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ORIGINAL ARTICLE

Diagnosis of subscapularis tendon tears: Are available diagnostic tests pertinent for a positive diagnosis?

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KEYWORDS
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Summary
Hypothesis: Clinically, subscapularis tendon tears are suggested by the presence of increased passive external rotation compared to the opposite side, resisted internal rotation manoeuvres (Lift-Off test [LOT], Belly-Press test [BPT], Napoleon test and Bear-Hug test [BHT] and positive Internal Rotation Lag Sign and/or Belly-Off Signs). Associated bicipital involvement is frequent with subscapularis tendon tears, because it participates in the formation of the biceps pulley. The Palm-Up test (PUT) is used for the biceps, and the Jobe test for the supraspinatus.
Material and methods: In this multicenter study, we evaluated the positive diagnostic value of the clinical tests, LOT, BPT, BHT, PUT, and the Jobe test for subscapularis tears as well as

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their anatomical value. The relationships of the different parameters studied were compared statistically by analysis of variance (ANOVA). This prospective multicenter study was performed from January 2009 to February 2010 and included 208 cases of subscapularis tendon tears, isolated or associated with partial (Ellman 1, 2 or 3) or full thickness (SFA stage 1) supraspinatus tears.

Results: The severity of the subscapularis tear was quantified according to the SFA classification into four stages and according to the level of injury (the lower 1/3 and upper 2/3). The three tests LOT, BPT and BHT were correlated to the severity of observed tears ($P < 0.05$). The more deficient the test results were, the more severe the anatomical damage. The LOT is the test that cannot be performed most often (18%) but when it is positive, it is predictive of very severe tears. The BHT is the most sensitive of all tests (82%). The frequency of biceps involvement was correlated to the severity of subscapularis damage. There was no significant correlation between biceps involvement and subscapularis tests, or between supraspinatus involvement and subscapularis tests. There was no correlation between the Palm-Up test and subscapularis tears with associated supraspinatus involvement however, it was significantly correlated to biceps involvement ($P < 0.05$). The Jobe test was disappointing because it was often positive even for isolated subscapularis tears.

Conclusion: Even though all three tests were performed (LOT, BPT, BHT), 24% of the subscapularis tears were only diagnosed during surgery. The role of the Internal Rotation Lag Sign and Belly-Off Sign in improving the diagnosis of tears was not studied in this work.

Level of evidence: II.

Introduction

Clinically, subscapularis tears are suggested by the presence of increased external rotation of the arm, arm and elbow to the body (RE1) compared to the opposite side [1,2] and loss of strength in response to resistance. Gerber et al. [1], were the first to publish and popularize tests for the evaluation of subscapularis tears: the Lift-Off test (LOT), which was described in 1991, then the Belly-Press test (BPT) described in 1996, because certain patients were incapable of performing the LOT because of pain or limited joint range of motion [3].

The Lift-Off test is performed by placing the back of the hand of the arm being studied on the mid lumbar spine (Fig. 1) [1]. The patient is then asked to perform internal rotation by lifting the hand off the back while the examiner places pressure on the hand. The test is considered positive if the patient cannot resist, lift the hand off the back or if she/he compensates by extending the elbow and shoulder. Although this test is very specific for severe tears, it is not highly sensitive for partial thickness tears [3—6]. Hertel et al. [4] showed that the Internal Rotation Lag Sign can increase the sensitivity of LOT without changing the specificity. The examiner holds the patient's elbow as well as the patient's hand in maximum internal rotation (by lifting the dorsal side of the hand as far as possible away from the back). The patient is asked to remain in that position and the test is positive if the arm and hand suddenly drops by more than 5° (positive lag sign). Hertel explains this sensitivity by the fact that muscular unity can be tested more sensitively when it is maximally shortened [4]. This helps identify the smallest subscapularis tears which LOT tends to miss [4].

