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*ORIGINAL STUDY*

# How reliable are imaging protocols in the diagnosis of subscapularis tears?

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**The purpose of the study is to evaluate the accuracy of detecting subscapularis tendon tears on different imaging modalities in comparison with surgical findings. In addition, the accuracy of long head of biceps tendon pathology in assisting the diagnosis of a subscapularis tear was evaluated.**

**Retrospectively, 336 patients who underwent surgery in the UZ Brussel for rotator cuff pathology and had pre-operative imaging at the hospital were included. Pathology of the subscapularis tendon and the long head of biceps tendon on imaging modalities was compared to arthroscopic and/or open surgery findings.**

**111 of the 336 patients (33.0%) had a subscapularis tear diagnosed during surgery. None of the imaging modalities reaches the cut-off weighted kappa value (k) for substantial agreement of 0.61. Magnetic resonance imaging and magnetic resonance arthrography have the highest k of 0.288, indicating minimal agreement with arthroscopy. Computed tomography arthrography (k = 0.167) and ultrasound (k = 0.173) shows both no agreement. Biceps instability was significantly correlated with a subscapularis tear, but the negative predictive value was always higher than the positive predictive value on ultrasound, magnetic resonance arthrography and computed tomography arthrography. The negative predictive value for detection of full thickness tears is as high as 96.2% on magnetic resonance arthrography.**

**Accurate imaging diagnosis in daily practice of subscapularis tendon tears remains a challenge with the best results for magnetic resonance arthrography. The value of biceps instability lies in its negative predictive value rather than its positive predictive value.**

**Keywords :** Subscapularis tear ; arthroscopy.

## INTRODUCTION

The subscapularis (SSC) tendon undergoes degeneration in the same way as other muscles of the rotator cuff, but to a lesser extent. Tears can cause anterior shoulder pain *(1,2)*. The pattern of degenerative SSC tears is C-shaped from superomedial on the articular side, to the lateral side and then to inferolateral. When the tear reaches the lateral border, and thus the biceps pulley, the stability of the long head of biceps tendon (LHBT) can become compromised *(3,4)*. The prevalence is around 29-37% in cadaver studies and around 8-69% in clinical studies *(5,6,7,8,9)*.

Subscapularis tears are often classified according to the Lafosse system, which was later modified by Garavaglia et al. *(10,11)*. Imaging modalities are not absolute in detecting subscapularis tears. Some secondary signs have been described to improve the diagnosis *(12,13)*.

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In recent imaging studies, ultrasound sensitivity for Garavaglia type 1a, 1b and 2 tears is lower (+/- 28%) than for larger tears (+/-75%) *(9)*. With a 65% sensitivity and 98% specificity, computed tomography arthrography (CTA) causes some false negatives, especially partial thickness (PT) tears *(14)*. Magnetic resonance imaging (MRI) is a good examination for evaluating the rotator cuff together with fatty degeneration and atrophy of the muscle belly. For any Full-thickness (FT) rotator cuff tear, the sensitivity is 92% and specificity is 93%. For PT tears, the sensitivity is 64% and specificity 92%. For magnetic resonance arthrography (MRA), these values for FT tear rise to 95% and 99%, and for PT tears 86% and 96% respectively *(15)*.

With this study, we wanted to evaluate how often the diagnosis of a surgically confirmed subscapularis tear had been made on preoperative imaging. Our hypothesis was that the majority of smaller tears are overlooked. We also evaluated the prognostic factor of biceps instability.

## MATERIALS AND METHODS

This retrospective controlled study was approved by the Commission of Medical Ethics on December 7th 2016 with reference B.U.N. 143201629636.

405 patients who underwent surgery for a rotator cuff repair between January 2005 and September 2016, were identified. 69 were excluded because there were no imaging protocols in our electronic patient records. For the remaining 336 patients each imaging protocol (ultrasound, CTA, MRI or MRA) was independently and retrospectively compared to the surgical protocol.

