Protocol optimization in the MRI evaluation of the rotator cuff focused on the supraspinatus tendon.

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Aims and objectives

Shoulder pain is the third most common musculoskeletal complaint which patients consult their doctor for, after low back pain and knee pain (1) and has a prevalence in the general population between 16% and 26%. The most prevalent cause of shoulder pain, occurring in approximately 65%-70% of patients is rotator cuff disease (2). This prevalence increases with age, and it is estimated that, by the age of 70 years, more than 50% of the population will have a full or partial thickness rotator cuff tear. It is a real public health problem because of its functional impact.

There are some different imaging techniques, which can be used to detect rotator cuff abnormalities including ultrasonography (US), and magnetic resonance (MR) imaging (3).

US evaluation of the rotator cuff is performing to diagnose injuries with a standard study of each tendon in its two orthogonal planes following the curve of the distal part. We all know that US gives a really good view of the fibrillar structure of tendons (fig.1).

Advantages of US include portability, low cost, lack of contraindications and the spatial resolution of images obtained with US is sometimes higher than images obtained with routine MR imaging (3), whereas both image acquisition and image interpretation seem to be very dependent on the experience of the physician. That's why, now, MR imaging tends to be the main technique used to make the assessment of the rotator cuff because radiologists consider this technique less operator dependent than with US and high accuracies in the diagnosis of rotator cuff disease can be achieved (4,5,6). The other huge advantage of the use of MR imaging is the global assessment of all shoulder structures.

Nevertheless, there are some important difficulties, which have to be known by the radiologists. Indeed, there are difficulties like claustrophobia and contraindications owing to metallic implants and electronic devices, cost, and accessibility, which are the common lot of MR imaging. But for shoulder, some studies have shown that MR imaging is not without any serious technical limitations like patients movements due to shoulder pain because of the position, the magic-angle effect (fig.2) and possible partial volume effect (which are two important difficulties because of the curved part of tendons (7,8,9)), but also some problems inherent to the structure of the rotator cuff. The cuff has a complex anatomy (10,11) with a lot of layers and interconnections as we can see on the figures n°3 and n°4, for example supraspinatus and infraspinatus tendons have common crossed fibers (12). All these difficulties create an important intra and inter-observer variability (13,14), especially for non-specialized radiologists in musculoskeletal system.
Defined imaging techniques and protocols are important to minimize such operator dependence.

Otherwise, the first tendon of the rotator cuff injured is supraspinatus tendon because of its position; its complex curve and its mobility depend of the humeral position (fig. 5). There is also a lack of vascularisation in the deepest part of the tendon with difficulties for regeneration. Most of the rotator cuff injuries found by imaging techniques concern the supraspinatus.

Currently, MR protocol is based on gleno-humeral joint study composed of strict axial, oblique coronal and sagittal (based on the axis of the humerus) planes.

We saw in previous paragraphs that US has the advantage of imaging the tendons in their two orthogonal planes with a good spatial resolution, and that supraspinatus tendon seems to be the first tendon concerned by injuries. We attempted to apply a similar methodology to MRI of the most movable and weakest tendon, the supraspinatus tendon with a new slice placement by reducing technical limitations like magic angle and partial volume effect.

The main objective of our study is to compare the diagnostic performance of a new specific supraspinatus angled sagittal T2-weighted sequence labelled « of cuff » to that of our standard MRI protocol in detection of rotator cuff injuries.

Then, we will assess if this new sequence is easier than the classical protocol for the identification of each tendon path and for the characterization of the tears.

**Images for this section:**
Fig. 1: Fibrillar structure of supraspinatus tendon studying by ultrasonography.

Fig. 2: Coronal MR images in T2-weighted sequence focused on the supraspinatus tendon illustrating the magic-angle effect: increased signal on the curved part of the tendon disappearing after different shoulder position.
Fig. 3: Rotator cuff anatomy: anterior side.
Fig. 4: Rotator cuff anatomy: superior side.
**Fig. 5:** Figures: drawing showing the mobility of the supraspinatus tendon based on the humeral position. On the left: Internal rotation: supraspinatus trajectory facing downwards. On the right: External rotation and abduction: the supraspinatus tendon seems to be more straight.
Methods and materials

Conducted at a teaching hospital in Tours France, our study included all patients referred for MRI examination for possible rotator cuff injury since February 2014.