The Belly-Press test, described by Gerber et al. [3], in 1996, is performed with the arm along the body and slightly flexed (elbow ''forward''), the elbow flexed at 90° and the palm of the hand against the stomach (Fig. 2). The patient is then asked to perform external rotation by pushing back towards the abdomen while the examiner pushes in the opposite direction. The test is considered positive if the patient cannot resist, or if s/he compensates by flexing the wrist and extending the arm. Burkhart et al. [7] have described a variation of this test: the Napoleon, in which the patient must maintain internal rotation by pushing the palm of the hand against the abdomen with the wrist extended. The test was considered positive if the wrist was flexed at 90° and intermediate with flexion between 30 and 60°. The more extensive the tear, the greater the degree of positivity of the Napoleon test [7].

The sensitivity of the BPT can also be increased by the diagnostic Belly-Off Sign, described by Scheibel et al. [5], in 2005. The patient is in the same position as previously, then the examiner creates a maximum of internal rotation by pushing the patient's hand against his/her abdomen. The patient is asked to maintain the position and if the examiner identifies sudden external rotation when s/he removes her/his hand, the test is positive. The author describes a rate of sensitivity and specificity of nearly 100% making this test promising for the subscapularis, although it should be validated by another author [5].

More recently, a new test was described by Barth et al. [6] in 2006 called the Bear-Hug test (BHT). The BHT is performed by asking the patient to place the palm of his hand on the contralateral shoulder, with the fingers extended (to avoid gripping), the arm is in anteflexion and the elbow at 90° (Fig. 3). The patient is asked to perform internal rotation with resistance from the examiner who tries to remove the hand from the patient's shoulder using force that is perpendicular to the axis of the palm. The test is positive if the patient cannot resist. As with each of these tests, the

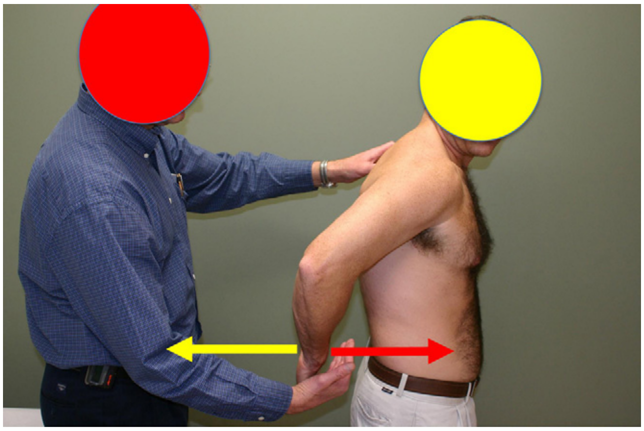

Figure 1 Gerber Lift-Off test.

results of the BHT are in comparison to the controlateral side to define any weakness. Pain can also be analyzed during the test. The BHT seems to be more sensitive than the LOT to small partial thickness tears of the upper 2/3 of the subscapularis [6].

Bicipital involvement is frequently associated with subscapularis tears because of the close anatomical relationship of the two [8—11]. Clinical exploration of the biceps is often performed with the Palm-Up test (PUT). This is resisted flexion of the elbow, arm and elbow against the body, with the elbow flexed at 90° and the palm of the hand facing upwards. This test can identify a tear of the long portion of the biceps (LPB), by the presence of a bunched muscle (Popeye sign), or acute pain in the bicipital groove in case of LPB damage. Although isolated subscapularis tendon tears are a specific entity of rotator cuff tears, limited posterior extension of the tear towards the supraspinatus can be included [12]. The Jobe test is the most common test to explore strength deficits linked to a supraspinatus tear [13]. This includes

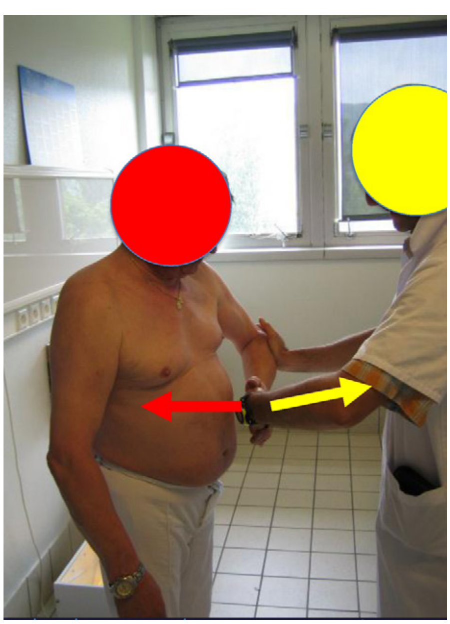

Figure 2 Gerber Belly-Press test.