The 309 arthroscopic surgeries, 22 open surgeries and 5 arthroscopic surgeries that were converted to open surgeries in this study were performed by three senior orthopaedic surgeons, all specialised in shoulder pathology. Arthroscopic surgical protocols were standardized, whereas protocols of open surgical procedures were descriptive.

205 ultrasounds were performed or supervised by 8 different senior radiologists. 194 CTA studies were protocolled by 6 different senior radiologists, 35 MRI's by 4 and 101 MRA's by 6. As these protocols were descriptive, the information was converted to a standardized protocol similar to the arthroscopic one. When there was no information about the SSC in either protocol (12 shoulders), the tendon wad assumed to be normal.

The subscapularis tendon was evaluated according to the Garavaglia classification. The LHBT was evaluated for the presence of a (sub)luxation, partial or full tear.

Cohen's kappa value and weighted kappa value were used to evaluate agreement and interpreted according to Altman's Kappa Benchmark scale. For statistical analysis, tendons with Garavaglia grade 2 to 4 on ultrasound were aggregated into one group, because of the limited number of cases in these grades. For CTA, MRI and MRA, aggregation was done for grades 3 and 4. A p-value of $< 0.05$ was used as threshold of significant correlation.

## RESULTS

Surgery identified 111 aberrant SSC tendons in 336 patients (33.0%). Patient groups with and without SSC tears were age and gender comparable (Table I). More than half of the SSC tears were of Garavaglia types 1a and 1b. (Fig. 1)

Sensitivity ranges from 41.5% on ultrasound to 53.8% on MRI, whereas specificity ranges from

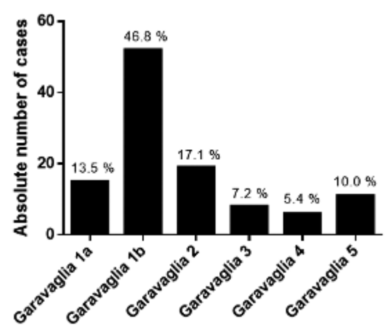


***Figure 1.*** — Distribtion of subscapularis tears according to the Garavaglia classification.

***Table I:*** *Age and gender distribution of patients according to the presence of a subscapular tear*

| | No SSC tear | SSC tear | p value |
|---|---|---|---|
| Gender | 108M/117F | 54M/57F | 0.40 |
| Age | 56.49 +/-10.57 (range 28-80) | 58.27+/-7.69 (range 31-80) | 0.52 |

*SSC: Subscapularis tendon, M: male, F: female*

***Table II:*** *Comparison of different imaging modalities*

| | Sensitivity | Specificity | Kappa value | Quadratic weighted kappa value |
|---|---|---|---|---|
| Ultrasound | 41.5% | 85.0% | 0.173 +/- 0.050 | 0.402 |
| MRI | 53.8% | 81.8% | 0.288 +/- 0.130 | 0.346 |
| MRA | 52.8% | 84.6% | 0.288 +/- 0.068 | 0.647 |
| CTA | 50.0% | 74.6% | 0.167 +/- 0.050 | 0.291 |

*MRI: magnetic resonance imaging, MRA: magnetic resonance imaging arthrography, CTA: computed tomography arthrography*

***Table III:*** *Correlation of instability of the long head of biceps tendon with subscapularis tendon tears*

| Biceps instability | Subscapularis tear on arthroscopy/ open surgery | | p value |
|---|---|---|---|
| | Yes | No | |
| Ultrasound | | | |
| Yes | 15 | 12 | 0.01 |
| No | 50 | 128 | |
| MRI | | | |
| Yes | 7 | 5 | 0.61 |
| No | 6 | 17 | |
| MRA | | | |
| Yes | 15 | 7 | 0.01 |
| No | 21 | 57 | |
| CTA | | | |
| Yes | 22 | 10 | 0.01 |
| No | 42 | 119 | |
| Surgery | | | |
| Yes | 53 | 28 | 0.01 |
| No | 58 | 197 | |

