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Diagnostic value of the hourglass biceps test for the detection of intra-articular long head of the biceps hypertrophy

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Background: Shoulder surgeons performing tenodesis note a great variability in morphology of the proximal biceps. The hourglass biceps test measures the integrity of the intra-articular biceps tendon. The hourglass maneuver (HM) is positive when there is a passive flexion deficit compared to the contralateral shoulder in a relaxed patient in the supine position.
Hypothesis: Preoperative HM is correlated with an increased width of the biceps portion resected during tenodesis.
Methods: This prospective study evaluated all patients (N = 58) who underwent biceps tenodesis between January and September 2019. Two groups of patients were compared: group 1 (n = 20) had a positive HM and group 2 had a negative HM (n = 38). The smallest (s) and largest (L) width of the tendon were measured intraoperatively, and the L/s ratio was calculated. The HM was then evaluated as a diagnostic test by creating a contingency table and determining the sensitivity and specificity of the test for different L/s ratios. A receiver operating characteristic curve was created and the area under the curve (AUC) was calculated.
Results: A nonsignificant difference was found between the mean largest biceps width in group 1 compared to group 2 (11.65 mm [range: 5-21] vs. 9.71 mm [range: 6-20], respectively; $P < .05$). The AUC was 0.81; the sensitivity was 68.9% and specificity, 80.8%.
Conclusion: Preoperative positivity of the HM is linked to the increased width of the biceps portion resected during tenodesis. The hourglass biceps test should be predictive of intraoperative hourglass biceps according to our definition.

An hourglass biceps (HB), first described by Boileau et al in 2004,[5] reflects a hypertrophic pathology of the intra-articular biceps tendon. If the diameter of the long head of the biceps (LHB) is greater than that of the bicipital groove, intra-articular blockage of the tendon may occur as a result of mechanical conflict during sliding of the biceps. This is visible during dynamic maneuvers.

Although this theory is sometimes debated, it is indisputable that LHB morphology is heterogeneous and its width is variable.[2,9] Anatomically, the LHB has a horizontal intra-articular and vertical extra-articular portion, making it difficult to evaluate by sectional imaging.[6] Some studies have shown promising results by diagnosing HB using dynamic ultrasonography.[19] However, Doppler ultrasonography[21] or magnetic resonance arthrography[16,17] has been shown to be less accurate at detecting proximal biceps pathologies. To date, no study has provided evidence of a sensitive and specific imaging examination for the diagnosis of HB.

Clinically, the hourglass maneuver (HM) described by Boileau et al can indicate this pathology. It is positive when there is a passive shoulder elevation deficit compared with the contralateral

The study was approved by the local Institutional Review Board (IRB number: OS-RGDS-2019-09-006-COURAGE-O). All patients gave their informed consent to participate in the study.

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Figure 1 Positive hourglass maneuver for the right shoulder.

side on a relaxed patient in the supine position (Fig. 1).[5] However, the correlation between preoperative HM and intraoperative dimensions of the biceps after externalization is variable (Figs. 2 and 3), and many false positives and false negatives occur with this test. This maneuver has never been studied as a diagnostic test to predict the existence of an HB. A biceps hypertrophy can lead to difficulties during arthroscopic techniques of subpectoral tenodesis; on the other hand, it could suggest a successful self-blocking biceps tenotomy. Preoperative planning of biceps hyeprtrophy could allow anticipating biceps management.

Our hypothesis was that patients with a preoperative positive HM would have a significant increase in size of the intra-articular portion of the biceps when compared to patients with a negative preoperative HM. The aim of the study was to investigate the diagnostic value of preoperative HM for predicting an HB.

Material and methods

Study population

This prospective study included all patients undergoing shoulder arthroscopy with tenodesis of the LHB between January and August 2019. All patients were diagnosed with LHB tendinopathy with or without rotator cuff tear. At least 1 clinical sign of bicipital symptoms was reported during clinical examination (palpation of the bicipital groove, O'Brien maneuver, and Speed test).

