around it [13],[14]. Figure 1 presents the anatomical view of where the LHBT is located within the rotator interval with the supraspinatus tendon (SSP) behind and the subscapularis tendon (SSC) in front, the coracohumeral ligament (CHL) and the superior glenohumeral ligament (SGHL) above and the humeral head cartilage below, the glenoid and superior labrum inside and the biceps outside. Although the surfaces are not flat, it seemed to us to be possible to look at this anatomical region through a functional geometric model with a cuboid shape called the “biceps box” [11]. Figure 2 presents the modelling of the “biceps box”.

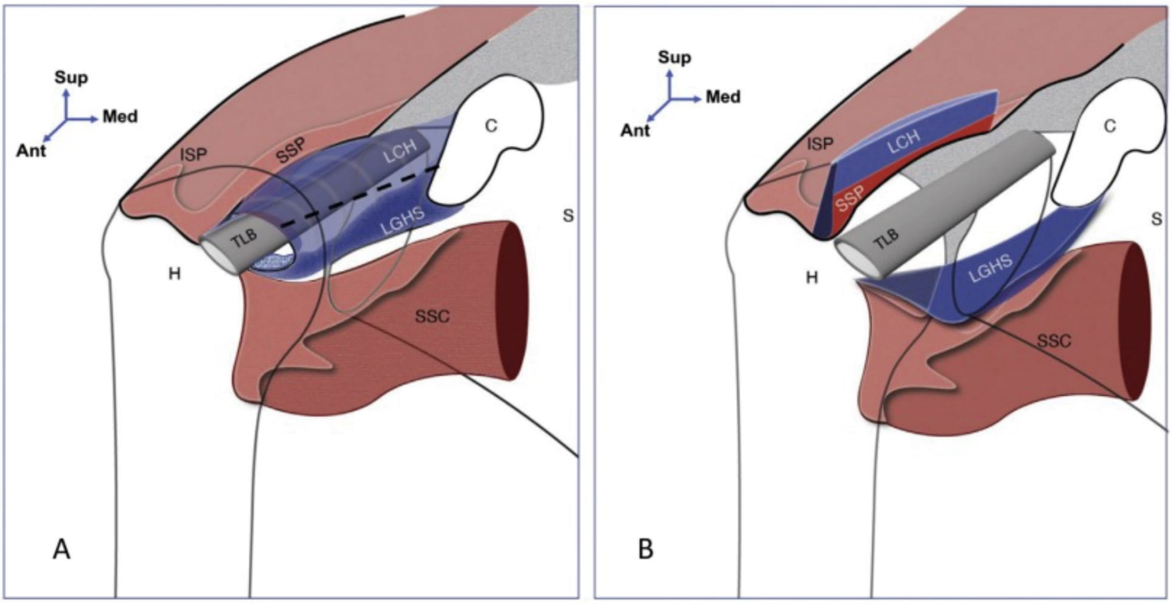

Figure 1: Anatomical representation of the "biceps box" in a right shoulder, frontal view, ISP infraspinatus, SSP: supraspinatus, LCH [CHL]: coracohumeral ligament, TLB [LHBT] long head of biceps tendon, LGHS [SGHL]: superior glenohumeral ligament, SSC: subscapularis, H: humerus, C: coracoid. A: Rotator interval closed, dashes showing the opening line for diagram B; B: Rotator interval open.

