Diagnostic accuracy of preoperative magnetic resonance imaging for detecting subscapularis tendon tears: a diagnostic test study

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INTRODUCTION

Although the biomechanical importance of the subscapularis tendon has been recognized in biomechanical1 and clinical studies,2 it has long received little attention in the medical literature,3 and has been called the “forgotten tendon”.4 Only 1% of rotator cuff tears affect only the subscapularis,5,6 but more than half of all patients with supraspinatus tears present an associated tear of this tendon.7,8

The accuracy of magnetic resonance imaging (MRI) is usually lower for detection of subscapularis tears than for rotator cuff tears overall,9,10 with sensitivity ranging from 25% to 94%5,11 and specificity from 61.9% for detection of subscapularis tears. The shoulder surgeon presented sensitivity of 51.1% to 59.0% and specificity of 61.9% for detection of subscapularis tears. Sensitivity was higher for the musculoskeletal radiologists, while specificity was higher for the shoulder surgeon. The mean accuracy was 67.6%, i.e. lower than that of rotator cuff tears overall.

METHODS

We included patients who underwent arthroscopic rotator cuff repair and who had firstly undergone high magnetic field MRI without contrast. The images were independently evaluated by a shoulder surgeon and two musculoskeletal radiologists. Sensitivity, specificity, positive and negative predictive values, accuracy and inter and intra-observer agreement were calculated.

RESULTS:

MRIs on 200 shoulders were evaluated. The incidence of subscapularis tears was 69.5% (41.5% partial and 28.0% full-thickness). The inter and intra-observer agreement was moderate for detection of subscapularis tears. The shoulder surgeon presented sensitivity of 51.1% to 59.0% and specificity of 61.9% for detection of subscapularis tears. Sensitivity was higher for the musculoskeletal radiologists, while specificity was higher for the shoulder surgeon. The mean accuracy was 67.6%, i.e. lower than that of rotator cuff tears overall.

OBJECTIVE:

To compare the findings from MRI and arthroscopy for diagnosing subscapularis tears.

DESIGN AND SETTING:

Diagnostic test study performed in a tertiary care hospital.

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Conclusions:

The 1.5-T MRIs without contrast showed mean sensitivity of 70.2% and mean specificity of 61.9% for detection of subscapularis tears. Sensitivity was higher for the musculoskeletal radiologists, while specificity was higher for the shoulder surgeon. The mean accuracy was 67.6%, i.e. lower than that of rotator cuff tears overall.

KEYWORDS:

- Subscapularis tendon
- Accuracy
- Inter-observer agreement
- Intra-observer agreement

AUTHORS’ KEY WORDS:

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ABSTRACT

BACKGROUND: The accuracy of magnetic resonance imaging (MRI) for making the diagnosis of subscapularis tears presents wide variation in the literature and there are few prospective studies.

OBJECTIVE: To compare the findings from MRI and arthroscopy for diagnosing subscapularis tears.

DESIGN AND SETTING: Diagnostic test study performed in a tertiary care hospital.

METHODS: We included patients who underwent arthroscopic rotator cuff repair and who had firstly undergone high magnetic field MRI without contrast. The images were independently evaluated by a shoulder surgeon and two musculoskeletal radiologists. Sensitivity, specificity, positive and negative predictive values, accuracy and inter and intra-observer agreement were calculated.

RESULTS: MRIs on 200 shoulders were evaluated. The incidence of subscapularis tears was 69.5% (41.5% partial and 28.0% full-thickness). The inter and intra-observer agreement was moderate for detection of subscapularis tears. The shoulder surgeon presented sensitivity of 51.1% to 59.0% and specificity of 61.9% for detection of subscapularis tears. Sensitivity was higher for the musculoskeletal radiologists, while specificity was higher for the shoulder surgeon. The mean accuracy was 67.6%, i.e. lower than that of rotator cuff tears overall.