Our standard MRI protocol (1.5 or 3 Tesla, Avanto, Siemens) after locator in the three planes included:

- Fat-Sat T2-weighted strict axial sequence, based on the scapular orientation (fig.6),

- After greater tubercle location, an oblique coronal Fat-Sat T2-weighted sequence in the plane of the suprapinatus tendon (fig. 7,8,9),

- A strict sagittal Fat-Sat T2-weighted sequence based on the axis of the humerus and the coil (fig.10 and 11)

- A strict sagittal T1-weighted sequence (fig.12).

We added a sagittal T2-weighted sequence with Fat Sat labelled "of cuff", positioned orthogonally to the convex part of the supraspinatus tendon on the humeral head located on the coronal sequence (fig.13 and 14).

A dedicated shoulder phased-array coil was used for signal detection. The humerus was positioned in slight external rotation and abduction (near 20°).

The parameters are noted in table n°1.

We included all major patients without standard contraindications after oral information and oral consent.

We obtained agreements of the ethics committee and the CNIL (Commission nationale de l'informatique et des libertés, France).
Since February 2014, we've included 66 patients. Their mean age is 50.8 years old (between 17 and 76 years old).

There are 34 men and 32 women.

We then compared the standard protocol to the additional sagittal T2 sequence for diagnostic performance.

Four radiologists in blinded analysis currently review each shoulder examination: two senior radiologists specialized in musculoskeletal system, one resident in radiology and one general radiologist.

They have to choose for each tendon (supraspinatus, infraspinatus, subscapularis and biceps) in each protocol (standard protocol or « of cuff » sequence) between the four following answers: no tear, tendinopathy, partial-thickness tear or full-thickness tear (definitions summarised in table n°2). Answers are then collected in an Excel table. There is at least one month between the reading of the standard protocol and the reading of the new sequence.

Then, they have to say if the location of tendons and characterization of tears are easier with the new sequence or not.

We can compare the performance of the both protocols by considering that the standard protocol is our reference.

After this data collection, we try to track the future of patients (surgical reports, other additional examination, and arthroscopy reports) to detect possible differences with MRI imaging.

This study is still in progress.
Fig. 6: Axial sequence in T2-weighted fat-suppressed sequence.
Fig. 7: Anatomical landmarks to place accurately coronal sequence.
Fig. 8: Slice placement for coronal sequence.
Fig. 9: Coronal T2-weighted fat-suppressed sequence with location of supraspinatus distal part.
Fig. 10: Slice placement for standard sagittal sequence in humeral long axis.
**Fig. 11:** Standard sagittal T2-weighted fat-suppressed sequence.
Fig. 12: Sagittal T1-weighted sequence.
Fig. 13: Slice placement for sagittal sequence labelled "of cuff": slices are disposed orthogonally to the supraspinatus distal part.
Fig. 14: Sagittal T2-weighted fat-suppressed sequence labelled of cuff. The difference between the anterior and the posterior surfaces of the greater tubercle (GT) is easy on this slice.
### Table 1: Sequence parameters used for our study.

<table>
<thead>
<tr>
<th>Imaging parameters</th>
<th>Axial T2-weighted Fat-suppressed TSE</th>
<th>Coronal T2-weighted Fat-suppressed TSE</th>
<th>Angled Sagittal T2-weighted Fat-suppressed TSE</th>
<th>Standard Sagittal T2-weighted Fat-suppressed TSE</th>
<th>Sagittal T1-weighted TSE</th>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
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</table>

**No tear** | No signal abnormality in T2-weighted sequence

**Tendinopathy** | Non fluid hyper intense signal in T2 weighted sequence
Or heterogeneous signal in T2 weighted sequence (fig.15)

**Partial-thickness tear** | Hyper intense fluid-like signal in T2 weighted sequence constituting a partial disruption of the tendon involved the articular or bursal surface (fig.16 and 17)