Magnetic resonance arthrography was performed to look for LHB inflammation or LHB subluxation. Tenodesis was offered after failure of 6 months of conservative treatment, including physiotherapy, reduction of physical activities, nonsteroidal anti-inflammatory drugs, and intra-articular steroid injections. Exclusion criteria included the main associated factors that could induce loss of passive shoulder antepulsion[14,15]: radiographic signs of glenohumeral osteoarthritis, a decrease in passive external rotation compared with the contralateral side, and previous biceps surgery on the same side.

Two groups of patients were compared: group 1 had a positive HM and group 2 had a negative HM.

Preoperative examination

During the preoperative consultation, patients were examined by a senior surgeon (O.C.) and a junior surgeon (Q.B. or A.G.H.). Active range of motion (active shoulder elevation, abduction, external rotation) was recorded as well as the results of clinical tests (O'Brien maneuver, Speed test, palpation of the groove). At the end of the clinical examination, the HM was performed in the supine position. The existence of a passive anterior elevation deficit was noted. If this deficit existed, it was also measured using a goniometer. A passive anterior elevation of 10° was considered a positive response to the HM as reported by Boileau et al.[5]

Surgical procedure

Patients underwent surgery in the beach chair position. A posterior port was created at the soft spot allowing complete inspection of the glenohumeral joint and the intra-articular part of the biceps. A single focal biceps tenotomy was performed at the most proximal supra-glenoid insertion possible. An endoscopic approach (Fig. 4) was then used on both sides of the bicipital groove laterally to the insertion of the pectoralis major. After locating and opening the bicipital groove, the biceps tendon was exteriorized using the medial instrument approach.[4,22]

Using a graduated ruler, the tendon of the biceps was cut 3 cm from its proximal insertion (Fig. 5). The largest (L) and smallest (s) width of the resected part of the biceps tendon were then measured.

An HB was defined as a biceps tendon with a macroscopically visible, inconsistent template once externalized. The largest (L) and smallest (s) widths of the resected tendon were measured and the L/s ratio determined for each biceps. Three clinical thresholds were then defined: the first threshold was set at an L/s ratio of 1.1:1, corresponding to a resected intra-articular portion whose largest

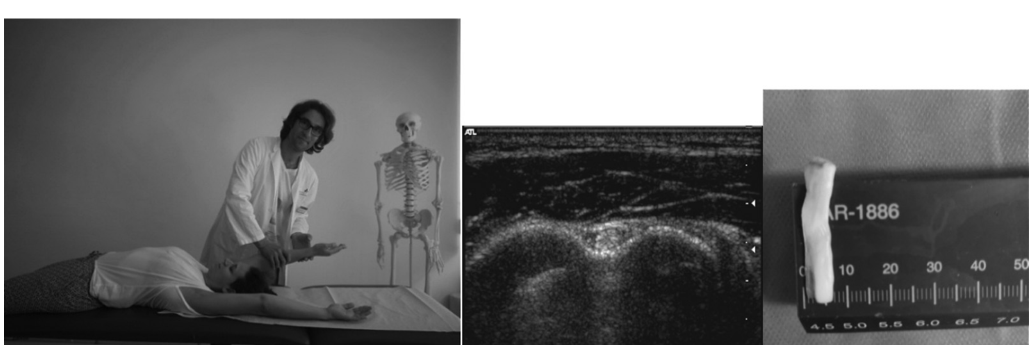

Figure 2 Patient with a positive hourglass maneuver on the right side, a thin biceps with a homogenous morphology and an ultrasounograph without hypertrophy.