CONCLUSION: The 1.5-T MRIs without contrast showed mean sensitivity of 70.2% and mean specificity of 61.9% for detection of subscapularis tears. Sensitivity was higher for the musculoskeletal radiologists, while specificity was higher for the shoulder surgeon. The mean accuracy was 67.6%, i.e. lower than that of rotator cuff tears overall.
The study included patients undergoing arthroscopic surgery for rotator cuff repair who had firstly undergone preoperative 1.5-T MRI without the use of intra-articular or intravenous contrast. Patients were excluded if the interval between MRI and surgery was longer than one year, or if MRI was not available in digital format. Patients who refused to participate were also excluded, as were cases of reoperations. Examinations with moving artifacts were also excluded.

The local institutional review board approved the study (Comissão de Ética para Análise de Projetos de Pesquisa, CAPesq), in a session on August 19, 2015, under research protocol number 12952.

Index test - magnetic resonance imaging
All MRI scans were performed using a 1.5-T unit (HDxt, GE Medical Systems, Milwaukee, Wisconsin, United States) and a dedicated three-channel shoulder coil. The patients were placed in a supine position with their arms in a neutral position. Neither intra-articular nor intravenous gadolinium was used for any of the examinations. The protocol used was as follows: axial, oblique coronal and oblique sagittal fat-suppressed intermediate-weighted images (TR: 2717-3784 ms; TE: 42-46 ms; FOV 15 cm; slice thickness 3-4 mm; matrix 288 x 192); and oblique coronal and oblique sagittal T1-weighted images (TR: 350-517 ms; TE: minimum; FOV 14-15 cm; slice thickness 3-4 mm; matrix 288 x 192).

The examinations were blindly evaluated using Osirix 9.0 (Pixmeo SARL, Bernex, Switzerland) by two musculoskeletal (MSK) radiologists (5 and 10 years of experience) and a shoulder surgeon with 12 years of experience. The shoulder surgeon reassessed the examinations after three months, with the MRIs randomly rearranged.

Reference standard - arthroscopy
Arthroscopic surgery was carried out with the patients placed in a beach chair position under general anesthesia and interscalene block. The integrity of the subscapularis tendon was evaluated with the 30º optic positioned in the posterior portal while an auxiliary performed the posterior lever-push maneuver. When the biceps tendon impaired visualization of the subscapularis, it was debrided or tenotomized. Arthroscopies were performed by three shoulder surgeons with 10 to 12 years of experience. The surgeons were not blinded to the MRI findings, but were blinded to the results from the study observers.

Subscapularis evaluation
In the MRI evaluation, the subscapularis tendon was classified in one of the following categories: intact tendon, partial-thickness tear or full-thickness tear. In the arthroscopic evaluation, the same categories were used. The tendon was considered intact when no signs of tear were present, independent of presenting normal or high signals in T2. Tears were considered partial when articular, intra-substantial or longitudinal tears were present, without complete discontinuity. Full-thickness tears included those affecting the upper third, upper two-thirds or entire extent of the tendon.

Other variables analyzed
The following clinical and demographic data were evaluated: sex; age; preoperative function, as measured on the American Shoulder and Elbow Surgeons (ASES) scale; University of California Los Angeles (UCLA) shoulder rating scale; and time between MRI and surgery. Data regarding the other tendons were collected by means of arthroscopy: supraspinatus (intact, partial tear or full-thickness tear); infraspinatus (intact or torn); and biceps (intact or torn). Biceps stability was also evaluated. For the variables visualized by means of MRI, the mean from the four evaluations of the continuous data (coracohumeral interval, measured in mm) was used. For the categorical data, a consensus reached among the evaluators regarding the following was used: fatty degeneration as described by Fuchs et al., categorized as I or ≥ II; and presence of cysts in the lesser tuberosity, categorized as absent or present.

