dGEMRIC in the presence of metal: improving T1 maps at 3.0T

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Introduction

Delayed Gadolinium-enhanced MRI of cartilage (dGEMRIC) is a powerful tool for investigating changes in cartilage health that has been used in a number of applications. An important potential new application of dGEMRIC is assessing the effect of surgery (e.g osteotomy) on cartilage health. It is not clear how to implement dGEMRIC effectively to assess cartilage near metal surgical implants. While using titanium reduces artifact compared to other non-magnetic metallic materials (e.g. stainless steel), a significant distortion in the images and T1 maps remains. The presence of metal causes variations in both B_1 and B_0. Because there are theoretical and practical limits on the performance of adiabatic inversion pulses in the presence of high B_1 and B_0 distortions we evaluated the quality and accuracy of saturation recovery (SR) spin echo sequences as well as inversion recovery (IR) sequences for quantitative T1-mapping. The Metal Artifact Reduction Sequence (MARS) based on view-angle tilting (VAT) has been used to reduce the extent of B_o artifact in clinical imaging[1], but has not been applied in a T1 mapping series.

Research question: Can we improve the performance of dGEMRIC in the presence of metal at 3T using SR and MARS?

Methods

We created a phantom containing gadolinium-doped saline to which we could add a surgical implant with four screws (Arthrex High Tibial Osteotomy plate, titanium) (Figure 1). Images were taken using a Philips Achieva 3T MR scanner. Two T1-mapping techniques were employed: saturation recovery (SR) and inversion recovery (IR), each using FSE sequences. The plate was oriented along the B_0 direction with the screws perpendicular (the same orientation as in a patient when lying in the scanner). Each series was completed both with and without metal, and with and without MARS.

Series	TR	TE	TI	Matrix	Slice thickness	FOV
IR	2200 ms	15 ms	1800, 1200, 700, 400, 200, 150, 100, 50 ms	256 x 256	3 mm	100x100 mm
SR	1800, 1200, 700, 400, 300, 200, 150, 100 ms	15 ms	N/A	256 x 256	3 mm	100x100 mm

Table 1: Scan parameters for IR and SR series.

T1 maps were produced by curve fitting at each pixel using MATLAB. We defined a region of interest (ROI) containing the metal and excluding air surrounding the phantom. Histograms were created with 10 ms wide bins (T1 range 0-1000 ms) and normal T1 ranges were found from images without metal.

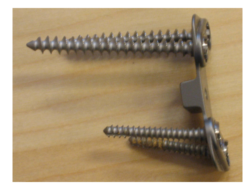

Figure 1: Titanium HTO plate

Results

Without metal, the normal ranges of T1 in the ROI were measured as 580-620 ms (IR, 99.56% of pixels) and 520-680 ms (SR, 96.79% of pixels). Qualitative comparison shows that using the SR series reduced the extent of the artifact substantially over the IR series, both with and without MARS (Figure 2). MARS visibly reduced the extent of the artifact in the IR map, while the effect on the SR map was more subtle (clear improvement may be seen at the centre of the plate, between the screws). The SR series also produced a larger range of normal T1 values in the homogeneous medium (range of 160 ms versus 40 ms).

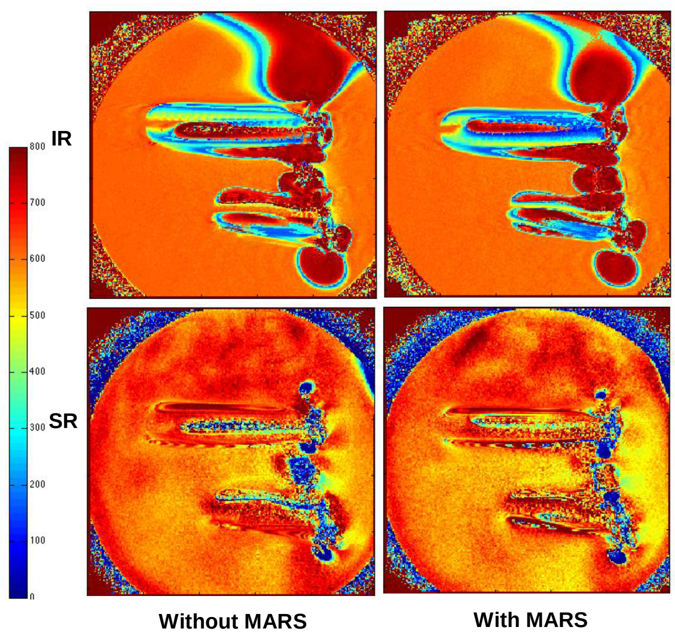

Figure 2: T1 maps. Clockwise from top left: IR without MARS, IR with MARS, SR with MARS, SR without MARS

Discussion

The two methods of reducing metal artifact (SR v. IR, and MARS) each showed some improvement to T1 maps with metal. It is clear in the IR map that MARS reduced the extent of the artifact (B_0 effect) but did not affect the apparent T1 calculated within the edges of the artifact (B_1 effect). It is also clear that using an SR series reduced the extent of the artifact as well, but the SR series caused more variability in calculated T1 values outside the artifact area. MARS slightly improved visualization of the plate on the SR map, and it visibly reduced the extent of the artifact on the original images.

The variability in T1 values produced by the SR series may limit the ability to differentiate normal from degenerated cartilage. The range of T1 measurements with IR dGEMRIC at 3T has been reported as 400-900 ms on small groups of normal and OA volunteers, with the ranges of each group overlapping (normal cartilage higher, degenerated cartilage lower)[2]. Further spread in T1 values in each group may reduce the sensitivity of this method.

In summary, the SR approach is clearly superior to the IR approach in the presence of B_1 artifact. The effect of MARS is less dramatic, but it should permit visualization of tissue, and presumably measurement of T_1, closer to the metal implant.

References

1. Kolind et al., JMRI, 2004, 2. McKenzie et al., JMRI, 2006