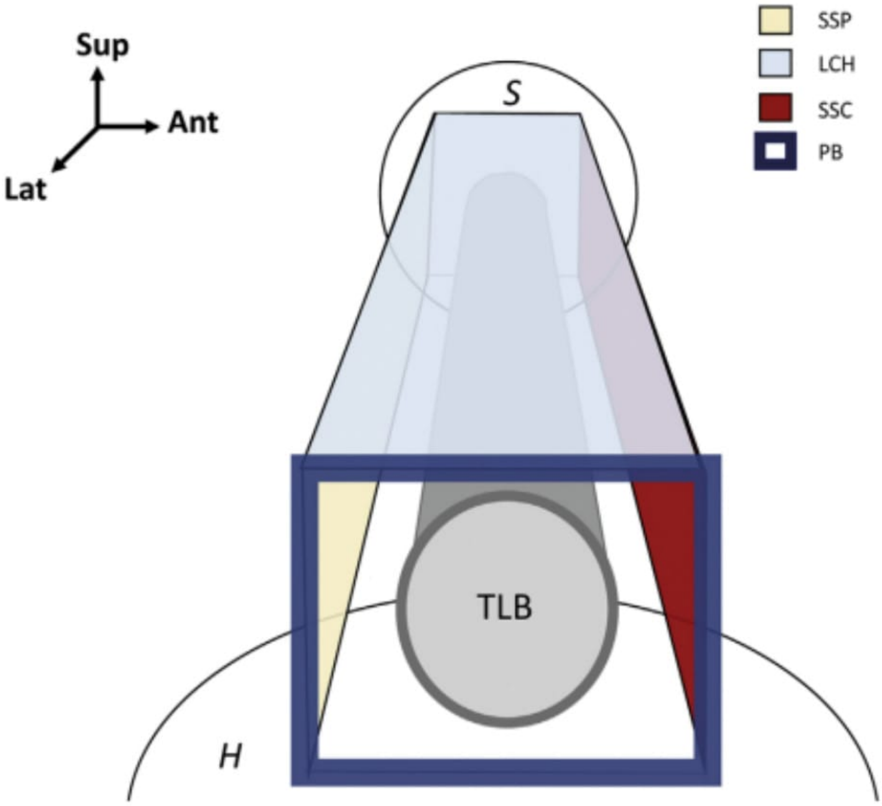

Figure 2: Modelling the walls of the "biceps box" in a right shoulder, S: scapula, H: humerus, TLB [LHBT]: long head of biceps tendon, Posterior surface: SSP supraspinatus, Superior surface: LCH [CHL] coracohumeral ligament, Anterior surface: SSC subscapularis, Lateral surface: PB [BP] biceps pulley.

Posterior wall of the biceps box

The SSP tendon is not a homogeneous structure. Clark and Harryman [15] described five layers that are distinct in terms of the orientation of their collagen fibres, their histological composition and their vascularisation.

- **Layer 1** is the most superficial and is made up of extensions of the CHL. It is extremely thin, measuring around one millimetre, with fibres following a diagonal orientation in relation to the axis of the muscles and fusing laterally with the periosteum of the greater tuberosity. It is characterised by the presence of large arterioles.
- **Layer 2** is 3–5 mm thick and is made up of fibres that run parallel to the axis of the tendon, organised into fibrous bands 1–2 mm in diameter forming fascicles that are tightly bound together. It is vascularised from the arterioles in the superficial layer. This layer extends towards the front into the rotator interval.
- **Layer 3** is not as thick as layer 2 and is made up of fibres bundled into smaller fascicles with a more varied orientation in relation to the axis of the supraspinatus tendon, producing a grid-like pattern. Although vessels are found in this layer, the majority of the large vessels in the first two layers terminate between layers 2 and 3.
- **Layer 4**is made up of loose connective tissue, in which there are thick bands of collagen fibres. In front, the fibres fuse with each other and intermingle with those of the CHL, forming the anterior cable of the SSP tendon. This layer is vascularised by capillaries from the joint capsule.
- **Layer 5** is 1.5–2 mm thick and it forms the joint capsule and extends from the labrum inside to the humerus outside, where the collagen fibres insert over the footprint through the Sharpey's fibres.

Superior wall of the biceps box

It is the rotator interval in strictest terms that forms the roof of the LHBT between SSP and SSC. From front to back, extensions of SSP, CHL and then SGHL can be found [16]. The CHL constitutes the main structure and can be compared to a roundabout, with multiple sheets crossing through and connecting the anterior and posterior parts of the rotator interval. Figure 3 shows a surgical view of the superior surface of the rotator interval. Jost described the rotator interval as having 4 layers at the CHL [13]. The superficial layer is the superficial CHL, layer 2 is made up of extensions of the fibres from SSP and SSC, layer 3 is the deep CHL and finally layer 4 is made up of extensions of the joint capsule and the SGHL. This means that it is not possible to define the borders of the CHL, which cannot be equated to an anatomic ligament structure. It is better to follow Arai's suggestion and to refer to a coracohumeral complex, which makes up a functional structure with multiple interdigitations wrapping around the LHBT like an octopus with its tentacles [17].

