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Original article

Evaluating postoperative rotator cuff healing: Prospective comparison of MRI and ultrasound

P. Collin[a,*], M. Yoshida[a,b], A. Delarue[c], C. Lucas[a], T. Jossaume[a], A. Lädermann[d,e,f], the French Society for Shoulder and Elbow (SOFEC)[g]

[a] Centre Hospitalier Privé Saint-Grégoire, boulevard Boutière 6, 35768 Saint-Grégoire cedex, France
[b] Nagoya City University Graduate School of Medical Science, Nagoya, Japan
[c] Service de kinésithérapie, Unité de Réadaptation Fonctionnelle en Milieu Professionnel Le Patis Fraux, 35770 Vern-sur-Seiche, France
[d] Service de chirurgie orthopédique et traumatologie de l'appareil moteur, Hôpitaux Universitaires de Genève, rue Gabrielle-Perret-Gentil 4, 1211 Geneva 14, Switzerland
[e] Faculté de médecine, Université de Genève, rue Michel-Servet 1, 1211 Geneva 4, Switzerland
[f] Service de chirurgie orthopédique et traumatologie de l'appareil moteur, Hôpital de La Tour, rue J.-D.-Maillard 3, 1217 Meyrin, Switzerland
[g] 56, rue Boissonade, 75014 Paris, France

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ABSTRACT

Background: The objective of this prospective comparative single centre study was to compare postoperative rotator cuff healing rates as assessed by magnetic resonance imaging (MRI) versus ultrasonography (US).
Material and methods: Between October 2012 and February 2013, 61 patients underwent arthroscopic repair of postero-superior rotator cuff tears. Each patient underwent MRI and US 6 months later. The findings were assessed independently by two observers. We compared intra-observer and inter-observer levels of agreement regarding healing rates assessed by MRI and US.
Results: Intra-observer agreement regarding the MRI interpretation was 95% (κ coefficient, 0.83) for one observer and 98% (κ coefficient, 0.94) for the other. Values of κ for inter-observer agreement ranged across readings from 0.76 to 0.90. When MRI was taken as the reference, US had 80% sensitivity and 98% specificity.
Discussion: MRI and US provide similar assessments of postoperative rotator cuff healing, although US is less sensitive. Intra-observer and inter-observer agreements are very good.
Level of evidence: III.

1. Introduction

Healing is challenging to assess after surgical repair of rotator cuff tears. Among evaluation techniques, the widely accepted reference standard is magnetic resonance imaging (MRI). MRI is a slice-imaging technique that visualises the tendons, does not involve radiation exposure, and produces images that can be revised by other observers. Nevertheless, MRI is still a costly method of somewhat limited availability and may be contra-indicated for medical reasons or because of claustrophobia. Furthermore, postoperative MRI images are difficult to interpret [1] and may contain artefacts generated, for instance, by metal anchors or wires (Fig. 1).

Ultrasonography (US) is being used in an ever-increasing range of situations [2–6]. This non-invasive, dynamic, and inexpensive imaging technique can be performed by the surgeon at the surgical centre. However, US is operator-dependent, and the images it provides cannot be reliably re-evaluated by other observers. Healing rates as assessed by US after arthroscopic rotator cuff repair seem high.

The objective of this study was to compare healing rates after surgical repair of rotator cuff tears as assessed using MRI and US. Our hypothesis was that US underestimated the frequency of recurrent tears compared to MRI.

2. Materials and methods

2.1. Patient selection

A prospective, comparative, longitudinal study was conducted at a single centre from October 2012 to February 2013. Consecutive

* Corresponding author. Tel.: +33 2 99 23 33 27.
E-mail address: collin.ph@wanadoo.fr (P. Collin).

