

## ■ UPPER LIMB

# Ultrasound evaluation of the distal migration of the long head of biceps tendon following tenotomy in patients undergoing arthroscopic repair of tears of the rotator cuff

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This study evaluates the position of the long head of biceps tendon using ultrasound following simple tenotomy, in patients with arthroscopically repaired rotator cuff tears.

In total, 52 patients with a mean age of 60.7 years (45 to 75) underwent arthroscopic repair of the rotator cuff and simple tenotomy of the long head of biceps tendon. At two years post-operatively, ultrasound revealed that the tendon was inside the bicipital groove in 43 patients (82.7%) and outside in nine (17.3%); in six of these it was lying just outside the groove and in the remaining three (5.8%) it was in a remote position with a positive Popeye Sign. A dynamic ultrasound scan revealed that the tenotomised tendons had adhered to the surrounding tissues (autotenodesis). The initial condition of the tendon influenced its final position ( $p < 0.0005$ ). The presence of a Popeye sign was statistically influenced by the pre-operative co-existence of supraspinatus and subscapularis tears ( $p < 0.0001$ ).

It appears that the natural history of the tenotomised long head of biceps tendon is to tenodese itself inside or just outside the bicipital groove, while its pre-operative condition and coexistent subscapularis tears play a significant role in the occurrence of a Popeye sign.

Lesions of the long head of biceps tendon (LHBT) are commonly associated with full-thickness rotator cuff tears, and contribute to anterior shoulder pain and limitation of forward flexion.<sup>1,2</sup> The lesions may vary in degree from tendinitis and delamination to subluxation or dislocation over the medial rim of the bicipital groove, and even to entrapment within the shoulder due to a hypertrophy-hourglass deformity of the tendon.<sup>3-6</sup>

In 1990, Walch, Patte and Boileau<sup>7</sup> observed the beneficial effect of spontaneous rupture of the LHBT and proposed simple arthroscopic tenotomy as treatment for patients with irreparable rotator cuff tears. The LHBT is innervated by a rich network of sensory sympathetic fibres that are a major contributor to anterior shoulder pain.<sup>8</sup> Arthroscopic tenotomy of an abnormal LHBT in patients with concomitant reparable rotator cuff tears is a technically simple, well-tolerated procedure that results in significant relief from pain and does not affect post-operative rehabilitation.<sup>9,10</sup> However, it may result in a cosmetic defect, known as a Popeye sign,<sup>11</sup> in between 3% to 70%, as well as fatigue or cramping pain, or even loss of strength of supination of the forearm,<sup>2,10,12</sup> possibly leading to a worse functional outcome.

As a result, whether a simple tenotomy or tenodesis should be used for the treatment of LHBT lesions remains controversial; there is a

wide variation in reported outcomes with no clear-cut advantage of either method.<sup>2,13-16</sup>

However, the reasons why simple tenotomy may result in such a broad spectrum of outcomes and complications have not been established and the natural history of the tenotomised LHBT has not been adequately investigated.

The primary aim of this study was to evaluate with dynamic ultrasound (US) the condition and position of the LHBT following simple tenotomy at a minimum of two years post-operatively. The secondary aims were to correlate the pre-operative pathology of the rotator cuff and biceps tendon with the position of the LHBT following tenotomy and to detect factors that affected its spontaneous tenodesis.

## Patients and Methods

Between January 2007 and April 2008 a total of 72 consecutive patients (72 shoulders) underwent arthroscopic rotator cuff repair. In 57 patients, after initial arthroscopic evaluation of the shoulder, we performed a simple tenotomy of the LHBT just before the repair of the rotator cuff. Of these patients, 54 agreed to participate in the study and to undergo all necessary future clinical and imaging. Two were lost to follow-up leaving 52 patients in the final study group. At the time of operation, their mean age was 60.7 years (45 to 75) with

