Dipolar Contrast Imaging Applied to In vivo Musculo-skeletal Imaging

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Introduction

The classical sequences used in MRI enable us to see liquid-like tissues (relatively long T_2) [1]. Less classical sequences like magnetization transfer or solid-state MRI techniques enable us to indirectly detect the solid-like protons (very short T_2) [2-3]. For the very first time, we present here a method to obtain high-resolution images of middle range T_2 protons, this images being obtained on a clinical scanner. We implement and use a variant of Magic Sandwich Echo (MSE) imaging [4] to selectively detect the protons moderately linked by dipolar interaction [5,6]. In vivo high-resolution images are obtained, showing the advantage of this technique in musculo-skeletal imaging. This technique enables us to exhibit protons linked to macromolecules by dipolar interaction and that, independently of any notion of magic angles properties of the tissue imaged ie independently of the macroscopic anisotropy of the tissue.

Methods

We implemented a modified MSE sequence to ensure the best refocusing of the signal and reduce the effect of the imperfections of the RF pulses [7]. (Figure 1) on a 1.5 Tesla GE Signa scanner.

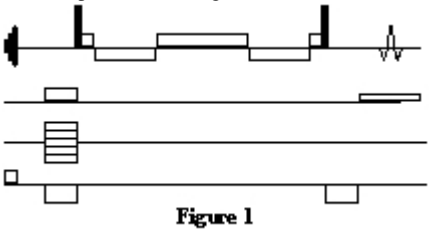

Figure 1

The in vitro tests were conducted using a solenoidal coil built in-house. Samples of bovine cartilage and tendon were excised and imaged using a spin echo and MSE sequence. (T_E=30ms, T_R=2.5s, the total flip angle of the MSE burst was set to 1440 degree). The ratio of the spin echo and MSE images were obtained to generate images depicting dipolar contrast [5-7]: $I_{Dipolar}=(I_{MSE}-I_{SE})/I_{MSE}$. The mean ratio of dipolar interaction was obtained for each of the different tissues imaged. The histopathological analysis of the samples was also done. In vivo images of the human knee were obtained using a clinical phased array coil (USA instruments). We used a T_E of 40ms and a T_R of 2500ms. The total flip angle of the MSE burst was 1440 degrees.

Results

Figure 1 shows (a) the spin echo image and (b) dipolar contrasted image of two samples of the same tendon immersed in water. The sample on the right is a native tendon while the left one has been denatured. Under polarized light (c) the native tendon sample stained using haematoxylin-eosin (magnified 40 times) shows a strong anisotropy due to the collagen fiber orientation while we can note a complete destruction of the structural organization of collagen in the tendon denatured by heating(d). The destruction of fiber oranization decreases dramatically the dipolar ratio observed (from 42% to 11%). In vivo (Figure 2) we were able to produce a signal enhancement of 35% in cartilage and tendon, and an increase of 10% was observed in muscle showing that dipolar interaction is also present in tissues exhibiting no magic angle properties.

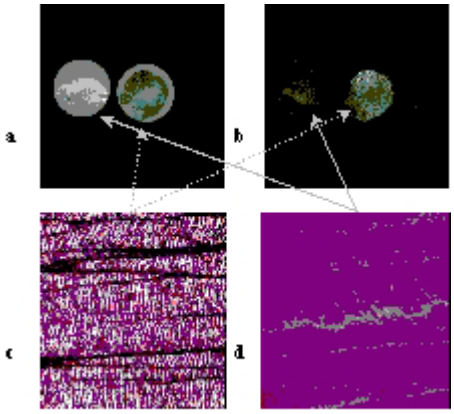

Image 1

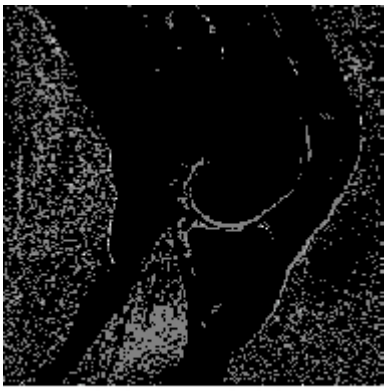

Image 2

Discussion

This technique is very promising for musculo-skeletal imaging. In vivo, it enabled us to clearly visualize the collagen present in cartilage, tendons and muscle while at the same time, the signal of liquid-like tissues was suppressed. This may have implications in studies assessing degenerative joint dieseases such as osteoarthritis.

References

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