*MRI: magnetic resonance imaging, MRA: magnetic resonance imaging arthrography, CTA: computed tomography arthrography*

***Table IV:*** *Biceps instability and its relation to full-thickness subscapularis tears*

| Imaging Modalities | Arthroscopy | | |
|---|---|---|---|
| | No FT tear | FT tear | p value |
| MRA Biceps instability | | | |
| No | 75 | 3 | 0.01 |
| Yes | 14 | 8 | |
| CTA Biceps instability | | | |
| No | 146 | 15 | 0.01 |
| Yes | 23 | 9 | |

*MRA: magnetic resonance imaging arthrography, CTA: computed tomography arthrography*
*FT: Full-thickness subscapular tear*

74.6% on CTA to 85.0% on ultrasound for detecting a subscapularis tear, regardless of the type (Table II). When taking the type of tear into account, agreement (Cohen's kappa value) between imaging and surgery ranged from 0.173 (none) for ultrasound to 0.288 (minimal) for MRI and MRA. Weighted kappa values ranged from 0.346 (minimal) for CTA to 0.647 (moderate) for MRA.

Biceps instability was significantly correlated with SSC tears on all imaging modalities and surgery except for MRI. The positive predictive value (PPV) for any SSC tear when biceps instability was visualised, was 55.6% on ultrasound, 68.2% on MRA, 68.8% on CTA and 65.4% on surgery. The negative predictive value was 71.9% on ultrasound, 73.1% on MRA, 73.9% on CTA and 77.3% on surgery (Table III). For detecting any FT tear on surgery, the presence of biceps instability on imaging had the highest NPV on MRA (96.2%) (Table IV). There is no correlation between a LHBT partial or full tear and a SSC tear.

## DISCUSSION

Our hypothesis could partially be confirmed. The results showed that a significant amount of both smaller and larger subscapularis tears go undetected on the different imaging modalities that were evaluated. Instability of the long head of biceps tendon is a predictive factor for subscapularis tendon tears.

In total, 111/336 patients had a SSC tear (33.0%) which is an average result compared to other studies (8%-69%) and in line with studies reporting on patients that underwent surgical rotator cuff repair. Narasimhan et al. reported a prevalence of 31.4%, Garavaglia et al. 37%, Lin Lin et al. 39% and Adams et al. 40.5%. Type 1a, 1b and 2 occurred in 77.4% of our SSC tears, which is a little more than the reported 69-73%. Isolated SSC tears occurred more in our series than reported by others (15% vs 4.6%-6%). This may be due to a preferentially nonoperative approach regarding isolated supraspinatus tendon tears *(7,9,10,16)*.

205 ultrasounds were performed with a sensitivity for detection of any SSC tear of 41.5%, which is comparable to Narasimhan's sensitivity of 39.5%. Our specificity (85.0%) is, however, lower than theirs (93%). Narasimhan et al. described the sensitivity for smaller tears (type 1a, 1b and 2) as relatively low, around 25%, and for larger tears (type 3, 4 and 5) as much higher, around 75%. Since we grouped all FT tears together (type 2 to 4), we cannot directly compare our results, but we obtained a sensitivity of 25% (surgical confirmed FT tears that were protocolled on ultrasound as FT tears), which is much lower. For surgically confirmed PT tears that were protocolled as PT tears, we obtained a sensitivity of 24.3%, equally over- or underrated. This is in line with Narasimhan's findings. On the basis of a sensitivity of 30%, a

specificity of 100% and a large number of false negative ultrasound results for PT tears, Singisetti and Hinsche concluded that ultrasound is a reliable test for large full thickness SSC tears, but mainly fails in detecting PT tears and tendon fraying. In contrast, our Cohen's Kappa value is 0.173 and indicates no agreement with surgery. The quadratic weighted kappa, with rising penalties for higher disagreement, is 0.406 indicating a moderate level of agreement. PT SSC tears as well as FT SSC tears are difficult to diagnose on ultrasound *(9,17)*.