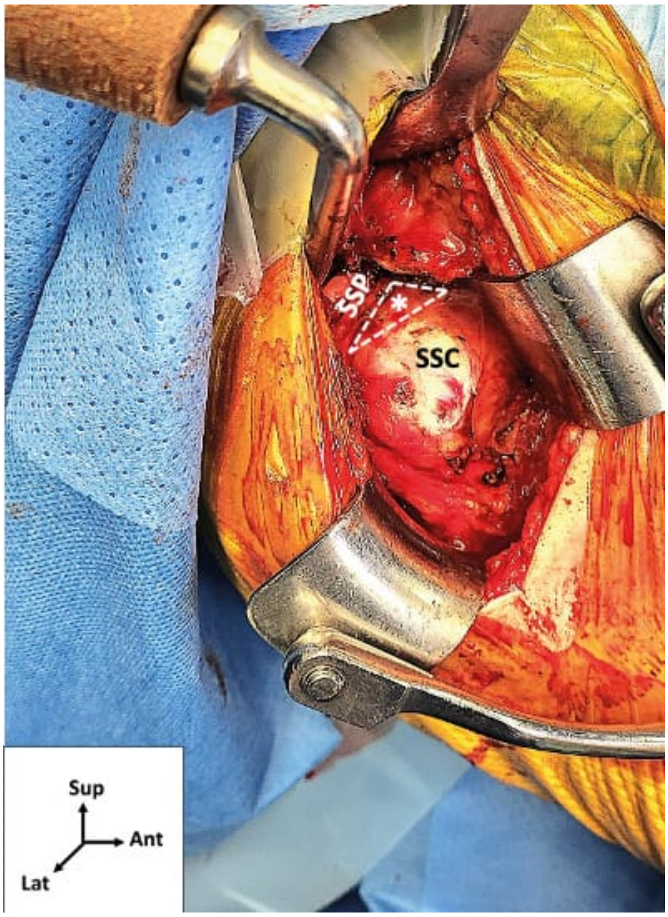

Figure 3: Surgical view of the superior surface of the closed rotator interval in a right shoulder, indicated by the triangle marked in dashes, SSP: supraspinatus, *: coracohumeral ligament, SSC: subscapularis.

The second important structure of the rotator interval is the SGHL which literally winds around the LHBT [18], [19]. The insertion of the SGHL is inside, over the anterosuperior labrum then it immediately fuses with the anterior part of the coracohumeral complex with nothing to distinguish these structures histologically. The course of the SGHL continues towards the front, becoming intermingled with the superior body of SSC as far as the anterior part of the biceps pulley. Here, the SGHL splits into the SSC tendon and fibrocartilage takes over, then it follows a posterior course passing under the LHBT to form a sling to support the LHBT suspended above [15],[19].

Anterior wall of the "biceps box"

The anterior surface is made up of SSC and the superior and middle glenohumeral ligaments [19]. From a functional perspective, the superior border of SSC supports the LHBT when it turns 90° at end of the intra-articular portion just before the bicipital groove [20]. This means that any SSC injury will always have an impact on the stability of the LHBT [7]. As described for the superior wall, the terminal course of the SGHL brings it to fold around the biceps to form the anterior border of the biceps pulley [19].

