SWIFT Imaging of Osteochondral Repair in Equine Model with correlation to µCT

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Introduction

MRI provides unique means for assessing the properties of articular cartilage and bone; however, the limited signal from calcified structures imposes difficulties in conventional measurements. A recently introduced method SWIFT (1,2) overcomes these difficulties by capturing signal also from spins with extremely short T_2 relaxation times. In the present study, SWIFT was utilized for the assessment of cartilage and bone properties of spontaneously repaired cartilage defects in an equine model. For reference high-resolution µCT was applied (3).

Materials and methods

Osteochondral lesions of 6 mm in diameter were surgically created in one of the intercarpal joint (on os carpale IV) of 24 months old equines (n=6). Chondral lesions avoiding penetration of the subchondral plate were similarly created in the contralateral joint. The lesions were let to heal spontaneously for 12 months. After sacrificing the horses, osteochondral plugs (14 mm in diameter that included the cartilage defect) were harvested and stored at -20° until processing. Surgical marks were made to plugs to identify the ROI from the images. The experiments were approved by the local authority.

The specimens were imaged at 9.4 T (Oxford instruments Plc, Witney, UK) with a 19 mm quadrature RF volume transceiver (RAPID Biomedical GmbH, Rimpar, Germany) and Varian Direct Drive console (Varian Inc. Palo Alto, CA, USA). The parameters of the SWIFT sequence were as follows: total number of views was 144000 with a FOV = 35 mm, BW = 62.5 kHz, 256 complex points (137 µm isotropic resolution) and a nominal flip angle of approximately 5°. Fat saturation was obtained by applying an HS4 inversion pulse centered at fat resonance after every 16 views; water saturation similarly by applying the saturation pulse at water resonance. Unsaturated images were acquired with identical timing parameters. In addition to SWIFT, proton density (PD) weighted image and T_2 relaxation time was measured using an FSE sequence in a 1-mm slice covering the lesion site. For reference, the samples were imaged using a high-resolution µCT scanner (SkyScan 1172, Aartselaar, Belgium) with isotropic resolution of 20 µm, 100 kV tube voltage and 100 µA current. Five frame averages and 180° rotation with 0.700° step was used. SWIFT and µCT images were reconstructed off-line using LabVIEW and NRecon programs, respectively. For comparison between SWIFT and µCT images, the 3-D datasets were re-sliced at the same locations using the landmarks on the samples. The slices were finally averaged over a thickness of 0.7 mm

Results and Discussion

The native cartilage and repair tissue appear high in signal on SWIFT images and the delineation of deep cartilage from calcified cartilage and subchondral bone is superior as compared to PD images (Figure 1). Sample 1 shows the chondral defect being filled with repair tissue without alterations in bone, as evident from PD, SWIFT and µCT images. In Sample 2, the defect reveals the replacement of subchondral bone with repair tissue with hyperintense signal on SWIFT, low in fat protons according to the fat saturated SWIFT image, relatively short T_2 relaxation time and void of mineral according to µCT. There is a small focus of low SWIFT signal within the repair tissue that is seen as a calcification on the µCT image (red arrow). Sample 3 shows hypo-intense SWIFT signal in the bone under the osteochondral defect (blue arrow), which proves to have dense bone on the corresponding µCT image. This area is particularly well highlighted on the fat-saturated SWIFT image lacking signal in the area of the dense bone.

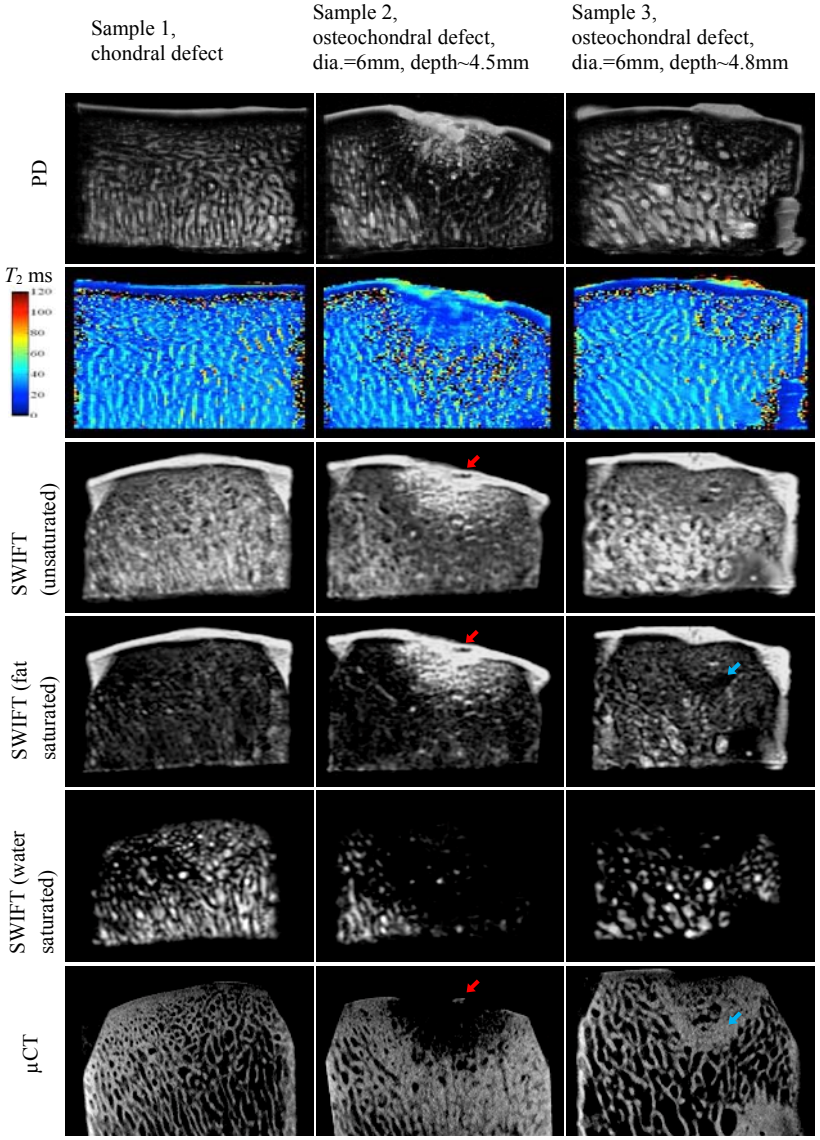

Figure 1. Proton density weighted images, T_2 relaxation time maps, unsaturated SWIFT images, SWIFT with fat saturation and water saturation and µCT images of three representative cases with chondral and osteochondral lesions. The SWIFT images and µCT images were re-sliced from the 3-D data set to the same location using surgical landmarks.

SWIFT shows superior delineation of cartilage from calcified structures. Furthermore, it reveals a high level of detail in calcified structures of tissue. It appears to provide complementary information on the filling of the subchondral bone defect. Differential saturation of fat and water further sensitizes the SWIFT technique to reveal osteochondral structures in normal and repaired tissue.

References

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