194 CTA's were performed with a sensitivity for detection of any tear of 50.0% and a specificity of 74.6%. Both were lower than reported by Charousset et al. (respectively 65% and 98%) and Szymanski et al. (71% and 83% respectively). However, when Szymanski et al. excluded delaminated tendons, theoretically the most challenging type to detect on CTA, sensitivity dropped to 58% and specificity rose to 91%, which is comparable to our findings. This indicates that CTA has difficulty detecting smaller as well as larger FT tears. Szymanski et al. reported minimal to moderate agreement with kappa values ranging from 0.38 to 0.47 (minimal to weak agreement), while our values were much lower. We obtained a kappa value of 0.167 (no agreement) and a quadratic weighted kappa value of 0.291 (minimal agreement). In conclusion, CTA lacks sensitivity for subscapularis tears and has difficulties in estimating any extent of a tear *(14,18)*.

Sensitivity for the 35 MRI's and 101 MRA's is 53.8% and 52.8% respectively, which is higher than Foad and Wijdicks' sensitivity of 40% and 36% for MRI and MRA respectively and Garavaglia's 25% for MRI. However, our sensitivity is lower than Gyftopoulos' 80% for MRI, Lin Lin's 82.2% for MRI and Pfirmann's 91% for MRA. Our specificity (81.8% and 84.8% respectively) is comparable to Pfirmann's 79-86% for MRA but lower than Gyftopoulos' 91% for MRI, Lin Lin's 92.1% for MRI and Garavaglia's 98% for MRI. Foad and Wijdicks concluded that MRA does not improve detection for SSC tears over MRI. In accordance, our study found kappa values in the range of minimal agreement ($\kappa$ 0.288 on both MRA and MRI). Although the quadratic kappa value for MRI remains in the same range of agreement ($\kappa$ 0.346), the value for MRA rises significantly to 0.647 indicating substantial agreement with surgery. Therefore, in our study, MRA compared with MRI, did not improve the recognition of any SSC tear, but was more precise in evaluating the extent (type) of tear *(6,7,10,19,20)*.

Biceps instability was significantly correlated ($p < 0.05$) on all different imaging modalities and surgery except for MRI. Here we see the same tendency as the other modalities but because of the low number of cases, the factor chance is more prominent. The PPV (55.6%-68.8%) is on every modality lower as the NPV (71.9%-77.3%). Shi et al. reported a NPV of 98% and a PPV of 35% on MRI for biceps instability but this was only for FT tears. Because our population includes a numerous group of PT tears, this high NPV cannot be achieved. If we make the distinction 'No FT tear' vs 'FT tear' on arthroscopy, the NPV rises to 90.7% and 96.2% on CTA and MRA respectively. Therefore, we can conclude that the diagnostic value lies primarily in the NPV and not in the PPV so when diagnosing biceps instability, one must be cautious to relate it to an SSC tear. Furthermore, we can conclude that it can be used for the differentiation between PT and FT tears *(13)*.

## LIMITATIONS

Several limitations of this study have to be considered. First, in the process of converting the imaging protocols on file to the standard protocol for comparison with the surgical data, interpretation may have resulted in an incorrect categorization of the presence and type of tear. Secondly, the broad group of radiologists that were responsible for the imaging protocols may have introduced bias due to a variable level of musculoskeletal skill and expertise, but this corresponds with clinical reality. Thirdly, using surgical protocols as reference is not infallible. SSC tears, especially smaller types, may have been overlooked or not described correctly. This may have resulted in more false positive results for the imaging records.

## CONCLUSION

In conclusion, imaging modalities seem not to be reliable for excluding and evaluating the presence and extent of subscapularis tendon tears in comparison with surgical findings. MRA proved to be the best imaging modality for evaluating SSC tears as substantial agreement was reached. LHB instability is an important indicator of the presence of tears of the subscapularis tendon, especially FT tears.

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