Ultrashort Echo Time Imaging of the Shoulder

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Introduction

Recently, MRI of tendon and tendon insertions using Ultrashort echo time (UTE) methods is receiving increasing attention. Although initial results have been obtained applying UTE techniques throughout the body, e.g. in spine, knee and ankle imaging (1-3), reports on UTE of the shoulder so far have been sparse. A key factor here is that several tendons that are part of the rotator cuff show severe magic angle (MA) effects. The magic angle artifact in ordered tissues is manifest as an apparent prolongation of T2 in the absence of dipolar coupling (4). In conventional imaging of the shoulder this results in an artificially high signal of in particular the supraspinatus tendon, when echo times are chosen too short. However, magic angle effects do even play a role in UTE imaging (5,6). The purpose of this study is to investigate the magic angle artifacts on UTE imaging in the shoulder, and to demonstrate the feasibility of UTE imaging of the shoulder without magic angle artifacts on a vertical field open MR system.

Materials and Methods

The most basic UTE sequence consists of an excitation pulse, a delay that is disputably referred to as TE (7), followed by sampling of the free induction decay. Long T2 suppression can be achieved by subtraction of a later echo or by appropriate prepulses. The MA effect can change the T2 of a tissue by an order of magnitude. Typically, for tendon the T2 may change from ≈ 1 ms to several milliseconds. Orientational sensitivity may be introduced by the second echo that has a TE of several ms, i.e. of the order of T2 of the tendon at the MA. An influence can be expected from the excitation RF pulse, since long T2 tissues "see" more of the pulse than short T2 tissues. A third handle on the MA effect is the field orientation; on a vertical field system the suprapinatus tendon is no longer at the MA.
A healthy volunteer was imaged on a cylindrical 1.5 T system (Philips Achieva 1.5T, Best, Netherlands), using a dual echo UTE sequence TR/TE1/TE2 = 9 ms /80 µs/4.6 ms. K-Space was sampled using a koosh-ball trajectory on a 144 matrix with 1 mm isotropic resolution and an acquisition window of 1.2 ms. The sequence was repeated with the same settings on a 1.0T vertical field system (Panorama 1.0T) with a slightly longer TE1 of 100 ms. TE2 was 6.9 ms to have water and fat in-phase. The excitation pulses were nonselective block pulses of 40 µsec and a flipangle of 10 degrees. On the 1.5T cylindrical system, the influence of excitation pulse duration was studied using a single echo UTE sequence with RF-pulse durations of 40 – 660 µs.

Results

On a cylindrical 1.5T system the supraspinatus tendon shows high signal on the first echo (fig. 1a). On the second echo (fig. 1b), the magic angle effect maintains this high signal in part of the tendon (thin arrow), whereas signal is absent in other regions. In the subtraction image this results in a low signal region in the tendon, and poor definition of the tendon in the image. Figure 1a shows that the first echo image is as good as immune to magic angle effects, and that the problem is introduced by the second echo that serves to suppress long T2 tissues. On the vertical field 1.0T system, however, there is a homogeneous decay of tendon signal in the second echo image at 6.9 ms (fig. 1e, thick arrow). The subtraction image then shows the supraspinatus tendon in positive contrast, as well as other short T2 structures, e.g. the glenoid labrum and the capsular ligament.
The single echo UTE sequence on the cylindrical system showed no apparent signal variations in the supraspinatus tendon as a function of RF pulse duration that could be attributed to MA.

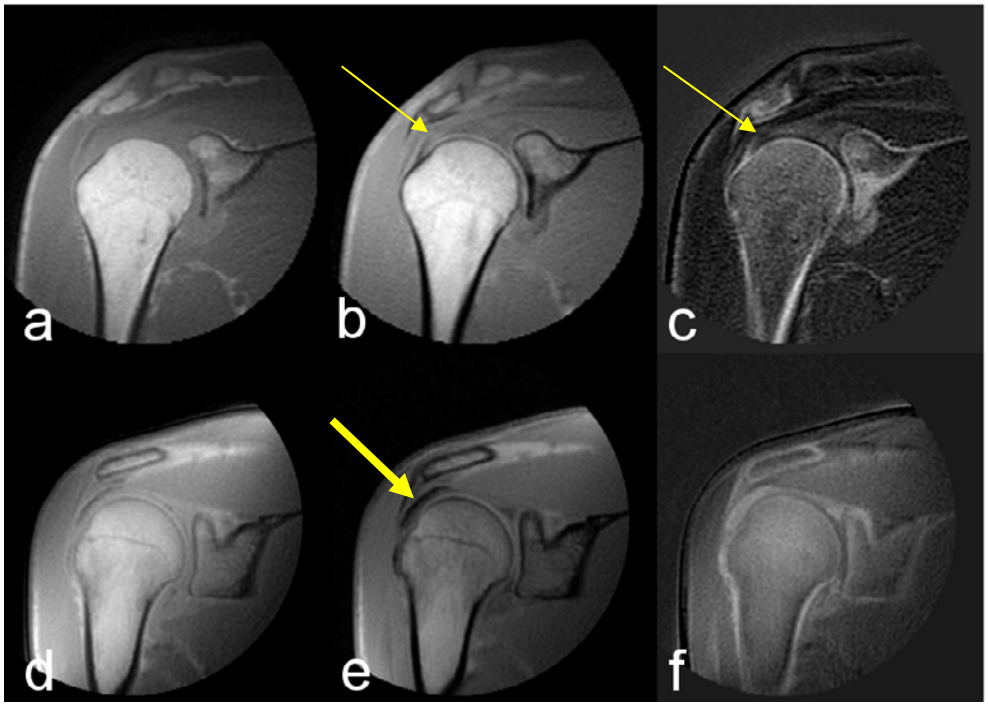

Figure 1: UTE imaging of the shoulder. Images acquired on a cylindrical 1.5T system: first echo (a), second echo (b) and subtraction image (c). Images acquired on a vertical field 1.0 T open system: first echo (d), second echo (e) and subtraction image (f). Labrum, supraspinatus tendon and capsular ligament are visualized.

Discussion and Conclusion

For MA effects in UTE, the time scale of the sequence components is essential: on the longest time scale of several ms, the second echo introduces severe MA artifacts for the supraspinatus tendon. RF-excitation in this study had a time scale of up to 600µs and did not have an apparent effect. Note that signal with a T2 shorter than about 500 µs is progressively filtered out of the image by the mere duration of the acquisition window (8). The echo time of the first echo, finally, is on an even shorter time scale, and the first echo showed immunity to MA effects in these experiments. MA effects on the first echo were reported by Bydder et al. (6), however, and it is conceivable that MA effects enter the first echo image through the duration of the acquisition window or the duration of RF pulses for certain short T2-species with orientation dependence. Long-T2 suppressing prepulses were beyond the scope of the present work, but based on their duration MA sensitivity can be expected (9). Field direction had a direct impact on the MA effect: it was demonstrated for the first time to our knowledge, that a vertical field system is advantageous for UTE imaging of the shoulder tendons because it minimizes MA artifacts.

References

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