**Full-thickness tear** | Hyper intense fluid-like signal in T2 weighted sequence with complete disruption from the bursal to the articular surface (fig. 18)

### Table 2: Definitions of the different possible appearances of tendons.
**Fig. 15:** Tendinopathy affecting the distal part of the supraspinatus tendon in coronal T2-weighted fat-suppressed sequence.
Fig. 17: Figures 16 and 17: Partial-thickness tear: partial disruption affecting the distal part of the infraspinatus tendon on its inner face in coronal and sagittal "of cuff" T2-weighted fat-suppressed sequences.
Fig. 18: Full-thickness tear affecting the supraspinatus tendon with retraction (*) of this one in coronal T2-weighted fat-suppressed sequence.
Results

The intermediate results, noted in June 2014 showed some important points.

First of all, radiology technicians need a quite long period to learn the new protocol because the slice placement has been really different than the standard use. That's why, quality of the exams during about a month, was poor. They had to break away from their own practices and radiologist had to teach them the good slice placement.

36 MRI have been done.

On these exams, only 31 respected the protocol, 19 of them showed rotator cuff tears.

Radiologists found that the interpretation of 13 of them was easier with « cuff » protocol specially to identify each tendon (supraspinatus versus infraspinatus). New protocol seems to increase sensivity to detect little tears (Fig. 19 to 28).

Otherwise, there isn't any loss of information compared to the standard protocol.

Images for this section:
**Fig. 21:** Figures 19,20,21: Coronal T2-weighted fat-suppressed images: there is possibly a tear (*) at the distal part of supraspinatus or infraspinatus tendon. It is quite difficult to specify the localization on this sequence alone.
Fig. 22
Fig. 23

Limit between anterior and posterior surfaces?
Fig. 24: Figures 22,23,24: Standard sagittal T2-weighted fat-suppressed images: we can see that there is at least a partial-thickness tear of the supraspinatus distal part but we cannot exclude a possible thin tear of the infraspinatus distal part. The fluid-like signal seems to reach the infraspinatus anterior fibers.
Fig. 28: Figures 25,26,27,28: Sagittal "of cuff" T2-weighted fat suppressed images: we can more easily assert that the tear is a full-thickness tear injuring supraspinatus distal part but the infraspinatus tendon seems to be spared. The limit between both tendons is more evident by visualizing the two sides of the greater tubercle. Supraspinatus tendon is viewed in a perpendicular way what makes the characterization of tears clear.
Conclusion

Our purpose was to be closer than US methodology with MRI technique to improve performance in rotator cuff study especially for the supraspinatus tendon by reducing technical limitations like magic angle and partial volume effect.

This approach has already been considered by a workgroup of radiology of University of Wisconsin Hospital in 2001 and by a Korean team in early 2014 with inconsistent result. Tuite and al. (15), showed in 2001 that there was a slight improvement in the diagnostic accuracy for partial-thickness tear with the angled oblique sagittal sequence but only for one reader; in 2014 Kim and al. (16) showed there was no significantly different diagnostic performance in detection of partial and full thickness supraspinatus tendon tears compared with standard MRI protocol. But there are some differences between these studies and our work: indeed, we study the entire cuff and not only the supraspinatus tendon even if it remains central in developing this work. Most of our MRIs are done on a 3-T MRI. Tuite's study (15) is becoming to be quite old and we know that MRI performances are in perpetual improvement. Our reference is the standard protocol and not the arthroscopy considered in the other studies like the gold standard. Moreover, if the main objective is to compare diagnostic performance, there are some important different points like the ease of reading the exam even for a non-specialised radiologist in musculoskeletal system.

We showed that it was complicated to break away from the standard use but after a learning time, we can hope a good quality of this exam. Based on our first results, we can say that interpretation of abnormalities seems to be easier with the « cuff » protocol because of a better location of each tendon and a better facility to identify little injuries.

These first impressions have to be confirmed at the end of our study. It seems to give a quite important hope to facilitate shoulder study for exigent radiologists, who believe that MRI imaging is operator dependent as the US study is usually considered. It could even help those who aren't specialised in musculoskeletal system. We can expect a decrease of inter and intra-observer variability and a better quality of this exam.

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References