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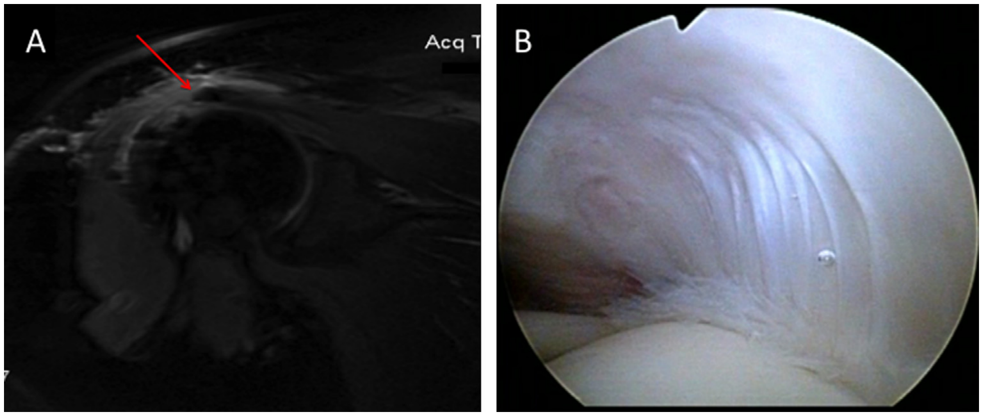

Fig. 1. Example of the challenges raised by interpreting postoperative MRI scans. A. Postoperative MRI: T2-weighted proton-density fat-suppressed coronal slice through the right shoulder 3 months after arthroscopic repair of a rotator cuff tear. The image strongly suggests a recurrent tear with stage II retraction in the Patte classification (red arrow). B. Posterior view during arthroscopy: the tendon is fully healed.

Table 1
Criteria developed by Sugaya et al. to evaluate tendon healing.

Sugaya classification	
Type I	Sufficient thickness, homogeneous tendon (low signal on T2 images)
Type II	Sufficient thickness, partial high-intensity from within the tendon
Type III	Insufficient thickness without discontinuity
Type IV	Minor discontinuity on more than one slice, suggesting a small tear
Type V	Major discontinuity suggesting a moderate or large tear

patients who underwent arthroscopic repair of a postero-superior rotator cuff tear performed by a single surgeon (PC) were included if they met the following criteria: age between 21 and 75 years, tear in the supra-spinatus and/or infra-spinatus tendons, grade 1 or 2 retraction in the Patte classification [7], fatty degeneration grade I or II according to Goutallier [8], and normal passive motion ranges. Exclusion criteria were medical contra-indications to MRI, claustrophobia, gleno-humeral osteoarthritis, chronic inflammatory disease, concomitant lesion of the anterior rotator cuff, incomplete repair, history of surgery on the same shoulder, and missing data. During the study period, rotator cuff repair procedures were performed in 76 patients according to a previously published technique [9]. Among them, 12 had exclusion criteria and 3 declined participation in the study. The remaining 61 patients had a mean age of 59 years (range: 38–72 years). The dominant shoulder was involved in 43 cases.

2.2. Clinical evaluation

Each patient was evaluated by an independent observer before and 6 months after surgery. Each evaluation included motion range measurements and Constant score determination [10].

2.3. Imaging studies

Each patient underwent both MRI and US 6 months after surgery. This time interval was selected based on previous studies showing that it was sufficient for an assessment of tendon healing [11]. The 5-stage assessment system developed by Sugaya et al. [12] and validated for US [13] was used to assess tendon repair (Table 1). All imaging studies were performed by operators who were blinded to patient data.

The MRI protocol included the following:

- T2-weighted fat-suppression sequences in the oblique coronal, oblique sagittal, and transverse planes including the entire scapula;
- T1-weighted sequences in the transverse and sagittal planes.

Ultrasonography was performed with the patient seated on a chair, facing the radiologist, who used a high-frequency linear probe (7.5–14 MHz, APLIO 400, Toshiba, Zoetermeer, The Netherlands). All tendons were examined along their long and short axes. The supra-spinatus and infra-spinatus tendons were imaged with the arm in retroversion and the hand resting on the buttock. A single sonogram was obtained in each patient. All sonograms were performed by the same radiologist (TJ).