Lateral wall of the "biceps box"

In the literature, the term biceps pulley is widely used to shed light on the pathogenesis of the LHBT [21]. Yet whether this concept represents an actual anatomical structure is debatable. Figure 4 shows a surgical view of the biceps pulley. It is possible to consider the pulley split into two regions: the lateral part, corresponding mainly to the anterior border of SSP [22] and the medial part, corresponding to the folded SGHL and CHL [23]. In this simplistic description, the transition between the lateral and medial pulley seems to have been forgotten although anatomically there is indisputably continuity of the tissue of the biceps pulley. Kolts, in a histopathological study of 19 cadavers, proposed the existence of the semicircular humeral ligament (SCHL), which he identified as part of the biceps pulley made up of thickened CHL tissue in the order of millimetres that macroscopically forms an arch [16]. The SCHL as he described it has rarely been picked up in the subsequent literature, although it is likely to be the most anterior part of what Burkhart [24] called the rotator cable.

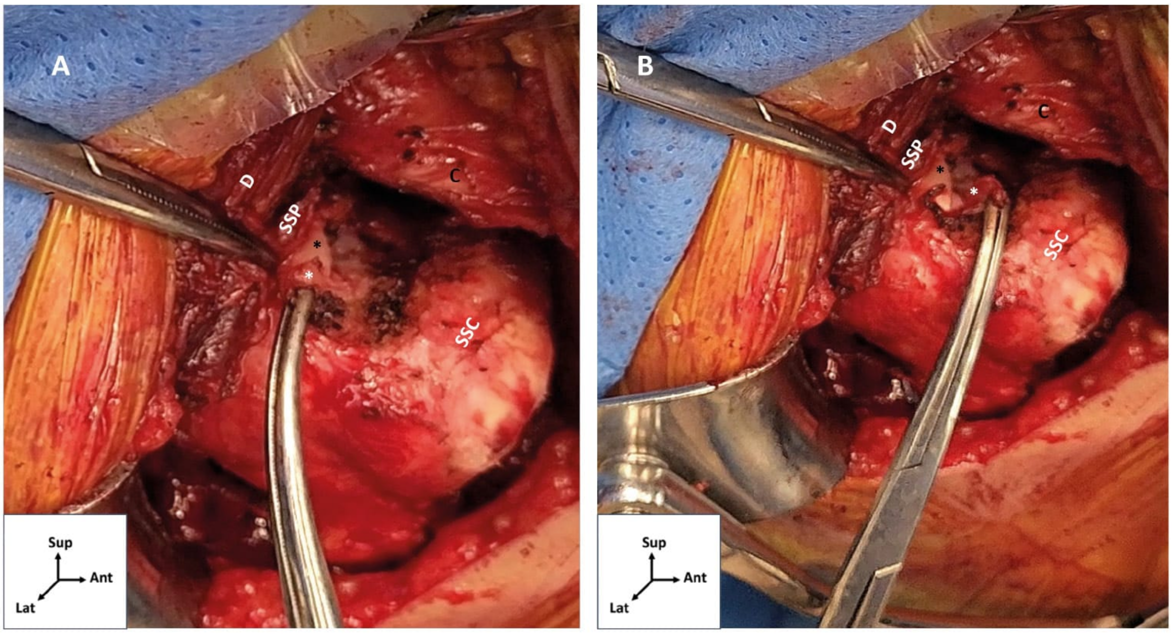

Figure 4: Surgical view of the superior surface of the open rotator interval in a right shoulder, D: deltoid, SSP: supraspinatus, *: long head of biceps, *: biceps pulley, SSC: subscapularis, C: coracoid. A: Biceps pulley overlaying the biceps. B: Detachment of the posterior border of the biceps pulley with the long head of biceps remaining covered by the anterior band of the supraspinatus.

The “biceps box” and its interconnecting structures

The cohesion of the “biceps box” is found in the tissue continuum linking the different walls. Figure 5 presents a model showing the extensions of the biceps box. This tissue continuum can be reduced down to a fusion of the anterior, posterior or lateral extensions, with some authors putting forward the hypothesis that there is an identifiable sheet, fasciculus obliquus (FO), that connects through the CHL, SSP and SSC [25],[26],[27]. In an article about the SSP insertion over the footprint of the rotator cuff, Mochizuki et al reported that 21% of cases showed an anatomical variation for the anterior insertion, which appeared to also insert over the lesser tuberosity, literally spanning the LHBT [28].