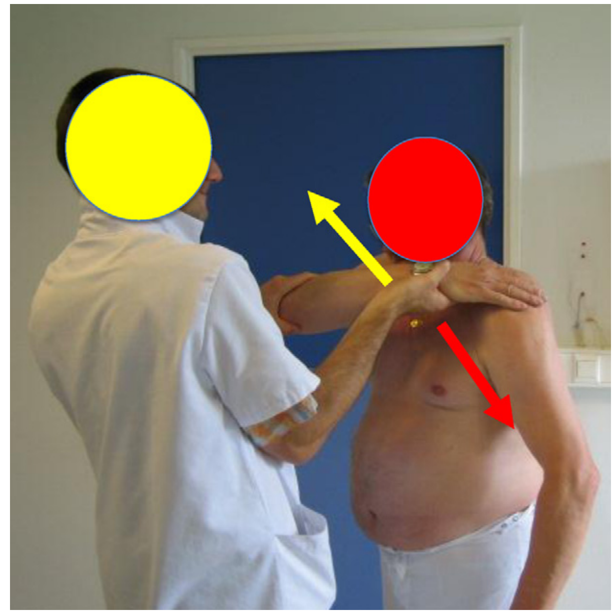

Figure 3 Bear-Hug test.

raising the scapula to 90° of antepulsion with resistance, the elbow extended and the thumbs facing down.

The aim of this study was to evaluate the diagnostic value of five clinical tests: LOT, BPT, BHT, PUT, and Jobe, in a population presenting with definite subscapularis tears.

Materials and methods

This was a prospective multicenter study of 208 cases of subscapularis tears including 11 centres (Annecy, Cambrai, Dunkerque, Grenoble, Lille, Libourne, Lyon, Nice, Paris, Strasbourg) from January 2010 to January 2011. Patients were included in the study during arthroscopic evaluation. Cases included isolated subscapularis tears or associated with partial (Ellman 1, 2, or 3) or complete supraspinatus tears (stage 1 of the SFA classification). The choice to repair the tears or not, and the choice of surgical technique was left up to the surgeon. Revision surgery for rotator cuff tears, massive tears extending to the supraspinatus and infraspinatus and a lack of a preoperative diagnostic video were exclusion criteria for the study. Preoperative data were collected on an online form (Calimed©). Preoperative clinical tests (LOT, BPT, BHT, PUT, and Jobe) were standardized in all the centres thanks to a video which was sent showing how to perform each of the tests (as well as the descriptions provided above), before beginning inclusions. For each test a subjective analysis of strength was requested (normal strength, deficient strength, no strength) and the presence of pain was noted during the test. A descriptive analysis of cuff tears was performed afterwards on the 208 videos recorded by the 12 centres and observed by four surgeons. These surgeons classified subscapularis tears into four types. Type 1 included partial thickness tears with fibers of the subscapularis detached from the lesser tuberosity, without injury to the bicipital groove. Type II corresponded to partial thickness tears of the fibers of the subscapularis from the lesser tuberosity associated with a partial tear from the

Table 1 Preoperative range of motion in patients included in the series ($n = 208$).

Range of motion	Anterior elevation		Internal rotation		Internal rotation (Constant score/10)	
	Group 1 (°)	Group 2 (°)	Group 1 (°)	Group 2 (°)	Group 1	Group 2
Mean	152	150	49	43	4.5	5.4
Minimum	50	20	0	10	1	1
Maximum	180	180	90	80	10	10

Table 2 Analysis of internal rotation according to the Constant score in relation to the subscapularis tear in isolated tears.

