The ultrastructure of bone using selective saturation in SWIFT at 9.4 T

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INTRODUCTION

In musculoskeletal imaging there is an abundance of intrinsic water and fat interfaces leading to problems of image blurring. SWIFT (Sweep Imaging with Fourier Transform) [1] is a novel imaging sequence having virtually zero TE and is well suited for musculoskeletal applications. However SWIFT, as well as other radial acquisition methods are prone to chemical shift blurring artifact. Here we introduce a selective fat/water acquisition strategy in SWIFT and demonstrate the suppression of the blurring effect due to fat/water interfaces. Selectively saturated SWIFT images show resolved bone ultrastructure including lamellar bone organisation, tendon-cortical bone interface and trabeculae.

METHOD

The regular SWIFT sequence is a continuous series of similar frequency-modulated (FM) pulses where gradient values are changing smoothly from pulse to pulse. The acquisitions take place in the gaps of the FM pulses [2] during established steady-state of magnetization. To achieve chemical-shift-selective suppression, a magnetization preparation (MP) block is repetitively incorporated in the SWIFT sequence. To avoid disturbance of the steady state for the non-selected spins, which are imaged, the length of MP block is kept much less than the spin's T1 values. Likewise, to achieve suppression of the selected spins, the time between blocks must be less their T1 values. Figure 1 presents the modified SWIFT sequence. In this case, the MP block is composed of a long adiabatic full passage (180°) pulse centered on selected resonance. Two crusher gradients applied before and after the pulse are used to avoid T2 interference.

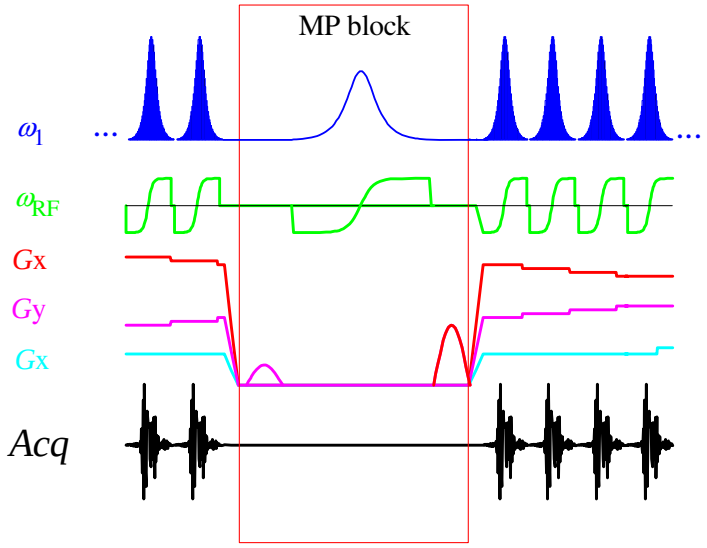

Fig.1

EXPERIMENT AND DISCUSSION

Images of in vitro specimens from lamb tibia were acquired at 9.4 T using SWIFT. The images reveal the Achilles tendon (T) adjoining the periostium and the outer layer of the compact cortical bone (C) (Fig.2). Interdigitation of tendon fibers with the compact cortical bone is notable at the tendon/bone interface. The interlacing trabeculae of the inner layer of medullary or cancellous bone (M) are enclosing cavities that contain the fatty bone marrow.

The data reveal the blurring of interfaces when using "classical" SWIFT imaging (Fig.2a). On the other hand when using water (Fig.2b) or fat (Fig.2c) suppression, the interfaces appear sharp and the respective components are clearly resolved. Note the blurring at the medullary or cancellous bone trabeculae and fatty bone marrow interface on the left (Fig.2a). After SWIFT image acquisition using water/fat suppression, there is a sharp delineation of trabeculae and bone marrow. Furthermore, the image on the right (Fig.2c) depicts the gain in S/N in the water containing ultralow T2 components, such as tendon (T), compact cortical bone (C), and medullary or cancellous bone (M).

The acquisition parameters: The total number of spokes (views) was 92000 (including positive and negative gradient direction), diameter of *FOV*= 2.5cm, b_{wmax} = 125 kHz, $\theta \approx 22°$, 256 complex points in radial direction, isotropic resolution is 0.098 mm, the total acquisition time of each images was 40 min.

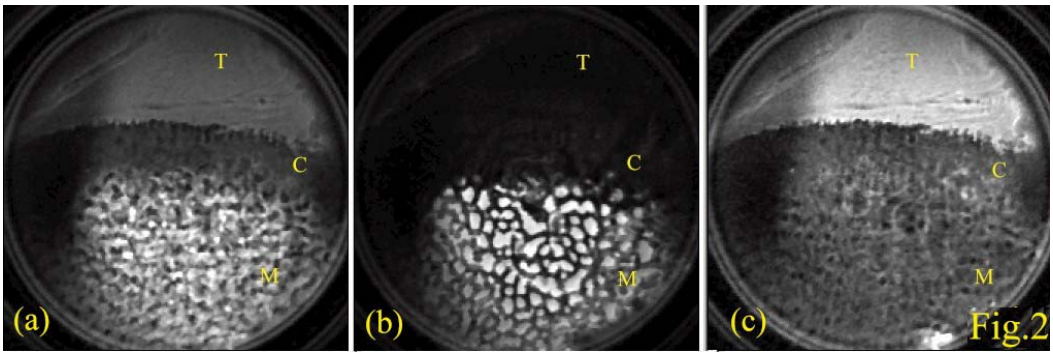

Fig.2

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