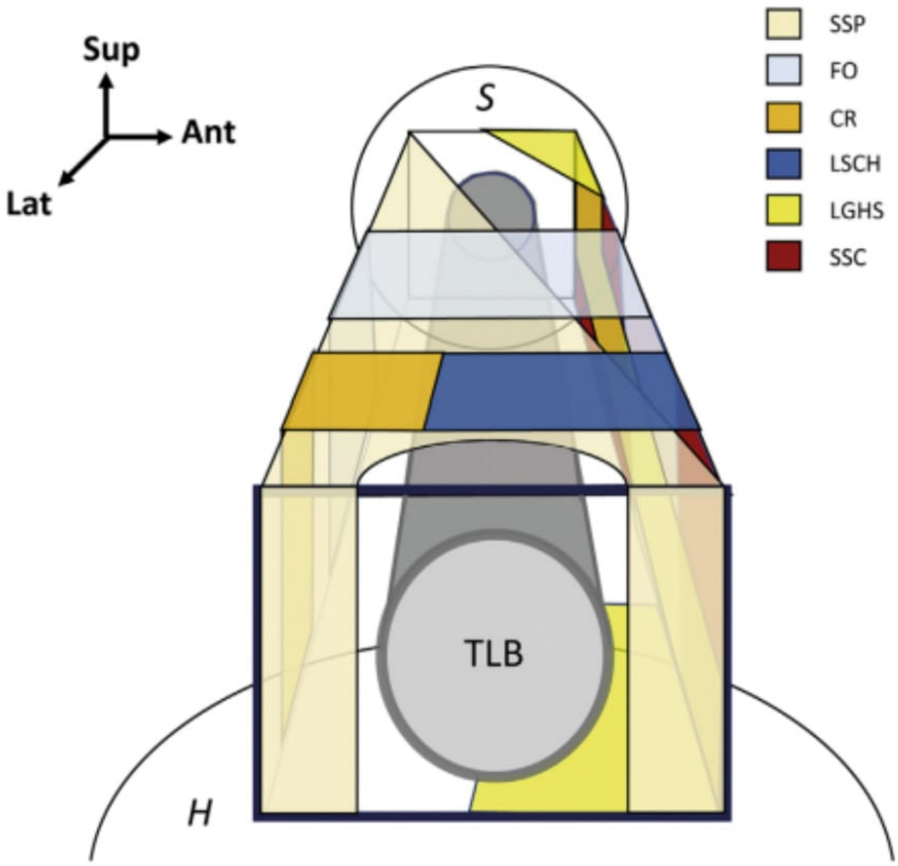

Figure 5: Modelling the extensions crossing the "biceps box" in a right shoulder, S: scapula, H: humerus, TLB [LHBT] long head of biceps tendon, Posterior surface: SSP supraspinatus, FO fasciculus obliquus, CR [RC] rotator cable, Superior surface: LGHS [SGHL] superior glenohumeral ligament, FO fasciculus obliquus, SSP supraspinatus, CR [RC] rotator cable, LSCH [SCHL] semicircular humeral ligament, Anterior surface: LGHS [SGHL] superior glenohumeral ligament, FO fasciculus obliquus, SSC subscapularis.

Vascularisation and innervation of the "biceps box"

Laumonnerie, when looking at innervation of the glenohumeral capsule, highlighted the role of the lateral pectoral nerve in the deep sensory innervation of the anterior capsule and rotator interval [29],[30]. This is a pedicle of vessels and nerves arising from the brachial plexus, running along pectoralis minor, then into the cellular fat tissue under the coracoid, before terminating laterally in the anterosuperior capsule through the CHL. In this model, the "biceps box" can be meaningfully be compared to the tissue sheaths that hold blood vessels.

DISCUSSION

The SFA Biceps Group's interest in the environment around the biceps was born out of a desire to improve our understanding of the origin of anterosuperior shoulder pain, which can be too easily attributed to LHB tendinopathy, even when it is healthy on macroscopic examination. The issue is that there is a lack of consensus over even the definition of a pathological LHBT [31]. This prompted us to revisit the classification of lesions in a pathological biceps, introducing the notion of extrinsic lesions.