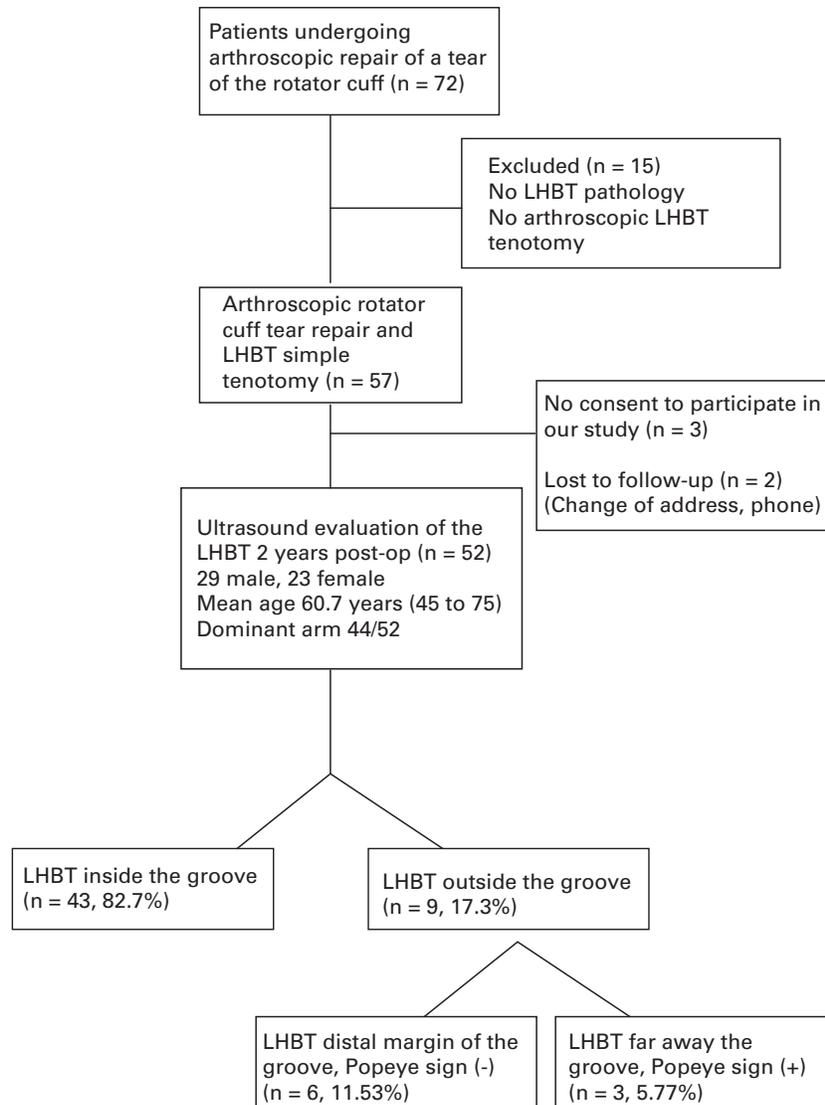


Fig. 1

Study flow diagram of patients who underwent simple tenotomy of the long head of biceps tendon (LHBT) and rotator cuff repair.

29 male and 23 female patients. The dominant arm was affected in 44 patients (84.6%) and 21 (40.4%) were employed; only six were treated as a result of work-related trauma (Fig. 1).

The characteristics of the rotator cuff tear and the condition of the LHBT were determined by pre-operative MRI and direct arthroscopic evaluation. In all patients reparable rotator cuff tears were detected. Using the Cofield classification,<sup>17</sup> the tear was judged to be small (avulsion of supraspinatus) in 16 shoulders (30.8%), medium (< 3 cm) in five (9.6%), large (3 to 5 cm) in 25 (48.1%), and massive (> 5 cm) in six (11.5%). The subscapularis tendon was completely torn in two patients with a reparable massive rotator cuff tear and partially torn, at its superior margin, in four patients with a co-existing large supraspinatus tear.

All patients had a lesion of the LHBT. In 14 patients (26.9%) it was severely inflamed with tendinitis, in eight (15.4%) it was delaminated, in 13 (25%) it showed moderate hypertrophy, and in nine (17.3%) there was an hour-glass deformity. Finally, in eight patients (15.4%) the LHBT was either subluxed or dislocated over the medial rim of the bicipital groove.