2.4. Statistical analysis

To compute levels of agreement, we collapsed the patients into two groups based on the Sugaya stage: I, II, and III (no recurrent tear) and IV or V (recurrent tear). Each MRI scan was interpreted twice by the surgeon (PC) and twice by the radiologist (TJ), using a blinded procedure. Inter-observer and intra-observer reliability for MRI readings was assessed by computing the κ coefficient. The sonogram was interpreted only once and the sensitivity, specificity, positive predictive value (PPV), and negative predictive value

Table 2
Classification of the lesions according to the reading and reader.

	Ultrasonography $n = 61$	MRI, 1st reading by the surgeon $n = 61$	MRI, 2nd reading by the surgeon $n = 61$	MRI, 1st reading by the radiologist $n = 61$	MRI, 2nd reading by the radiologist $n = 61$
Sugaya 1	0	6	5	7	8
Sugaya 2	44	40	39	36	36
Sugaya 3	4	5	6	8	6
Sugaya 4	5	2	3	1	2
Sugaya 5	8	8	8	9	9

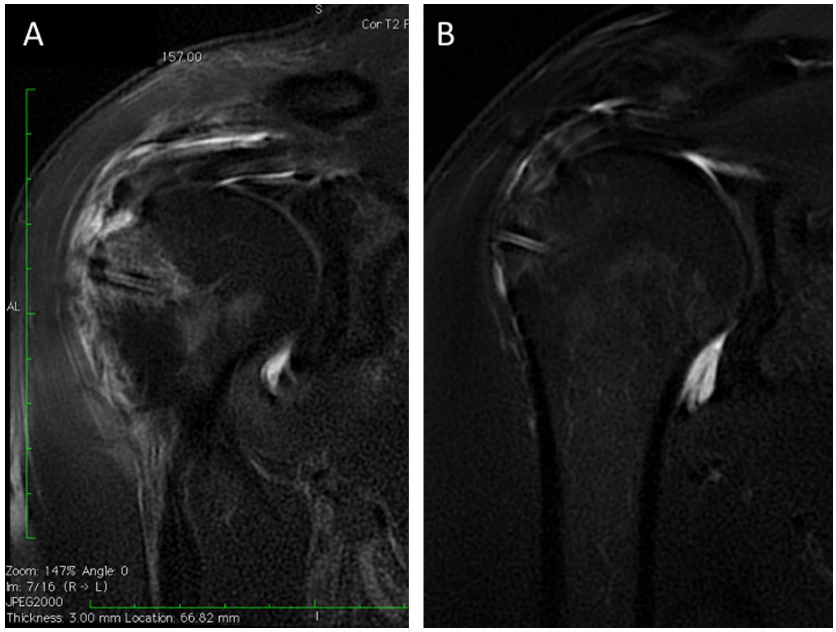

Fig. 2. MR arthrogram of the right shoulder after arthroscopic re-attachment of the rotator cuff. A. 2 months after surgery: note the high-intensity signal at the bone-tendon junction. B. 8 months after surgery: the high-intensity signal is no longer visible.

Table 3
Intra-observer agreement for the two MRI readings by the surgeon.

1st MRI reading	2nd MRI reading		
	No tear	Tear	Total
No tear	49	2	51
Tear	1	9	10
Total	50	11	61

(NPV) of US were computed using the MRI findings as the reference standard. A second analysis was performed.

3. Results

The Constant shoulder score improved from 56 to 78 points (range: 25–88). Table 2 lists the results according to the lesion type in the Sugaya classification.

3.1. MRI findings

Tables 3 and 4 report the MRI findings with the level of intra-observer agreement. Evaluation of the MRI scans twice by the same surgeon produced identical interpretations in 58/61 patients, yielding a 95% agreement rate (κ coefficient, 0.83). Table 4 reports the MRI interpretations by the radiologist. Evaluation of the MRIs twice by the same radiologist (TJ) produced identical results for 60/61 patients, yielding a 98% agreement rate (κ coefficient, 0.94). For inter-observer agreement, the κ coefficient ranged from 0.76 to 0.90 depending on whether the first or second MRI reading was used.

Table 4
Intra-observer agreement for the two MRI readings by the radiologist.