Group 1	Stage 1 (6)	Stage 2 (35)	Stage 3 (21)	Stage 4 (19)	Total (81)
Internal rotation/10	5.2	5.3	4.8	4.7	5

medial wall of the bicipital groove, but with preservation of the superior glenohumeral ligament. Type III corresponded to complete detachment of the subscapularis from the lesser tuberosity associated with significant disruption of the bicipital groove. Type IV corresponded to complete detachment of subscapularis fibers, creating a ''comma sign'' with the meeting of the subscapularis and supraspinatus fibers. We also divided the level of subscapularis tears into two groups (the lower 1/3 and the upper 2/3), and used the Ellman classification to identify partial thickness tears of the deep supraspinatus (grade 1: < 3 mm; grade 2: 3—6 mm or approximately 50% of the tendon thickness; grade 3: > 6 mm or > 50% of the tendon thickness) and we analyzed the morphology and the position of the biceps in relation to the bicipital groove. The biceps could be normally centered, subluxated, dislocated or torn. A correlation could then be evaluated between clinical tests and observed lesions. We defined two groups: Group 1 (called homogenous) including isolated subscapularis tears, and tears associated with Ellman grade 1 partial thickness supraspinatus tears and Group 2 (called heterogenous) including subscapularis tears associated with Ellman grade 2 and 3 supraspinatus tears and SFA stage 1 full thickness tears.

We chose an analysis of variance for the statistical analysis of the correlations between the different parameters with a linear fixed-effects model rather than an analysis of correlations. $P < 0.05$ was considered to be significant.

Results of 208 files were analyzed. On the other hand, data were missing from several files. The data actually available for each statistical test were systematically mentioned in the results.

In certain cases the proportion of data in each category was expressed as a percentage. Because of rounding errors when reading of the tables of results, the sum of the proportions could be different from 100 %. For example data distributed homogenously into three categories resulted in 33 % per category, thus an apparent total of 99 %. Thus, this was not a reporting or calculation error.

Results

This prospective study included 208 files. The series included 137 men (66%) and 71 women (34%), 150 right sides (72%) and 58 left sides (28%). The lesions identified during diagnostic arthroscopy were isolated subscapularis tears in 52 cases (25%), a subscapularis tear associated with a partial thickness supraspinatus tear in 68 cases (33%), and a subscapularis tear associated with a full thickness supraspinatus tear (stage 1 of the SFA classification) in 88 cases (42%). Partial tears of the supraspinatus included 29 grade 1 (14%), 28 grade 2 (13%) and 11 grade 3 (5%) in the Ellman classification. Thus Group 1 included 81 cases (isolated subscapularis tears) and Group 2 (subscapularis and associated supraspinatus tears) included 127 cases. Distribution of subscapularis tears according to the four stages of the SFA classification included in Group 1, six type I (7%) cases, 35 type II (43%), 21 type III (27%) and 19 type IV (23%), and in Group 2,12

Table 3 Evaluation of strength during the five clinical tests in all patients ($n = 208$).

Test	Could not be performed (%)	No strength (%)	Deficient strength (%)	Normal strength (%)	UK (%)
LOT	38 (18)	35 (21)	87 (53)	43 (26)	5 (2)
BPT	4 (2)	42 (21)	112 (56)	47 (23)	3 (1)
BHT	9 (4)	76 (41)	74 (40)	34 (19)	15 (7)
PUT	7 (3)	151 (92)		14 (8)	36 (17)
JOBE	9 (4)	158 (81)		36 (19)	5 (2)

UK: unknown.
The percentages in the columns ''could not be performed» and ''UK'' are in relation to the total of 208 patients. The percentages of the three other columns are in relation to the number of patients who were tested and for whom there is a result, that is the sum of the three columns ''no strength'', ''deficient strength'' and ''normal strength''.

type I (9%), 58 type II (46%), 26 type III (21%) and 31 type IV (24%).

There were more men than women in the two groups with 70 % in Group 1 and 59 % in Group 2. The mean age was 56.7 years old (range 41—76) in Group 1 and 58.3 years old (range 37—81 years old) in Group 2.