Statistical analysis
Continuous data were described using means and standard deviations. Categorical data were described using absolute and proportional frequencies. Accuracy was described using the diagnosis from arthroscopy as its reference and was determined through analyses on sensitivity, specificity, positive and negative predictive value and positive and negative likelihood ratio, with their respective confidence intervals. The intra and inter-observer analyses were performed using the kappa test and the modified Fleiss kappa test, respectively. The data were presented as absolute values and were categorized in accordance with the criteria of Landis and Koch: ≥ 0.81 almost perfect; 0.61 to 0.80 substantial; 0.41 to 0.60 moderate; 0.21 to 0.40 fair; and ≤ 0.20 slight. The value set for statistical significance was ≤ 5%. The software used was SPSS® for Mac 23.0 (Chicago, IL, United States). There was no need to impute data.

RESULTS
Between January 2013 and August 2017, 411 shoulders with rotator cuff tears were operated on. The following cases were not included: 57 open repairs, 70 cases with an interval between the MRI and surgery longer than one year, 6 cases with movement artifacts, 12 cases with previous surgery and 66 cases in which MRI was not available in digital format. Thus, MRIs for 200 shoulders (195 patients) were analyzed.
Table 1 shows the general characteristics of the sample according to subscapularis tendon condition. Supraspinatus and subscapularis fatty degeneration, biceps instability, gender and age differed between the groups. The other variables did not present statistically significant differences.

The comparison of subscapularis appearance among the five different evaluations is shown in Table 2. The shoulder surgeon detected fewer tears than those observed through arthroscopy (41.0% to 47.5% versus 69.5%). Radiologists, on the other hand, detected more tears than were observed through arthroscopy (74.5% to 78.5%). In the arthroscopic views, 30.5% of the sample presented intact tendons; 41.5%, partial tears; and 28.0%, full-thickness tears.

The inter-observer agreement was substantial for full-thickness tears (kappa 0.631; 95% confidence interval, CI 0.556-0.700; P < 0.001). For overall tears (partial or full-thickness), the results were moderate (kappa 0.463; 95% CI 0.383-0.534; P < 0.001). Intr observer agreement was almost perfect for detection of full-thickness tears (kappa 0.809; 95% CI 0.696-0.923; P < 0.001). For overall tears, the results were moderate (kappa 0.546; 95% CI 0.430-0.662; P < 0.001). These data are shown in Table 3.

The accuracy measurements are detailed in Table 4. The shoulder surgeon presented sensitivity of 35.7% to 39.3% (mean 37.5%) for full-thickness tears and 51.1% to 59.0% (mean 55.1%) for overall tears. The specificity was 91.7% to 94.4% (mean 93.1%) and 78.7% to 82.0% (mean 80.4%), respectively. For the MSK radiologists, the sensitivity ranged from 57.1% to 71.4% (mean 64.3%) for full-thickness tears and 83.5% to 87.1% (mean 85.3%) for overall tears, while the specificity was 85.4%

Table 1. General sample characteristics according to the presence or absence of the different subscapularis tendon conditions