1st MRI reading	2nd MRI reading		
	No tear	Tear	Total
No tear	50	1	51
Tear	0	10	10
Total	50	11	61

3.2. Comparison of MRI and US

US had 80% sensitivity and 98% specificity. The PPV was 92% and the NPV 94%.

4. Discussion

When problems arise after surgical repair of a rotator cuff tear, a crucial point for both the surgeon and the patient is whether tendon healing has been achieved, since tendon healing is among the conditions required to obtain a good final clinical outcome [9]. The goal of imaging studies in this situation is to confirm the site of the recurrent tear [14], e.g., medial to the medial row (Trantalis lesion) [15], and if possible its cause. Other points of interest are the quality of the bone, tendon, and muscle; and whether further surgery is feasible. Numerous factors make this information difficult to obtain by MRI. Inadequate coverage of the greater or lesser tuberosity may indicate partial healing and not a recurrent full-thickness tear [16,17]. Furthermore, only 10% of re-attached tendons generate a normal MRI signal. Thus, a common finding is presence within the tendon of an intermediate signal indicating granulation tissue or of a low-intensity signal produced by fibrous tissue [1,17–21]. These signal changes may persist for longer than 6 months, due to tissue remodelling [22,23], and seem to have no clinical implications (Fig. 2). Finally, evaluation of MRI scans is made difficult by the normal leakage of fluid into the subacromial space after opening of the rotator interval and passage of instruments through the tendon. Finally, metallic material (e.g., anchors or wires), inflammation, and neo-vascularisation generate numerous artefacts. These factors, together with the high cost and many contra-indications of MRI, lend considerable appeal to US as a method for evaluating the repaired rotator cuff. Our prospective study confirms the usefulness of US by showing high sensitivity and specificity compared to MRI taken as the reference standard. Therefore, our results validate the use of US for evaluating the rotator cuff after surgical repair. Similarly, in a recent study comparing MRI and US after rotator cuff repair, Codsi et al. found 92% agreement with a κ coefficient of 0.70 [24]. However, limitations of their study include the multicentre design (13 centres) with differences in the US protocols across centres and unblinded MRI interpretation.

Our hypothesis that the recurrent tear rate was higher by MRI was confirmed. Of the unhealed or recurrent tears shown by MRI, only 80% were also shown by US. This result should, however, be viewed with caution given the difficulties in interpreting the MRI scans (Figs. 1 and 2) [1], particularly in patients with partial-thickness tears [1,25].

Thus, none of the existing methods seems ideal for the post-operative evaluation of the rotator cuff. When a recurrent tear is suspected, a reasonable strategy may consist in a multi-modal evaluation, with standard radiographs initially to rule out migration of an anchor and to evaluate the acromio-humeral interval and bone morphology. The results of the present study support US as the second-line imaging method, to assess the tendon footprint. If further surgery is considered, then MRI with standard sequences, as well as MAVRIC sequences [26] in patients with metal anchors, provides additional information on the site of the recurrent tear, tendon trophicity and retraction, and fatty degeneration.

This work is the first prospective single surgeon study comparing MRI and US to assess tendon healing after arthroscopic rotator cuff repair. The number of patients is substantial and the MRI scans were read by observers who were blinded to patient data, including the US findings. A standardised reading protocol was used, in a single centre. Nevertheless, several limitations should be acknowledged. The first is that MRI was taken as the reference standard, as repeat arthroscopy was not feasible. Furthermore, the study design did not allow an assessment of inter-observer agreement regarding the US findings. The specificity and predictive values of US are dependent on the experience of the operator, who was a seasoned osteo-articular radiologist in our study. Recent publications have shown, however, that US skills can be acquired rapidly by orthopaedic surgeons, suggesting that generalised use of US may be feasible in the future [27,28].

5. Conclusion

MRI and US provide similar evaluations of the surgically repaired rotator cuff. However, sensitivity is lower with US. MRI is associated with very good levels of inter-observer and intra-observer agreement.

Disclosure of interest

P. Collin is a paid consultant for Tornier and Smith & Nephew and has received royalties from Tornier, Storz, and Advanced Medical Applications. This study was not supported by any non-institutional funds or grants.

The other authors have not supplied their declaration of conflict of interest.

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