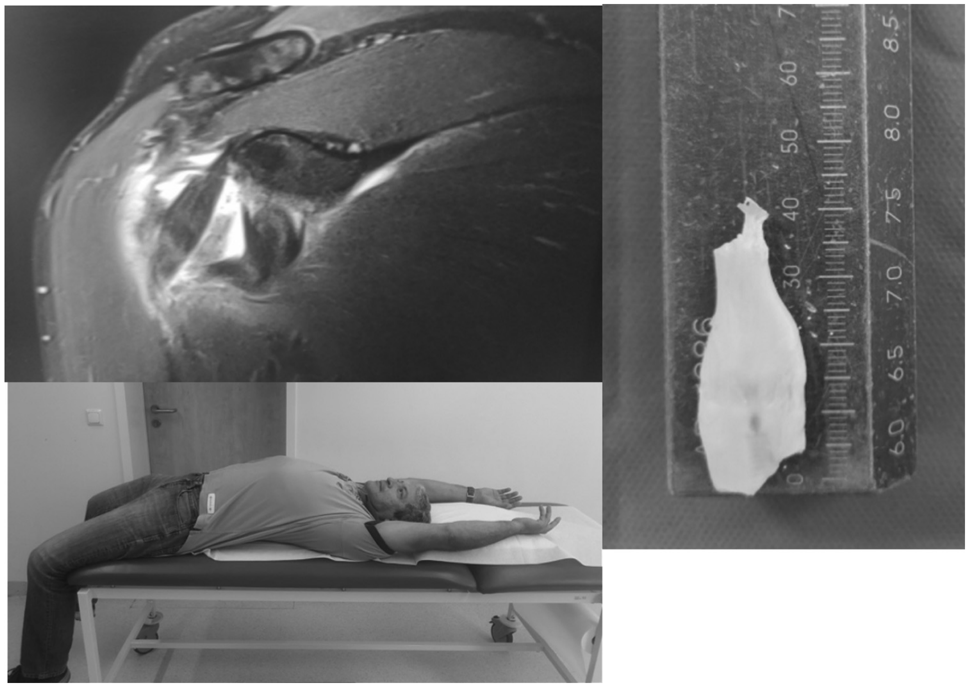

Figure 3 Patient with a negative hourglass maneuver.

width (L) was 110% greater than the smallest (s) width; the second and third thresholds were set at 1.25:1 and 1.5:1, respectively.

Note that in this series, 9 patients had an isolated biceps tenodesis, 12 had an associated acromioplasty, 34 had an acromioplasty associated with a rotator cuff repair, and 3 had an associated labral repair.

Statistical tests

Quantitative descriptive data are described as the number of observed (and missing, if any) values, mean, standard deviation (SD), median, first and third quartiles, and minimum and maximum values. Qualitative descriptive data are described as the number of observed (and missing, if any) values and the number and percentage of patients per class.

A comparison of the L/s ratio between group 1 (with a positive HM) and group 2 (with a negative HM) was performed using the nonparametric Wilcoxon test (because effective <30 in one of the groups). This comparison was adjusted for age (in classes <50, 50-60, >60 years), sex, and BMI (in classes 18-25, 25-30, >30 years), which were assumed to have an impact on the L/s ratio in a linear model. A comparison of the percentage of patients in the 2 groups with a threshold L/s ratio of >1.1:1, >1.25:1, and >1.5:1 was performed using the chi-square test. This comparison was adjusted for the same factors (sex, age, and BMI) as above using univariable and multivariable logistic regression.

A receiver operating characteristic curve was then created and the area under the curve (AUC) was determined. Finally, a contingency table was created to determine the specificity and sensitivity of the HM.

All calculations were performed using SAS for Windows (v 9.4; SAS Institute Inc., Cary, NC, USA), with the level of statistical significance set at $P < .05$.

Results

Study population

A total of 58 patients were included (30 male and 28 female). The mean age was 58 years (min-max: 15-76), and the mean BMI,

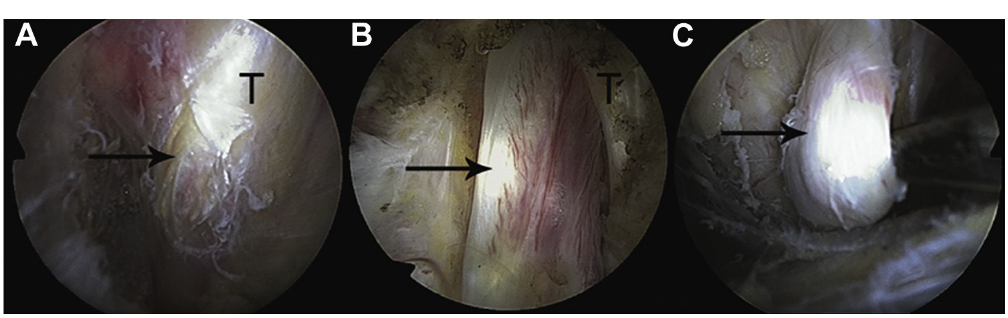

Figure 4 **(A-C)** Endoscopic tenodesis procedure.