In a prospective, randomised, multicentre study (13 sites) conducted for a Francophone Arthroscopy Society symposium (ID-RCB 2018 A01382-53) [10], we evaluated the functional results in isolated repairs to distal SSP tears according to whether or not the LHBT was preserved. Surgeons were asked to perioperatively categorise the LHBT as NORMAL or PATHOLOGICAL, depending on criteria set out in a video protocol [32]. One of the assessment criteria was LHBT instability which was a factor for classing as PATHOLOGICAL, even when there was no biceps injury (tear, fissure, separation of layers, hourglass biceps, SLAP tear). Three hundred and seventy-one patients were included in the study between 1 November 2018 and 1 February 2022. Out of these patients, 257 videos were used to analyse interobserver reliability between the operator (Op) and two senior observers (Obs1 and Obs2) in terms of the arthroscopic diagnosis of the LHBT. Dordain's analysis of this series found a moderate and low rate of concordance in the assessment between the observers and the operator (K Op-Obs1 = 0.51 and K Op-Obs2 = 0.39) and correct concordance between the two observers (K Obs1-Obs2 = 0.63) [12]. In the series, one of the criteria that created the most problems turned out to be recognising LHBT instability, especially at its posterior border. This difficulty can be attributed to a misunderstanding of the pathophysiological interactions between SSP and LHBT. The theoretical model of the "biceps box" should help us to improve our understanding of the anatomical complexity of this transitional zone.

An isolated extrinsic lesion does not seem to be enough to destabilise the LHBT, with significantly varying views found in the literature on the association between SSP and LHBT injuries [22]. We believe that the concept of the "biceps box" and its interconnected structures is not just a simple static model, but rather it opens up avenues for a dynamic theory that protects the LHBT. The most critical area seems to be the biceps pulley, where the closest relationships between the walls of the "biceps box" and LHBT exist. Habermeyer put forward a classification for lesions of the biceps pulley [18]. While it may be clear that damage to the medial pulley leads to biceps pathology [21], there is much lower consensus over the link between posterior damage and pain. In a partial or full thickness detachment of the anterior cable of SSP, it appears to us that several structures are able to compensate. The fasciculus obliquus described by Werner [25], which we believe can be understood as layer 4 of SSP as described by Clark and Harryman [15], maintains stability of the anterior cable of SSP and this appears to be sufficient, at least when there is some retraction, to compensate when the biceps pulley is lacking a posterior attachment. Another hypothesis, which does not exclude the first, is that a certain number of cases may in fact have a second and more anterior insertion of the SSP onto the lesser tuberosity, spanning the LHBT like the pillars of a bridge [28]. In this case, contraction of the supraspinatus tendon produces squeezing over the superior surface, stabilising the biceps in abduction or external rotation of the arm, which would minimise the pathophysiological impact of detachment of the anterior band of SSP on the LHBT.

Finally, the existence of identifiable capsular thickening, like Kolts' semicircular glenohumeral ligament, Burkhart's rotator cable extension [24], secures the biceps pulley even when there is damage to the lateral pulley, which is not always associated with posterior instability. Figure 6 shows an arthroscopic view of the continuum of the lateral pulley–anterior band of SSP in a supraspinatus tendon tear.