| Subscapularis tear | No tear (n = 61) | Partial tear (n = 83) | Full-thickness tear (n = 56) | P   |
|--------------------|-----------------|----------------------|-----------------------------|-----|
| **Supraspinatus tear [n (%)]** | | | | |
| None               | 5 (41.7)        | 2 (16.7)             | 5 (41.7)            | 0.139|
| Partial            | 19 (43.2)       | 18 (40.9)            | 7 (15.9)             |     |
| Full-thickness     | 37 (25.7)       | 63 (43.8)            | 44 (30.6)            |     |
| **Infraspinatus tear [n (%)]** | | | | |
| No                 | 40 (32.3)       | 53 (42.7)            | 31 (25)              | 0.472|
| Yes (partial + full-thickness) | 21 (27.6) | 30 (39.5) | 25 (32.9) | |
| **Supraspinatus fatty degeneration [n (%)]** | | | | |
| I                  | 51 (32.1)       | 73 (45.9)            | 35 (22.0)            | 0.001*|
| ≥ II               | 10 (24.4)       | 10 (24.4)            | 21 (51.2)            |     |
| **Infraspinatus fatty degeneration [n (%)]** | | | | |
| I                  | 48 (33.3)       | 61 (42.36)           | 35 (24.3)            | 0.372|
| ≥ II               | 13 (23.2)       | 22 (39.3)            | 21 (37.5)            |     |
| **Subscapularis fatty degeneration [n (%)]** | | | | |
| I                  | 59 (33.1)       | 77 (43.3)            | 42 (23.6)            | < 0.001*|
| ≥ II               | 2 (9.1)         | 6 (27.3)             | 14 (63.3)            |     |
| **LHB stability [n (%)]** | | | | |
| Stable             | 43 (41.0)       | 45 (44.6)            | 13 (12.9)            |     |
| Unstable           | 13 (16.5)       | 25 (46.3)            | 17 (31.5)            | < 0.001*|
| NA                 | 5 (29.4)        | 5 (29.4)             | 7 (41.2)             |     |
| **LHB tear [n (%)]** | | | | |
| Not torn           | 34 (38.6)       | 34 (38.6)            | 20 (22.7)            | 0.071|
| Torn               | 27 (24.1)       | 49 (43.8)            | 36 (32.1)            |     |
| **Gender [n (%)]** | | | | |
| Male               | 31 (31.3)       | 33 (33.3)            | 35 (35.4)            | 0.031*|
| Female             | 30 (29.7)       | 50 (49.5)            | 21 (20.8)            |     |
| **Cysts in the lesser tuberosity [n (%)]** | | | | |
| Yes                | 10 (28.6)       | 16 (45.7)            | 9 (25.7)             |     |
| No                 | 51 (30.9)       | 67 (40.6)            | 47 (28.5)            | 0.855|
| **Age, years (mean ± SD)** | 54.97 ± 16.42 | 56.53 ± 10.87       | 58.72 ± 6.77***     | 0.005*|
| **Coracohumeral interval, mm (mean ± SD)** | 8.19 ± 1.72 | 8.43 ± 2.01       | 8.01 ± 8.72         | 0.507|
| **Time between MRI and arthroscopy, days (mean ± SD)** | 123.97 ± 86.68 | 138.01 ± 86.94 | 160.61 ± 106.71 | 0.192|
| **ASES score (mean ± SD)** | 45.64 ± 21.98 | 43.76 ± 21.5 | 45.61 ± 19.05 | 0.608|
| **UCLA score (mean ± SD)** | 15.67 ± 5.47 | 15.07 ± 5.44 | 15.66 ± 5.44 | 0.644|

LHB = long head of the biceps; SD = standard deviation; ASES = American shoulder and elbow surgeons; UCLA = University of California Los Angeles; NA = Not applicable.
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Table 2. Comparison of the integrity of the subscapularis tendon between findings from magnetic resonance imaging and arthroscopy

| Subscapularis tear         | Shoulder surgeon (1st evaluation) | Shoulder surgeon (2nd evaluation) | MSK radiologist 1 | MSK radiologist 2 | Arthroscopy |
|---------------------------|-----------------------------------|-----------------------------------|-------------------|-------------------|-------------|
|                           | n       | %      | n       | %      | n       | %      | n       | %      | n       | %      |
| No                        | 118     | 59.0%  | 105     | 52.5%  | 51      | 25.5%  | 43      | 21.5%  | 61      | 30.5%  |
| Yes                       | 82      | 41.0%  | 95      | 47.5%  | 149     | 74.5%  | 157     | 78.5%  | 139     | 69.5%  |
| Partial                   | 48      | 24.0%  | 67      | 33.5%  | 88      | 44.0%  | 105     | 52.5%  | 83      | 41.5%  |
| Full-thickness            | 34      | 17.0%  | 28      | 14.0%  | 61      | 30.5%  | 52      | 26.0%  | 56      | 28.0%  |

MSK = musculoskeletal.