Figure 5 Cutting of the intra-articular portion of the resected biceps.

27 (min-max: 18-39). Sixty percent of the patients were affected on the right side, and the side of the dominant hand was affected in 74% of patients. One-third of patients (n = 19; 32%) were manual workers or practiced an overhead throwing sport. The characteristics of the study population are summarized in Table I.

Comparison of HM-positive and HM-negative groups

The measurements of the different portions of the biceps are shown in Table II. In the HM-positive group (n = 20), the means was 8.35 mm (min-max: 5-15) and the mean L, 11.65 mm (min-max: 5-21). The mean L/s ratio was 1.37:1 (min-max: 1-2.37:1). In the HM-negative group (n = 38), the mean s was 8.08 mm (min-max: 5-14) and the mean L, 9.71 mm (min-max: 6-20). The mean L/s ratio was 1.2:1 (min-max: 1-1.7:1).

Without adjustment, the difference in L/s ratio between patients with a positive HM vs. patients with a negative HM was not statistically significant (P = .08). Patients with a positive HM had a trend toward a higher mean (±SD) L/s ratio (1.37 ± 0.35) compared with patients with a negative HM (1.21 ± 0.21). When adjusted for age, sex, and BMI, the P value was .07.

Significant results were observed only for the L/s ratio threshold of 1.25:1, that is, a resected intra-articular portion with L 125% greater than s. The percentage of patients above this threshold was greater in group 1 than in group 2 (P = .04). Using the threshold of 1.25:1, the adjusted odds ratio for the HM group was 4.8 (95% confidence interval 1.05, 22.30).

The receiver operating characteristic curves and AUCs for the 3 thresholds and adjusted according to quantitative variables (age, sex, and BMI) are shown in Table III. The adjusted AUCs were acceptable (ranging from 0.7-0.8) or excellent (ie, from 0.8-0.9).[11] The highest AUC value was 0.81 for an HB defined by the L/s ratio threshold of 1.25:1 (95% confidence interval 0.70, 0.92). The receiver operating characteristic curve for this threshold is shown in Fig. 6.

A contingency table was constructed according to the model true/false positives and true/false negatives, with the assumption that a positive preoperative HM should correlate with an intraoperative biceps tendon with an L/s ratio of >1.25:1 (Table IV). The

Table I
Characteristics of the study population

	Total (N = 58)
Sex, n (%)	
Male	30 (51.7)
Female	28 (48.3)
Age, yr	
Mean (SD)	56 (13)
Median (IQR)	58 (51, 65)
Minimum-maximum	15-76
Age, n (%)	
<50 yr	14 (24.1)
50-60 yr	18 (31.0)
>60 yr	26 (44.8)
BMI	
Mean (SD)	27 (4)
Median (IQR)	27 (25, 29)
Minimum-maximum	18-39
BMI category, n (%)	
18-25	14 (24.1)
25-30	31 (53.4)
>30	13 (22.4)
Side operated on, n (%)	
Right	35 (60.3)
Left	23 (39.7)
Dominant hand, n (%)	
Right	43 (74.1)
Left	15 (25.9)
Manual worker, n (%)	
Yes	19 (32.8)
No	39 (67.2)
Preoperative shoulder range of motion of the operated shoulder	
Active flexion	
180°	22 (37.9)
145°-180°	15 (25.8)
90°-145°	18 (31.0)
45°-85°	3 (5.1)
<45°	0 (0.0)
Active abduction	
180°	6 (10.3)
145°-180°	14 (24.1)
90°-145°	30 (51.7)
<90°	8 (13.8)
Active external rotation	
>85°	2 (3.4)
45-85°	50 (86.2)
<45°	6 (10.3)

SD, standard deviation; *IQR*, interquartile range.

positive predictive value of this model was 74%, the sensitivity was 68.9%, and the specificity was 80.8%.

Discussion

Our study showed a nonsignificant difference in the largest width of the intra-articular portion of the biceps (in millimeters) between patients with or without a positive preoperative HM.