The cause of the tear was a single trauma in 106 cases (51%), recurrent trauma in 20 cases (10%), due to degenerative disease in 81 cases (39%), and the cause was unknown (UK) in one case. The proportion of traumatic cases compared to degenerative cases was similar in both groups: 31 (38 %) degenerative cases/50 (62 %) traumatic cases in Group 1 and 40 (38%) degenerative cases/76 (60%) traumatic cases and one of unknown cases in Group 2. A one-way analysis of variance (Group 1 or 2) did not show any significant difference between the two groups for the proportion of traumatic cases ($F(1,205) = 0.041$, $P = 0.84$).

Preoperative range of motion is reported in Table 1. In Group 1 there was increased external rotation and limited internal rotation compared to Group 2. Mean external rotation was 48.7° in Group 1 and 43.2° in Group 2 respectively, which was significantly different between the two groups ($P = 0.047$). The more internal rotation was limited, the more severe the subscapularis injury was (Table 2).

The mean Constant score was 51.9/100 (range 12—88) in Group 1 and 51.2/100 (range 12—86) in Group 2.

Analysis of the results of different tests in relation to strength and pain during the test are reported in Tables 3 and 4.

Although these three clinical tests were systematically performed to evaluate the subscapularis tears, 50 of 208 subscapularis tears were identified during surgery, or 24%.

The LOT could not be performed in 18% of the cases. The percentage of false negatives was 18% for BHT in relation to the total number of patients for whom results of this test were available (19 % in relation to the number of patients who passed the test), while these values were 21% and 26 % for the LOT test and 23% and 23% for the BPT respectively.

Test results and pain during testing were used to calculate sensitivity. Results were known for 141 patients for the LOT, 173 patients for the BPT and 164 patients for the BHT. Sensitivity (Se) was determined in three tests and was respectively: SeLOT = 74%, SeBPT = 76%, SeBHT = 82%. The ANOVA showed that the presence of pain was associated with the results of the test in three cases ($F(2,138) = 19.50$, $P = 3.5e\text{-}08$ for the LOT, $F(2,170) = 11.76$, $P = 1.6e\text{-}05$ for the BPT and $F(2,161) = 14.2$, $P = 2.1e\text{-}06$ for the BHT respectively). The positive tests were deficient and painful. The results are shown in Table 5.

A strong correlation between the severity of the deficit in the test results and the severity of the tear according to the SFA 4 stage classification was found for all the tests: LOT ($F(2,161) = 13.46$, $P = 3.94e\text{-}06$), BPT ($F(2,197) = 26.20$, $P = 8.15e\text{-}11$) and BHT ($F(2,180) = 7.22$, $P = 0.00097$). The

Table 4 Evaluation of pain during the five tests in all patients ($n = 208$).

Pain	No (%)	Yes (%)	NP (%)	UK (%)
LOT	20 (12)	145 (88)	4 (2)	39 (19)
BPT	36 (21)	136 (79)	3 (1)	33 (16)
BHT	29 (19)	124 (81)	11 (5)	44 (21)
PUT	12 (6)	182 (94)	3 (1)	11 (5)
JOBE	18 (11)	147 (89)	7 (3)	36 (17)

NP: not pertient; UK: unknown.
The percentages of the ''NP'' and ''UK'' columns are calculated in relation to the total of 208 patients. The percentages in the column ''No'' and ''Yes'' are calculated in relation to the total number of ''No'' and ''Yes'' responses, that is the number of patients in these two columns.

Table 5 Comparison of results of the three subscapularis tests in relation to strength and pain.

Pain	No (%)	Yes (%)	NP (%)
LOT no strength (31)	0	100	0
LOT deficient strength (79)	13	86	1
LOT normal strength (31)	58	39	3
BPT no strength (37)	11	89	0
BPT deficient strength (96)	10	89	1
BPT normal strength (40)	50	45	5
BHT no strength (64)	5	95	0
BHT deficient strength (69)	6	94	0
BHT normal strength (31)	42	55	3

n: number of patients per category.
Percentage: in proportion to the number of patients in the category.