All procedures were performed by or under the supervision of the same two surgeons (DK, PP), under general anaesthesia and with the patient in the beach chair position. A diagnostic arthroscopy of the glenohumeral joint and the subacromial space was followed by simple tenotomy of the LHBT when pathology was found (all cases in this series); acromioplasty, when required, and rotator cuff repair, were undertaken. Tenotomy involved division of the LHBT at its

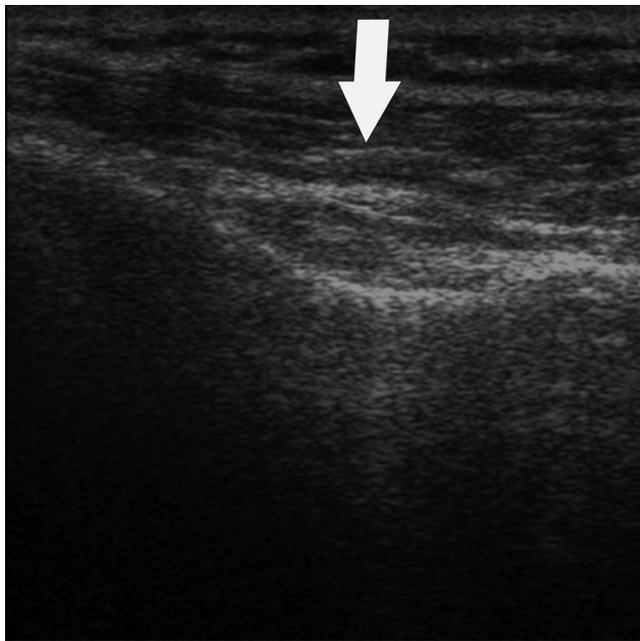


Fig. 2

Longitudinal ultrasound scan along the course of the long head of biceps tendon. It is shown inside the bicipital groove (white arrow).

proximal insertion at the supraglenoid tubercle; this allowed it to retract away from the joint into the bicipital groove. In cases of hourglass deformity the LHBT did not retract as a result of the enlargement and approximately 1 cm to 2 cm of the LHBT was excised.

Post-operatively all shoulders were protected in a broad arm sling for six weeks, while light pendulum exercises began as soon as pain allowed. Passive exercises, including forward flexion and external rotation, were initiated under the guidance of a department physiotherapist four weeks later. Active-assisted movement was permitted after the sixth post-operative week and hydrotherapy was encouraged at the same time. Return to high-demand daily activities was allowed six months post-operatively.

In all patients an ultrasound examination was performed at least two years post-operatively, by the same experienced examiner (AF), using a high-resolution linear-array transducer with variable high frequency (8 MHz to 13 MHz) (Siemens Antares, Erlangen, Germany). The evaluation was performed according to a standard protocol using a dynamic scan in all cases.<sup>18</sup> The LHBT and the repaired rotator cuff tendons were examined in the transverse and longitudinal planes with additional coronal views when necessary. The criteria used to diagnose the position of the LHBT were: a) visualisation of the LHBT stable inside the bicipital groove in all planes during dynamic scan, suggesting natural tenodesis, and b) a hypoechoic or anechoic cleft extending through the entire length of the groove.

The study had ethical approval and all patients gave informed consent.

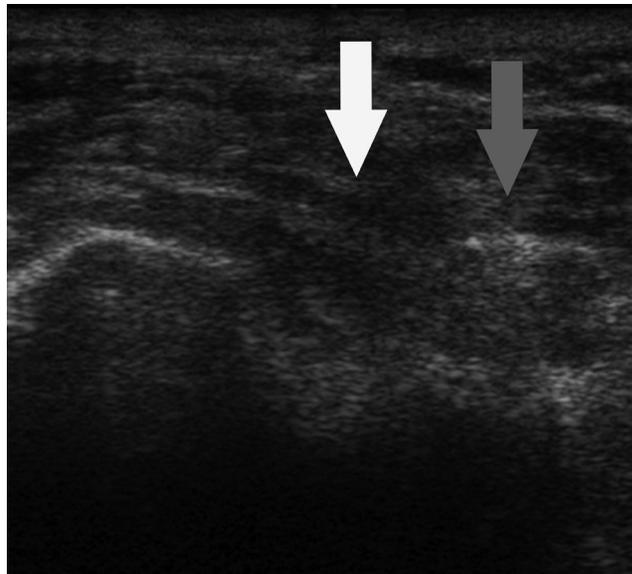


Fig. 3

Longitudinal ultrasound scan along the course of the long head of biceps tendon. Its distal migration (grey arrow) and an empty bicipital groove (white arrow) are indicated.

**Statistical analysis.** This was performed using the SPSS v19.0 (SPSS Inc., Chicago, Illinois). The chi-squared and analysis of variance (ANOVA) tests were used to correlate the pre- and post-operative position of the LHBT in the bicipital groove, age and the pre- and post-operative appearances of the rotator cuff. Significance was set at  $p < 0.05$ .