The mean smallest width of the freshly externalized portion was 8 mm (min-max: 5-15), which is slightly larger than that in other studies (min-max: 5-7 mm).[2,8,13] This difference can be explained by the different conditions used to measure the biceps in different studies. Some studies have measured the biceps on cadavers whose muscles and tendons can be retracted.[13] In comparison, we measured the biceps in situ, a few minutes after tenotomy and after shoulder arthroscopy, which could inflate the soft tissues. We measured the smallest and largest widths at the same time and under the same conditions and expressed them as the L/s ratio. It should be pointed out that even a small variation in measurement of the smallest width will change the predictive value of the HM.

Table II
Largest (L) and smallest (s) width of the intra-articular tendon and L/s ratio in the study population

	Preoperative HM positive (n = 20)	Preoperative HM negative (n = 38)	Total (N = 58)	*P* value not adjusted	*P* value adjusted
Largest intra-articular width (L), mm					
Mean (SD)	11.65 (4.86)	9.71 (2.82)	10.38 (3.73)		
Median (IQR)	11 (8, 15)	9 (8, 11)	10 (8, 12)		
Minimum-maximum	5-21	6-20	5-21		
Smallest intra-articular width (s), mm					
Mean (SD)	8.35 (2.64)	8.08 (2.03)	8.17 (2.24)		
Median (IQR)	8 (7, 9)	8 (6, 9)	8 (7, 9)		
Minimum-maximum	5-15	5-14	5-15		
L/s ratio				.0796	.0721
Mean (SD)	1.373 (0.349)	1.211 (0.213)	1.267 (0.276)		
Median (IQR)	1.310 (1.056, 1.590)	1.155 (1.000, 1.333)	1.200 (1.000, 1.444)		
Minimum-maximum	1.000-2.375	1.000-1.667	1.000-2.375		
Patients with L/s ratio ≥1.1:1, n (%)				.3611	.5132
Yes	15 (75.0)	24 (63.2)	39 (67.2)		
No	5 (25.0)	14 (36.8)	19 (32.8)		
Patients with L/s ratio ≥1.25:1, n (%)				.0410	.0431
Yes	13 (65.0)	14 (36.8)	27 (46.6)		
No	7 (35.0)	24 (63.2)	31 (53.4)		
Patients with L/s ratio ≥1.5:1, n (%)				.0954	.1036
Yes	7 (35.0)	6 (15.8)	13 (22.4)		
No	13 (65.0)	32 (84.2)	45 (77.6)		

Table III
Area under the curve (AUC) for each of the L/s ratio thresholds after adjusted and nonadjusted logistic regression

Threshold tested	Model tested	AUC	AUC difference	Standard error	95% CI	*P* value
L/s ratio ≥1.1	Adjusted	0.7996		0.0573	0.687, 0.912	
	Diagonal	0.5000		0	0.5, 0.5	
	Adjusted − Diagonal		0.2996	0.0573	0.187, 0.412	<.0001
	Unadjusted	0.5607		0.0652	0.433, 0.689	
	Adjusted − Unadjusted		0.2389	0.0803	0.082, 0.396	.0029
L/s ratio ≥1.25	Adjusted	0.8130		0.0550	0.705, 0.921	
	Diagonal	0.5000		0	0.5, 0.5	
	Adjusted − Diagonal		0.3130	0.0550	0.205, 0.421	<.0001
	Unadjusted	0.6278		0.0621	0.506, 0.75	
	Adjusted − Unadjusted		0.1852	0.0681	0.052, 0.319	.0066
L/s ratio ≥1.5	Adjusted	0.7128		0.0814	0.553, 0.872	
	Diagonal	0.5000		0	0.5, 0.5	
	Adjusted − Diagonal		0.2128	0.0814	0.053, 0.372	.0089
	Unadjusted	0.6248		0.0797	0.469, 0.781	
	Adjusted − Unadjusted		0.0880	0.0794	−0.068, 0.244	.2674

CI, confidence interval.