Table 6 Distribution of patients in relation to the SFA classification of supscapularis tears, and the subscapularis test results.

SFA classification	Type I (%)	Type II (%)	Type III (%)	Type IV (%)
LOT no strength (35)	0 (0)	10 (29)	10 (29)	15 (43)
LOT deficient strength (87)	6 (7)	42 (48)	21 (24)	18 (21)
LOT normal strength (43)	10 (23)	25 (58)	3 (7)	5 (12)
BPT no strength (42)	1 (2)	7 (17)	12 (29)	22 (52)
BPT deficient strength (112)	8 (7)	51 (46)	29 (26)	24 (21)
BPT normal strength (47)	8 (17)	32 (68)	5 (11)	2 (4)
BHT no strength (76)	2 (3)	29 (38)	18 (24)	27 (36)
BHT deficient strength (74)	9 (12)	33 (45)	20 (27)	12 (16)
BHT normal strength (34)	3 (9)	21 (62)	7 (21)	3 (9)

n: number of patients per category.
Percentage: in proportion to the number of patients in the category.

Table 7 Correlation between the tests and the SFA classification of subscapularis tears in Group 1.

Group 1	Type 1 $n = 6$ (%)	Type 2 $n = 35$ (%)	Type 3 $n = 21$ (%)	Type 4 $n = 19$ (%)	$n = 81$ (%)
Positive LOT	67	62	95	95	84
Positive BPT	67	65	90	100	81
Positive BHT	67	67	95	95	88
Positive JOBE	100	73	100	100	75

Table 8 Distribution of patients according to the level of the tear, and the different subscapularis test results.

Level of the tear	Lower 1/3 (%)	Upper 2/3 (%)
LOT no strength (26)	9 (35)	17 (65)
LOT deficient strength (67)	31 (46)	36 (54)
LOT normal strength (42)	33 (79)	9 (21)
BPT no strength (31)	5 (16)	26 (84)
BPT deficient strength (91)	44 (48)	47 (52)
BPT normal strength (45)	35 (78)	10 (22)
BHT no strength ($n = 59$)	22 (37)	37 (63)
BHT deficient strength (60)	36 (60)	24 (40)
BHT normal strength (34)	18 (53)	16 (47)

n: number of patients per category.

more deficient the test results were, the more severe the tear was. The results are shown in Table 6.

In Group 1 (isolated subscapularis tears), the degree of test positivity increased significantly in proportion to the severity of the subscapularis tear ($P < 0.05$), (Table 7). The Jobe test was also frequently positive, including in isolated subscapularis tears.

The results of the subscapularis tests were significantly correlated to the level of subscapularis tear (LOT: $F(2,132) = 3.23$, $P = 0.000277$; BPT: $F(2,164) = 16.67$, $P = 2.58\text{e-}07$; BHT: $F(2,150) = 3.23$, $P = 0.0421$). The results are summarized in Table 8. Involvement of the biceps increased with the severity of the subscapularis tear. In Group 1, bicipital tears were observed during arthroscopy in a mean 65% of cases and in 33% of type 1, 57% of type 2, 75% of type 3, and 72% of type 4 cases respectively. Nevertheless there was no significant correlation between biceps tears and subscapularis tests (LOT: $F(2,126) = 0.73$, $P = 0.49$; BPT: $F(2,155) = 0.46$, $P = 0.64$; BHT: $F(2,145) = 1.76$, $P = 0.18$). Except for the BPT, there was no significant correlation between supraspinatus tears and the subscapularis test (LOT: $F(1,163) = 0.27$, $P = 0.60$; BPT: $F(1,199) = 4.14$, $P = 0.043$; BHT: $F(1,182) = 0.56$, $P = 0.46$). The results are summarized in Tables 9 and 10.

Analysis of the results did not show any relationship between subscapularis tears and the level of the tear, associated supraspinatus tears or the results of the Palm-Up test respectively ($F(1,162) = 0.50$, $P = 0.48$ for subscapularis tears; $F(1,134) = 0.08$, $P = 0.77$ for the level of the tear; and $F(1,163) = 0.11$, $P = 0.74$ for associated supraspinatus tears). On the other hand biceps involvement was statistically correlated with a positive Palm-Up test ($F(1,129) = 7.04$, $P = 0.0090$).