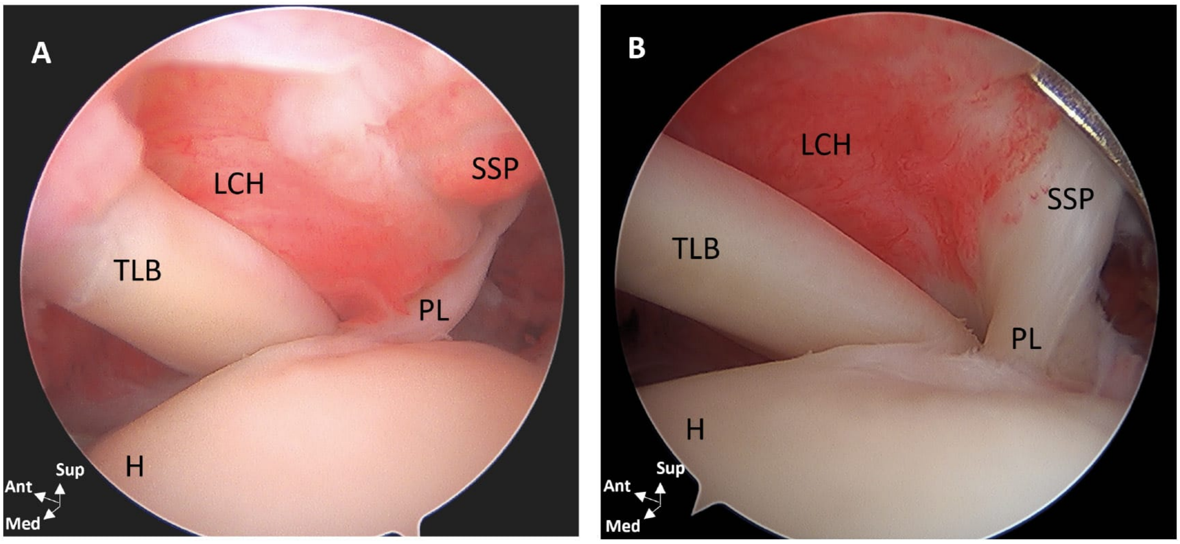

Figure 6: Arthroscopic glenohumeral view of the posterior surface of the rotator interval with a right shoulder supraspinatus tear, H: humerus, TLB [LHBT] long head of biceps tendon, LCH [CHL]: coracohumeral ligament, PL [LP]: lateral pulley, SSP: supraspinatus. A: Overlap of the lateral pulley and the anterior band of the supraspinatus; B: traction on the anterior band of the supraspinatus demonstrating the tissue continuum between the lateral pulley and the supraspinatus.

One of the angles that we bring to the concept of the "biceps box" in improving understanding of anterior shoulder pain comes from considering the zone to be innervated by a plexus of vessels and nerves [29]. There has been very little exploration of the management of anterosuperior impingement [7] in supraspinatus tendinopathy apart from in the context of anterior instability, unlike in posterosuperior shoulder impingement [33]. There are a number of articles in the literature that demonstrate the value of specific rehabilitation exercises in dynamic centring [34],[35]. There are multiple functional causes of decentring: posture, posterior capsular stiffness, fatigue during eccentric contraction of the external rotators or hypertonia of the internal rotators, scapulothoracic dyskinesis with anterior tilt of the scapula or contracture of pectoralis minor [34]. In the absence of any mechanical injury to the LHBT, especially if diagnostic injection is negative, we believe it is possible to consider a neurological origin for the pain, as well as nerve entrapment syndrome, in which the humeral head decentred anterosuperiorly compresses the lateral pectoral nerve packet. To our knowledge, this nerve cannot be assessed through EMG and this makes nerve involvement difficult to confirm. By contrast, there is an existing symptomatology specific to contracture of pectoralis minor, through which this nerve courses, and some surgeons have suggested that where there is a positive diagnostic anaesthetic injection, tenotomy of pectoralis minor can be performed with some success [36],[37]. We are convinced that tenotomy in this case constitutes denervation of the "biceps box" and it could lead to the development of new and more conservative approaches to treating the LHBT when it is not visibly the origin of shoulder pain.

CONCLUSION

The "biceps box" concept presents the environment of the LHBT as a functional unit made up of interconnected stabilising structures. Subacromial impingement, biceps tendinopathy, and anterosuperior impingement due to involvement of the biceps pulley are all known and well understood causes of anterior shoulder pain. Yet when anterior shoulder pain cannot be attributed to one of these causes, there is no consensus over the treatment strategy and the LHBT may be wrongly and probably unfairly deemed to be the cause. We believe that the "biceps box” model opens the way for new diagnostic and therapeutic approaches, whether consisting of injection into the lateral pectoral nerve, physiotherapy for dynamic humeral centring.

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