## Results

At two years post-operatively, the ultrasound revealed that the LHBT was still in the bicipital groove in 43 patients (82.7%; Fig. 2) and outside the groove in the remaining nine (17.3%). It is important to note that it was lying just outside and near the distal margin of the groove in six of these nine patients (11.5%; Fig. 3). In the remaining three (5.8%), it was far away from the groove, and only these patients had a positive Popeye sign.

On the dynamic scan, the LHBT was stable in all planes (transverse, longitudinal and coronal) and in all positions of the arm, presumably because a natural tenodesis had occurred to maintain its stability.

In an effort to investigate the circumstances that predispose to natural tenodesis inside or outside the bicipital groove we tried to correlate the pre- and post-operative positions of the LHBT, the age of the patient, the size of the rotator cuff tear and the presence of a further tear at final follow-up.

Using the chi-squared test we observed that the condition of the LHBT at the initial procedure was significantly related to its final position ( $p < 0.0005$ ) (Fig. 4). In all patients with hypertrophy, an hourglass deformity or inflammation of the LHBT, natural tenodesis occurred inside the groove. Only in one patient with delamination of

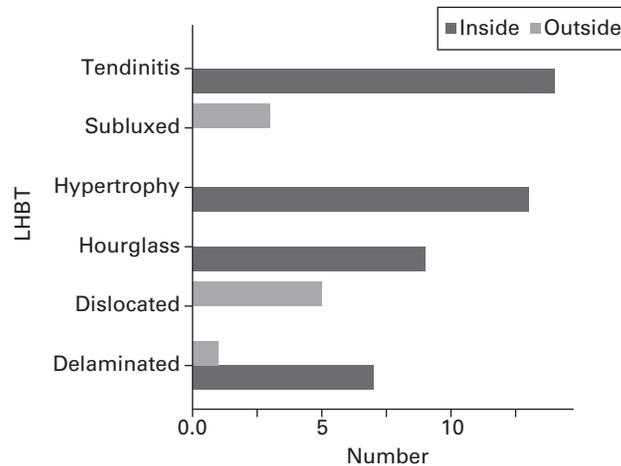


Fig. 4

Histogram showing the effect of pre-operative condition of the long head of biceps tendon (LHBT) on its final position. It was outside the groove when it was subluxed or dislocated at initial arthroscopy ( $p < 0.0005$ ).

**Table I.** The initial long head of the biceps tendon condition is dependent on the pre-operative rotator cuff tear size ( $p < 0.0001$ )

Size of rotator cuff tear	Long head of biceps tendon						Total
	Delaminated	Dislocated	Hourglass	Hypertrophy	Subluxed	Tendinitis	
Small	4	0	0	0	0	12	16
Medium	3	0	0	0	0	2	5
Large	1	3	7	11	3	0	25
Massive	0	2	2	2	0	0	5
Total	8	5	9	13	3	14	52

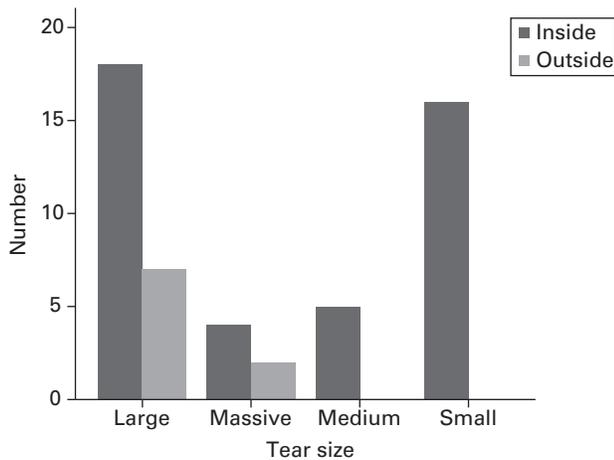


Fig. 5

Histogram showing the effect of size of the rotator cuff on final position of the long head of biceps tendon (LHBT). Large or massive rotator cuff tears predispose to distal migration of the LHBT outside the bicipital groove after simple tenotomy ( $p < 0.001$ ).

the LHBT, did the final ultrasound reveal that it was outside the groove. However, this patient had a tear of the subscapularis tendon at the initial arthroscopy. Furthermore, in all eight cases where the LHBT was found at arthroscopy

to be subluxed or dislocated, ultrasound examination at final follow-up revealed an anechoic cleft extending through the entire length of the bicipital groove.