Discussion

The analysis of variance with a linear fixed-effects model was chosen for statistical analysis in this study instead of traditional correlation analysis. Indeed, a correlation study determines whether two values are related by a specific mathematical model without searching for a relationship of cause and effect between these two values. The ANOVA determines whether a value depends upon factors which could influence it. Performing one-way ANOVA, is the equivalent of estimating whether one value depends upon another, which is conceptually similar to a correlation study with in addition, a cause and effect relationship. Compared to a correlation study, the ANOVA supposes a link of dependency between one variable and other, which is not true in a correlation study. On the other hand it has the advantage of being more flexible in the choice of mathematical model, not to require an ordered relationship for the factor values, and to easily integrate multifactorial models [14]. The main interest of this prospective study was to diagnose tears based on a reliable anatomical reference, on tests recorded on video and interpreted by four independent observers. On the other hand, the presence of subscapularis tears alone in this study and the absence of false positives made it

Table 9 Distribution of patients according to biceps involvement and the results of the different subscapularis tests.

LPB	Unstable (dislocated or subluxated) (%)	Stable but pathological (%)	Normal (healthy and centered) (%)	Torn (%)	NR (%)
Positive LOT (165)	84 (51)	31 (19)	22 (13)	14 (8)	14 (8)
Positive BPT (201)	100 (50)	36 (18)	27 (13)	22 (11)	16 (8)
Positive BHT (184)	96 (52)	32 (17)	22 (12)	20 (11)	14 (8)
PUT (165)	84 (51)	30 (18)	21 (13)	17 (10)	13 (8)
Positive PUT (151)	79 (52)	28 (19)	19 (13)	12 (8)	13 (9)
Negative PUT (14)	5 (36)	2 (14)	2 (14)	5 (36)	0 (0)

In parentheses in the first column (total group).

Table 10 Distribution of patients in relation to the type of supraspinatus tear and the different subscapularis test results.

Supraspinatus tear	None, isolated subscapularis tear (%)	Grade 1 Ellman (%)	Grade 2 Ellman (%)	Grade3 Ellman (%)	Full thickness tear SFA stage 1 (%)
LOT no strength (35)	8 (23)	3 (9)	3 (9)	1 (3)	20 (57)
LOT deficient strength (87)	25 (29)	18 (21)	13 (15)	6 (7)	25 (29)
LOT normal strength (43)	8 (19)	5 (12)	6 (14)	1 (2)	23 (53)
BPT no strength ($n = 42$)	14 (33)	3 (7)	2 (5)	2 (5)	21 (50)
BPT deficient strength ($n = 112$)	29 (26)	17 (15)	20 (18)	6 (5)	40 (36)
BPT normal strength ($n = 47$)	7 (15)	8 (17)	6 (13)	3 (6)	23 (49)
BHT no strength ($n = 76$)	19 (25)	9 (12)	14 (18)	2 (3)	32 (42)
BHT deficient strength ($n = 74$)	23 (31)	12 (16)	10 (14)	6 (8)	23 (31)
BHT normal strength ($n = 34$)	5 (15)	5 (15)	3 (9)	3 (9)	18 (53)

In parentheses in the first column (total group).

impossible to perform other statistical analyses, in particular for the specificity, positive predictive value and negative predictive value of each test. Although this is not an entirely homogeneous series of isolated subscapularis lesions, to our knowledge this study includes the largest population of isolated subscapularis tears evaluated either in open surgery or endoscopically (Group 1: 81 cases) because the series reported in the literature have included: 16 cases (Gerber et al. [1]), 21 cases (Nové-Josserand et al. [15]), 25 cases (Burkhart et al. [7]) and 17 cases (Lafosse et al. [16]). Although the three clinical tests (LOT, BPT and BHT) were used, 24% of the subscapularis tears were diagnosed during surgery. This rate of chance discoveries is nevertheless lower than in the study by Barth et al. [6]. These usually involved limited, partial thickness tears, as in other series in the literature [4—6]. We did not study the influence of increasing the sensitivity of the three most common tests using the IRLS and Belly-off sign to improve the preoperative diagnostic rate [4,5].