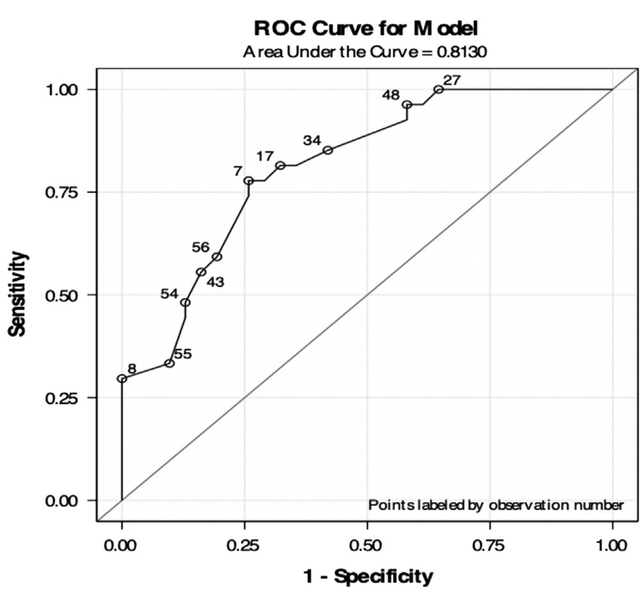

Figure 6 Receiver operating characteristic curve. Hourglass biceps with L/s ratio threshold of 1.25:1. Model adjusted according to the hourglass maneuver, age (in classes), sex and BMI (in classes).

There are several explanations for the lack of statistical significance in our study. First, a power analysis was not performed, and our statistical analysis may have been underpowered; hence, statistical groups of noncomparable sizes forced us to adjust less reliable statistical tests. In addition, an increased width of the intra-articular portion of the biceps is not the only factor explaining blockages in the groove. In some patients, with no major variations in tendon size, intra-tendinous delaminations have been observed with movable fringes (Fig. 7) that could also participate in the passive elevation deficit.

Table IV
Classification, sensitivity, and specificity of the hourglass maneuver (contingency table)

RATLLH2 L/s ratio ≥ 1.25:1)	Positive HM		
	Yes, n (%)	No, n (%)	Total, n (%)
Yes	22 (37.93)	5 (8.62)	27 (46.55)
No	10 (17.24)	21 (36.21)	31 (53.45)
Total	32 (55.17)	26 (44.83)	

RATLLH2, the ratio of L/s measurements in hypothesis number 2; *L*, largest intra-articular width; s, smallest intra-articular width; *HM*, hourglass maneuver.
Sensibility = 68.9% [22/(22+10)]. Specificity = 80.8% [21/(21+5)].

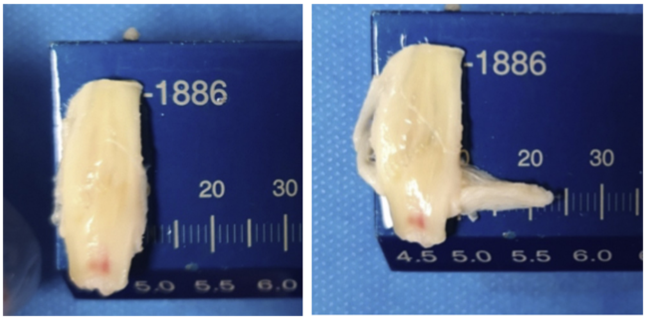

Figure 7 Cut long head of the biceps with a large, mobile fringe.

Future studies should measure the actual size of the bone groove by imaging and compare it to the different biceps widths measured intraoperatively. This could highlight any compression of the biceps in its groove and make screening by imaging difficult. Recent studies of the groove size by Rajan et al[20] estimated the average width to be 6.8 mm on the right and 7.7 mm on the left; thus, an HM also may be more likely with narrow bicipital grooves.

Regarding the use of the HM as a diagnostic test, an L/s threshold of 1.25:1 was more specific (81%) and sensitive (68%) in clinical practice than the other tests used in bicipital pathology. Gismervik et al[10] reported in their recent meta-analysis a sensitivity of 66% and a specificity of 36% for the O'Brien maneuver and a sensitivity of 20% and specificity of 88% for the Speed test.

We proposed 3 possible L/s ratios of 1.1:1, 1.25:1, and 1.50:1 for predicting a positive or negative HM. An L/s ratio of 1.1:1 was not large enough to detect a negative maneuver on clinical examination. The 1.25 ratio was more predictive and, thus, was retained for the rest of the study. The 1.50 ratio was also predictive, but the small number of patients with biceps with this morphology did not allow us to form any definitive conclusions. The choice of this ratio is arbitrary according to 3 hypotheses: low, high, and intermediate. The retained ratio of 1.25 thus means that in case of positivity, when the HM is positive, the enlarged width of the biceps corresponds to 125% of the physiological width of the biceps.

