SWIFT positive contrast technique for rat knee bone imaging at 14 T

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Introduction:

This work describes a comparison of ex-vivo MRI at high resolution in a clinically relevant model of antigen-induced arthritis (AIA) in rat. A GRE method is compared to the emerging SWIFT (1-3) imaging method at 14 T in application to this model. This represents feasibility for the first study at 14 T and of small rodent bones by SWIFT.

Methods:

Animal handling and model: Female Lewis rats (n=5, Janvier, France), weighing 150-175g and aged two months at receipt, were used in this study. Ethical committee approval was obtained for the protocol and animals were kept in the institutions animal facility with free access to food and water. Rats were sensitized and given antigen-induced arthritis in the right knee. These knees were taken after sacrifice at various timepoints in the disease progression and imaged ex vivo at 14 T.

Magnetic resonance imaging: Scanning used Agilent/Magnex 14 T preclinical scanner and an in-house constructed 2cm loop coil. Parameters for a conventional 3D gradient echo sequence included: TR/TE 15/6ms, flip angle 20°, isotropic resolution 62.5 µm, 4 averages, 1 hour scan time.

SWIFT (4-6) acquisition parameters were: hyperbolic secant pulse order 2 with 64 acquisition gaps and 16x shape oversampling (5), acquisition of 192 data points after the pulse, 40 mm FOV, 512^3 reconstruction matrix for 3D isotropic resolution of 62.5 µm. The TR was 4.4 ms, flip angle 8°, 262k isotropic radial views, and total scan time 20 min. Nominal dead time between end of pulse element and beginning of acquisition in each gap is 4 µs. Received data is 4x oversampled and Fourier domain processed with correlation to the transmitted pulse shape to final bandwidth of 62.5 kHz and 224 center out k-space points. Gap cycling is applied for sideband artifact reduction (6). All SWIFT acquisition and image reconstruction used CMRRpack v0.4f (http://www.cmrr.umn.edu/swift/).

µCT images for comparison used a Skyscan-1076 (Skyscan, Aartselaar, Belgium) with cone beam x-ray source and a CCD camera. The following parameters were used: 65 kV anode voltage, 180µA, 0.45° rotation step, 316ms exposure time per view, resolution 35µm in 20 minutes. Each rat received an estimated dose of 0.7 Gy during the image acquisition.

Results:

Comparison of three knees at different AIA timepoints shows the differences the extent of bone erosion and changes in the bone matrix. In cases where the bone structure becomes largely hypointense on GRE, the SWIFT offers the added advantage of visualization of the short T_2 bone species and better visualization of the bone matrix, despite the same image resolution and shorter scan time.

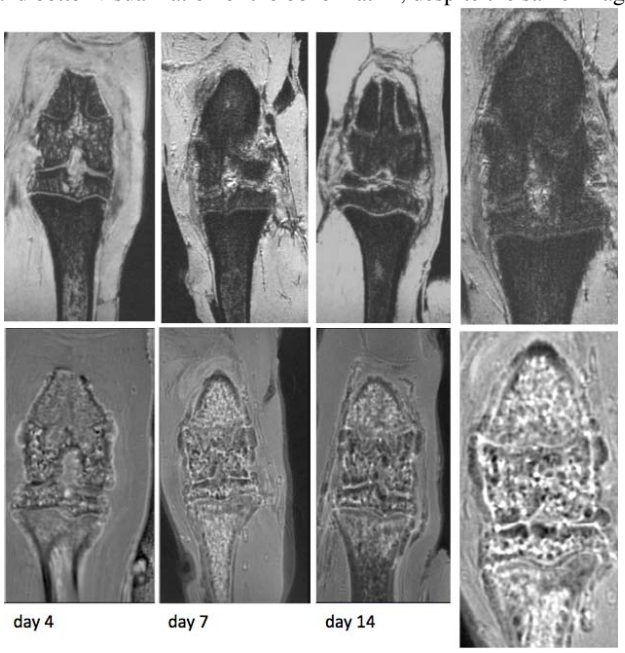

Figure 1. 14 T GRE and SWIFT in a knee with varying bone erosion at timepoints up to 14 days after AIA induction. Resolution 62.5 µm. 3 showing the complete knee and synovial structure and a zoomed example (day 7) to see the bone detail.

GRE: *At the later timepoints, the bone matrix and thickened ligaments all appear as hypointense signal.*

SWIFT: *Differences in the bone matrix are clearly visible and distinct from the surrounding ligament structures.*

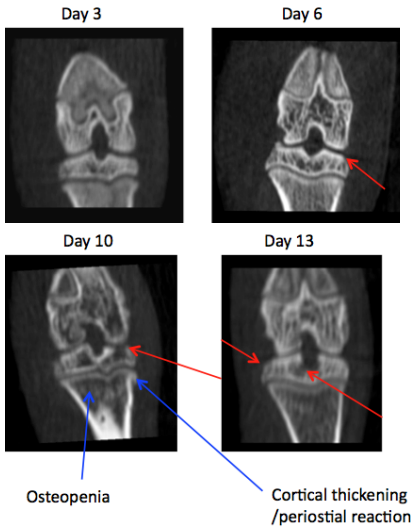

Figure 2. µCT images of different timepoints as a reference standard showing the effect of the model on the bone structure. Resolution 35 µm.

µCT: *In comparison, uCT can be used as a gold standard for bone matrix, but does not also show the soft tissue that can be seen in MRI.*

Discussion and Conclusions:

Despite the fact that ligaments and muscle contrast is not high on the SWIFT images there is a clear difference in the bone matrix visualization making this a highly interesting and complementary MR technique to completely assess articular disease. We present a feasibility study of ex-vivo rodent knee by application of the SWIFT sequence at 14 T.

References :

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