Our study shows that positive results with the three tests (LOT, BPT and BHT) confirmed the presence of a subscapularis tear, even if these tests could miss small subscapularis tears, or if they were, at times, negative. The more severe the tendon tear, the more deficient the test results were, both for anatomical type and the level of the tear. Pennock et al. [17] has shown that the subscapularis is activated whatever the position of the arm during each of these tests. The LOT cannot always be performed (in 18% of the cases in our series) because of pain or limited range of motion in the shoulder [5—7,18]. On the other hand, if the LOT is performed and positive it is more sensitive for the diagnosis of severe subscapularis tears which confirms the results in the literature [1,3—6]. Electromyographic results by Tokish et al. [19] have shown that the BPT activates the upper fibers in particular, while LOT activates the lower fibers. For Barth et al. [6], BHT seems to be more sensitive in detecting small tears of the proximal subscapularis. In our study, although the BHT also seemed to be more sensitive, it was slightly more sensitive for severe tears (type 3 and 4 SFA) and tears of the upper 2/3 of the subscapularis. This difference may be explained by the results of the electromyographic study by Chao et al. [20] which shows that flexion of the arm segment does indeed influence activation of fibers but differently than in the way suggested by Tokish et al. [19]. Chao et al. [20] showed that BPT and BHT at 45° flexion were good to evaluate the fibres of the superior subscapularis, while BHT at 90° flexion (as in this multicenter study) was a good test to evaluate the function of fibres of the inferior subscapularis. The different tests are least disturbed by other medial rotators such as the pectoralis major and the latissmus dorsi, with the arm segment in 90° elevation [20]. This explains why the BHT is more sensitive than the other tests (LOT and BPT).

Associated bicipital tears are a sign of associated injury to the biceps pulley in severe subscapularis tears which have also been reported in the literature at a frequency of 51—86% [1,3,14,17,21—23].

Our study showed that a positive Palm-up test is statistically correlated to the presence of a bicipital tear which does not confirm the results of the study by Beaudreuil et al. [24]. Nevertheless the few number of negative tests ($n = 14$ cases) in our study, makes it impossible to draw conclusions on the diagnostic value of these results. On the other hand, the Jobe sign cannot be considered a very specific test for the supraspinatus because it is often positive in the presence of isolated subscapularis tears (Group 1).

There is a statistically significant relationship between the presence of a supraspinatus tear and the BHT (P [0.043]), which is close to the limit of significance (0.050). Therefore this result should be interpreted with caution, and could be due to a statistical bias.

In our series, unlike the results of Barth et al. [6] supraspinatus or bicipital involvement did not seem to be correlated to positive subscapularis tests, including the BHT. Because of the lack of false positives and the cohort of subscapularis tears alone, we cannot confirm our hypothesis that these three tests are highly specific (LOT, BPT and BHT) for subscapluaris tears.

Conclusion

This prospective multicenter study confirms that the LOT, BPT and BHT tests are valid and are strongly correlated to the severity of subscapularis tendon tears (both their level and anatomical type). The BHT is a more effective and should be performed at 90° of flexion to test the inferior subscapularis and at 45° (in association with the BPT) to test the superior subscapularis. The two other tests should be associated (LOT and BPT) to minimize the risk of underestimating the presence of small subscapularis tears, because one quarter of subscapularis tears are discovered during surgery.

A negative LOT, a positive BPT and a negative BHT (90°) suggest a limited partial thickness tear. If the BHT at 90° is also positive, this suggests that the tear involves the superior subscapularis. Positive results in the three tests and a significant loss of strength suggest a severe lesion (full thickness tendon tear with retraction or type 4) and requires rapid, surgical management.

Other studies are necessary to analyze the influence of associating these three tests with the Internal Rotation Lag Sign and/or Belly-Off Sign on the rate of false negatives.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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