The originality of the study lies in its prospective nature and in the fact that no study has been published to date concerning an evaluation of the HM. Our findings may be of value to help plan the type of surgical procedure on the biceps. Tenodesis is being performed more frequently,[1] and there are several surgical techniques for tenotomy. An inside-out technique[4,12] externalizing the intra-articular portion of the biceps was used in this study and can be used on most biceps morphotypes (Fig. 8). Conversely, there are also all-inside[3,18] techniques using a forked arm interference screw (Fig. 9), allowing surgeons to tie the biceps using endoscopy, without having to externalize the biceps. In this technique, the presence of an hourglass biceps makes it difficult to “lower” the intra-articular portion out of the bicipital groove. Thus, it could be suggested that an inside-out technique is used in the event of a positive HM. A positive HM could also suggest the success of T-tenotomy[7] without the risk of a Popeye sign. Tenotomy or tenotomy/tenodesis of the latter would then give patients their original passive shoulder elevation only if a bipolar tenotomy is carried out and resection of the intra-articular part of the tendon is performed.[1]

Out study has several limitations. It was a monocentric study, and there was no calculation of the number of subjects required, which may have led to statistical bias overestimating our results. The large number of subjects in the “positive HM” arm challenges the objectivity of the evaluators, when this notion itself is debated by some shoulder surgeons. An explanation could be that the HM was performed at the end after having examined the biceps by 3 tests (palpation of the groove, O'Brien, Speed test). It may be that the large number of subjects with a positive HM is explained by an awareness of the maneuver after bicipital irritation.

Conclusion

There was no significant difference in the mean width of the biceps in patients undergoing tenotomy/tenodesis with a negative or positive preoperative HM. There was also a nonsignificant difference in the L/s ratio between the 2 groups. A positive HM during clinical examination was a predictor of an intra-articular portion of the biceps whose largest width was 125% greater than its smallest width (L/s ratio 1.25:1). Future investigations should include a multicenter study with a larger number of patients, intraoperative testing, and a negative HM after tenotomy or tenodesis.

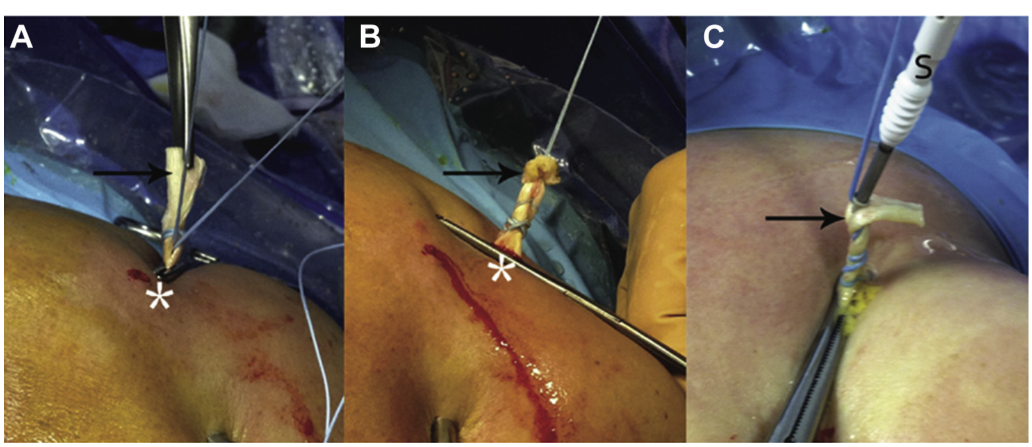

Figure 8 External view of a right shoulder. (**A** and **B**) The tendon (*arrow*) is clamped and reinforced using a straight-needle suture over 30 mm through the distal medial portal (*). (**C**) Its end is fed through the closed eyelet of the biocomposite screw (S) until the proximal end of the tendon reaches the eyelet.

Figure 9 "All inside" tenodesis technique using an interference screw on a fork (Arthrex, Naples, FL, USA).

Disclaimer

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