The initial condition of the LHBT (Table I) and its final position were also dependent on the size of the rotator cuff tear (Fig. 5), as well as on the presence of a concomitant subscapularis tear. More specifically, subluxed or dislocated LHBTs were more frequently present with massive or large rotator cuff tears, predisposing to final tenodesis outside the groove ( $p < 0.001$ , chi-squared test). In all cases where the subscapularis tendon had even a partial tear, the LHBT was not in the groove at final follow-up ( $p < 0.0001$ , chi-squared test) (Fig. 6). Three of these patients had a positive Popeye sign. Additionally, in patients with a further tear of the rotator cuff the LHBT was more frequently found outside the groove ( $p < 0.0001$ , chi-squared test) (Fig. 7).

It is also of note that natural tenodesis inside the groove was observed in younger patients. The mean age of the patients with the LHBT inside the groove was 60.9 (45 to 73) and of those with it outside the groove was 65.16 years (52 to 75), although this difference was not statistically significant ( $p = 0.319$ , ANOVA). Finally, it is important to note that the LHBT was adherent outside the groove in eight male patients (five labourers) and only in one female patient ( $p = 0.022$ , chi-squared test).

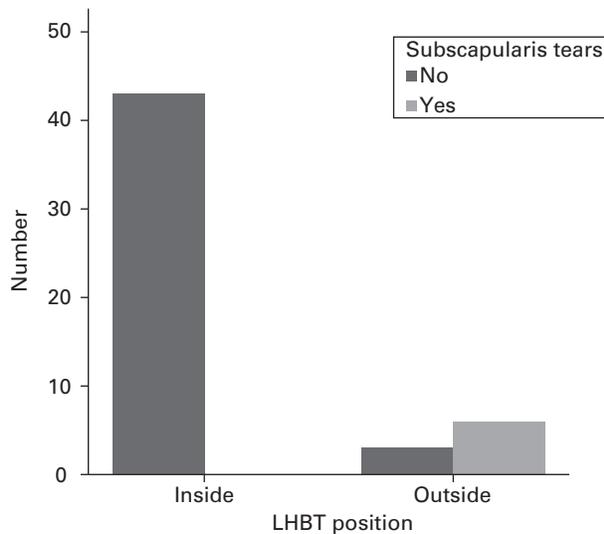


Fig. 6

Histogram showing the effect of concomitant subscapularis tear on the final position of the long head of biceps tendon (LHBT). Subscapularis tears predispose to final LHBT tenodesis outside the bicipital groove ( $p < 0.0001$ ).

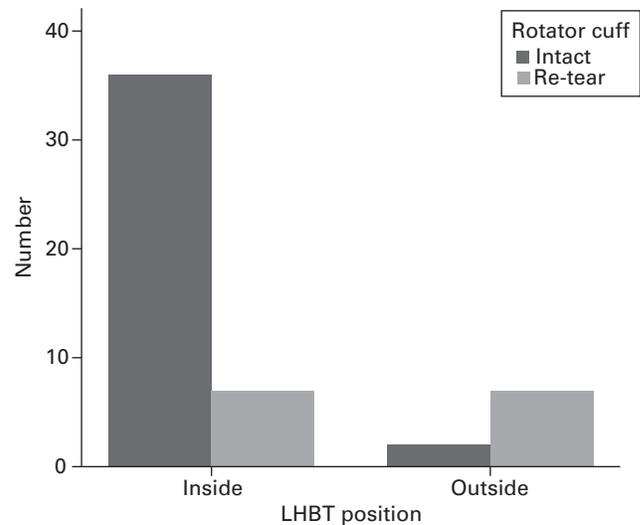


Fig. 7

Histogram showing the relationship between final position of the long head of biceps tendon and the rate of rotator cuff re-tear ( $p < 0.0001$ ).

## Discussion

Disorders of the LHBT have been extensively described,<sup>19,20</sup> and are a frequent cause of symptoms, especially in patients with concomitant rotator cuff tears.<sup>1-5</sup> Nevertheless, the treatment of these disorders with simple tenotomy or tenodesis<sup>9,15,16,21</sup> or with tenodesis with or without tenotomy<sup>22</sup> remains controversial. The post-operative position and condition of the LHBT following simple tenotomy have not been adequately studied, nor have specific factors affecting the achievement of a 'natural tenodesis' been identified.