Table 3. Inter-observer and intra-observer reliability results

| Parameter                          | K     | 95% CI          | P-value |
|------------------------------------|--------|-----------------|---------|
| Inter-observer reliability results |        |                 |         |
| Subscapularis tear (full-thickness + partial) | 0.463  | 0.383 - 0.534   | < 0.001 |
| Full-thickness tear                 | 0.631  | 0.556 - 0.700   | < 0.001 |
| Intra-observer reliability results  |        |                 |         |
| Subscapularis tear (full-thickness + partial) | 0.546  | 0.430 - 0.662   | < 0.001 |
| Full-thickness tear                 | 0.809  | 0.696 - 0.923   | < 0.001 |

CI = confidence interval.

Table 4. Values relating to sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios and accuracy of magnetic resonance imaging, compared with arthroscopy (gold-standard), for each evaluator

| Parameter                      | Subscapularis full-thickness tear | Subscapularis tear (full-thickness + partial) |
|--------------------------------|----------------------------------|-----------------------------------------------|
|                                | Mean 95% CI                      | Mean 95% CI                                   |
|                                | Inferior       | Superior       | Inferior       | Superior       | Inferior       | Superior       |
| Shoulder surgeon (1st evaluation) |  |                  |                  |  |                  |                  |
| Sensitivity                    | 39.3%  | 27.2% - 52.1%   | 51.1%  | 43.2% - 59.1%   |                  |
| Specificity                    | 91.7%  | 85.4% - 96.3%   | 82.0%  | 72.4% - 92.3%   |                  |
| Positive predictive value      | 64.7%  | 49.2% - 81.4%   | 86.6%  | 79.1% - 94.3%   |                  |
| Negative predictive value      | 79.5%  | 73.1% - 86.7%   | 42.4%  | 33.4% - 51.7%   |                  |
| Accuracy                       | 77.0%  | 71.2% - 83.5%   | 60.5%  | 53.2% - 67.3%   |                  |
| Should shoulder surgeon (2nd evaluation) |  |                  |                  |  |                  |                  |
| Sensitivity                    | 35.7%  | 23.2% - 48.3%   | 59.0%  | 51.0% - 67.1%   |                  |
| Specificity                    | 94.4%  | 91.2% - 98.5%   | 78.7%  | 68.3% - 89.8%   |                  |
| Positive predictive value      | 71.4%  | 55.1% - 88.4%   | 86.3%  | 79.7% - 93.2%   |                  |
| Negative predictive value      | 79.1%  | 73.2% - 85.2%   | 45.7%  | 36.6% - 55.5%   |                  |
| Accuracy                       | 78.0%  | 72.7% - 84.4%   | 65.0%  | 58.3% - 72.3%   |                  |
| MSK radiologist 1               |  |                  |                  |  |                  |                  |
| Sensitivity                    | 71.4%  | 60.1% - 83.4%   | 83.5%  | 77.7% - 90.0%   |                  |
| Specificity                    | 85.4%  | 80.2% - 91.1%   | 45.9%  | 33.4% - 58.1%   |                  |
| Positive predictive value      | 65.6%  | 53.1% - 77.2%   | 77.9%  | 71.6% - 84.7%   |                  |
| Negative predictive value      | 88.5%  | 83.2% - 94.7%   | 54.9%  | 41.1% - 69.3%   |                  |
| Accuracy                       | 81.5%  | 76.2% - 87.7%   | 72.0%  | 66.3% - 78.2%   |                  |
| MSK radiologist 2               |  |                  |                  |  |                  |                  |
| Sensitivity                    | 57.1%  | 44.2% - 70.2%   | 87.1%  | 82.7% - 93.3%   |                  |
| Specificity                    | 86.1%  | 80.1% - 92.1%   | 41.0%  | 29.5% - 53.6%   |                  |
| Positive predictive value      | 61.5%  | 48.4% - 75.3%   | 77.1%  | 70.2% - 84.1%   |                  |
| Negative predictive value      | 83.8%  | 78.5% - 90.2%   | 58.1%  | 43.7% - 73.2%   |                  |
| Accuracy                       | 78.0%  | 72.5% - 84.1%   | 73.0%  | 67.3% - 79.4%   |                  |