In an effort to analyse the factors that lead to complications after simple LHBT tenotomy, Lim et al<sup>23</sup> found that the development of a Popeye deformity was not significantly influenced by the age, body mass index or arm dominance of the patient and the only predisposing factor was male gender. Previous studies have correlated complications and functional outcome with demographic factors only, rather than anatomical predisposing factors.<sup>9,10,12,15</sup> We also found that in male labourers an 'empty' bicipital groove and a positive Popeye sign occurred more often. In addition to the demographic factors, the presence of a Popeye sign was affected by the pre-operative condition of the LHBT and the condition of the rotator cuff. Our study revealed that the groove was empty in some patients with large or massive pre-operative rotator cuff tears and more frequently when there was a coexistent tear in the subscapularis tendon, although none were empty in small and medium tears (Fig. 5). In these patients, at arthroscopy, the LHBT was almost always found dislocated or subluxated. Our results suggest that subscapularis tears, even partial ones, as well as post-operative re-tears of the cuff increase

the possibility of a Popeye sign. It appears that a subscapularis tear and/or a rotator cuff re-tear may contribute to the enlargement of the bicipital groove, thus reducing the stability of the tenotomised LHBT and consequently its propensity to adhere inside the groove.

Osabahr et al,<sup>15</sup> in a study comparing tenotomy and tenodesis, reported no significant differences between the two procedures other than the presence of a Popeye sign in up to 30% of patients (24 of 80) undergoing a tenotomy. However, despite the cosmetic deformity no significant functional impairment was observed. They suggested that a spontaneous tenodesis inside or outside the groove preserved the length of the biceps muscle as well as its function in some cases.<sup>15</sup> Our study corroborates these findings, demonstrating that the phenomenon of natural tenodesis occurs and explains the better functional results in patients where the tendon was lying inside the bicipital groove.

Ahmad et al<sup>24</sup> observed in cadavers that diseased LHBTs have a larger cross-sectional area and a higher mean load to failure compared with healthy tendons. Moreover, they observed a relative stenosis of the bicipital groove in shoulders with diseased tendons. These observations may explain the tendency for tenodesis to happen inside the bicipital groove in patients with combined rotator cuff tears and LHBT pathology. Our study supports this hypothesis in the clinical setting. More specifically, we observed that natural tenodesis inside the groove definitely happens in patients with hypertrophy of the LHBT or an hourglass deformity (increased cross-sectional area). However, natural tenodesis inside the groove is less likely to occur in patients where the LHBT was initially dislocated or subluxed, or where there was a re-tear of the cuff post-operatively.

Although we recorded a prevalence of an empty bicipital groove of 17.3% following LHB tenotomy, a positive Popeye sign was recorded in only 5.8% of cases. Male gender, large or massive rotator cuff tears with concomitant subscapularis tendon pathology and pre-operative LHBT dislocation or subluxation are strongly correlated with a Popeye deformity, while hypertrophied LHBTs with increased cross-sectional area adhere inside the bicipital groove.

The fact that all procedures were carried out by the same surgeons, in the same clinical setting, in a relatively homogeneous study population, with a uniform technique and a common post-operative protocol, together with retrospective analysis of prospectively collected data constitute the strengths of this study. Additionally all post-operative ultrasound investigations were carried out by the same experienced radiologist. The limitations include the relatively small study population, the different pre- and post-operative imaging modalities and the absence of supination-pronation forearm strength tests.

It is our practice to inform patients about the two surgical options and the possible prevalence of cosmetic deformities, muscle cramps or fatigue after tenotomy or local pain after tenodesis. Additionally, patients undergoing tenodesis are informed about the strict rehabilitation program, involving restriction of movement of the elbow and forearm for six weeks after surgery.<sup>25</sup> In the light of our findings, when considering tenotomy *versus* tenodesis for the treatment of LHBT lesions, we adopt guidelines suggested in previous studies,<sup>2,8-10,12,22,23</sup> but we also consider the intra-operative condition of the LHBT and the type of rotator cuff tear, especially when there is a coexistent subscapularis tear.

In conclusion, it appears that in most patients the natural history of the tenotomised LHBT is to tenodesise itself inside or just outside the groove. It is probably through this phenomenon that both the length and function of the tendon are satisfactorily preserved, and consequently a Popeye sign or functional impairment is rare following simple tenotomy. Moreover, specific factors affecting the natural tenodesis phenomenon, have been recognised. We therefore propose a shift towards using tenotomy, when managing LHBT pathology, even in professionally active middle-aged patients, especially in the absence of the predisposing factors for an empty bicipital groove.

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