CI = confidence interval; MSK = musculoskeletal.
**DISCUSSION**

Subscapularis tears, which rarely occur in isolation, are present in the majority of arthroscopies for rotator cuff repair. The accuracy of magnetic resonance imaging for tear detection presents wide variation in the literature. Studies published to date have presented some weaknesses, such as use of low magnetic field MRI, small samples and evaluation of diagnoses not restricted to rotator cuff disorders. The present study is the first to calculate intra-observer agreement in the majority of arthroscopies for rotator cuff repair. Intra-observer agreement, especially the latter. This study was the first to do this in relation to making a diagnosis of subscapularis tears. The design used, which was prospective and included consecutive cases, had only previously been used in a few articles on the same line of research. The large sample in the present study only involved patients undergoing arthroscopy to treat rotator cuff tears, thus increasing the internal validity of the data.

The inter-observer agreement found in the present study was substantial in relation to full-thickness tears (0.631), but lower than that reported by Choo et al. (0.78). Regarding overall detection of tears, considering both partial and full-thickness tears, the concordance observed in the present study was moderate (0.463), and lower than the values reported by most other authors. Only Lee et al. reported similar results. It is noteworthy that all of these authors analyzed MRI with contrast, applied intra-articularly or intravenously and that most utilized 3.0-T devices which may explain the results.

The arthroscopic inspection was performed without 70º optics, which could make it difficult to detect tears intraoperatively, according to other authors. In spite of this, use of standard inspection and the posterior lever-push maneuver allowed clear visualization of the subscapularis tendon in all the arthroscopies.

The inter-observer concordance analysis was performed for the two MSK radiologists and one shoulder surgeon; however, the analysis on intra-observer agreement assessed the latter only. The three evaluators knew the purpose of the study, which may have influenced the detection of tears. The surgeon had access to the MRI, both the images and the report, before performing the procedure. However, all the evaluators in the present study (MSK radiologists and shoulder surgeon) were blinded to the intraoperative findings and the surgeons were blinded to the results from the study observers.

Lastly, the time that elapsed between examinations and arthroscopy was 140 days on average, with a maximum of one year. Structural change to the tendon may have occurred during this period, although this is considered acceptable and was even used in a systematic review on this subject. Another possible criticism is that general sensitivity and specificity values were not obtained by reaching a consensus among the evaluators. However, the present authors believe that such consensuses have little practical applicability, since they are not routinely used in clinical practice.

One strong point of this study was the analysis on inter and intra-observer agreement, especially the latter. This study was the first to do this in relation to making a diagnosis of subscapularis tears. The design used, which was prospective and included consecutive cases, had only previously been used in a few articles on the same line of research. The large sample in the present study only involved patients undergoing arthroscopy to treat rotator cuff tears, thus increasing the internal validity of the data.

The findings from the present study have practical implications for both radiologists and orthopedists. For radiologists, they should emphasize the need for thorough evaluation of the subscapularis tendon and highlight that the differences between tears and tendinopathy may be the cause of false positives and negatives. New imaging protocols that optimize the analysis on this tendon could also be studied. For orthopedists, the findings show that...
cautious inspection is necessary, including actively searching for subscapularis tears, even when MRI shows no lesions. Lastly, the data presented may be useful for future meta-analyses, which would more clearly elucidate the limitations of MRI for detection of subscapularis tears.

CONCLUSION
The 1.5-T MRI without contrast showed a mean sensitivity of 70.2% and a mean specificity of 61.9% in relation to detection of subscapularis tears. The sensitivity was higher for the MSK radiologists, while specificity was higher for the shoulder surgeon. The mean accuracy was 67.6%, which was a performance rate inferior to that for posterosuperior tears of the rotator cuff.

Level of evidence: Level III, Diagnostic Study.

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