Magic Sandwich Echo (MSE) relaxation and dispersion Characteristics of Bovine Achilles Tendon

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Introduction:

MR imaging of tendons, ligaments and menisci have a number of features in common. The dominant structure is type 1 collagen, which is the most abundant protein in the animal kingdom. The anisotropic orientation of type 1 collagen in tendon exhibits different signal intensities in T_2-weighted images when placed in parallel or perpendicular with respect to the external magnetic field, B_0. The different orientations of the collagen fibers provide multiple orientations for the inter-nuclear vector of the dipolar coupled water molecules to collagen with respect to B_0. This results in non-zero dipolar couplings between the protons of water molecules associated with collagen fibers, which leads to T_2 anisotropy and hence variation of signal intensity in T_2-weighted images.. The short T_2 components especially in tendons, ligaments and menisci are not detected or poorly detected with conventional T_2 –weighted spin echo (SE) sequences due to the existence of residual dipolar interaction. Using currently available T_2-weighted MRI methods, short T_2 species can be visualized by employing magic angle [1] or ultra-short TE pulse sequences [2]. While magic angle orientation of specimens is possible, this approach is not feasible for *in vivo* applications. In the case of ultra-short TE pulse sequences, special RF and gradient electronics (fast switching) is necessary. Recently, Magic Sandwich Echo (MSE) technique has been applied to refocus the residual dipolar coupling [3-5]. This was achieved by taking the increase in signal intensity between the MSE and SE images on a pixel by pixel basis to generate a dipolar contrast map. However, the refocusing efficiency depends on number of parameters such as T_2 anisotropy of the tissue as well as amplitude of the burst pulse. The purpose of this work is to measure the MSE relaxation and dispersion characteristics on a model system of bovine Achilles tendon.

Materials and Methods:

Bovine Achilles tendon specimens (n=3) were used for MR imaging. All the experiments were performed on an Oxford 4.7T horizontal bore magnet interfaced to a UNITY INOVA spectrometer (Varian, Palo Alto, CA) equipped with 12-cm gradients having a maximum strength of 25 gauss/cm. A 3.0 cm custom-built, solenoid radio-frequency (RF) coil tuned to 200.78 MHz was employed. A series of high-resolution MSE-weighted images were acquired by varying the length of the burst pulse as well as amplitude. Similarly, a series of T_2 –weighted images were also acquired using SE pulse sequence and both relaxation maps were computed by fitting the signal intensity to an appropriate signal expression using a linear least-squares method.

Results and Discussion:

Fig.1 shows the representative high-resolution axial T_2–and MSE weighted images of bovine Achilles tendon (TE+TSL=20ms). In MSE weighted image, the tissue structural components in three different regions can be clearly visualized when compared to T_2 –weighted image. Furthermore, MSE weighted image has ~75-100% higher signal to noise ratio (SNR) than the corresponding regions of T□-weighted image due to strong dipolar interaction. T_2 relaxation times range from 4-10ms whereas the MSE-relaxation times range from 13-19ms, at 250Hz (**Fig. 2**). The average MSE-relaxation times are approximately 100% higher, at 250Hz, when compared to corresponding T_2 relaxation times. We also observed MSE dispersion in Achilles tendon (**Fig. 2**).

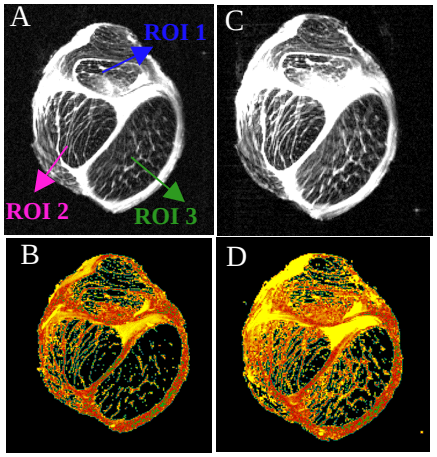

Figure 1. A) SE image B) SE map, C) MSE image and D) MSE map of bovine Achilles tendon. MSE -map was acquired at 250Hz. The imaging parameters are TR/TE=4000ms/(TE+TSL)=20ms, FOV=3.5cm×3.5cm, matrix=256×256, in -plane resolution =137μm×137μm, slice thickness =1.0mm.

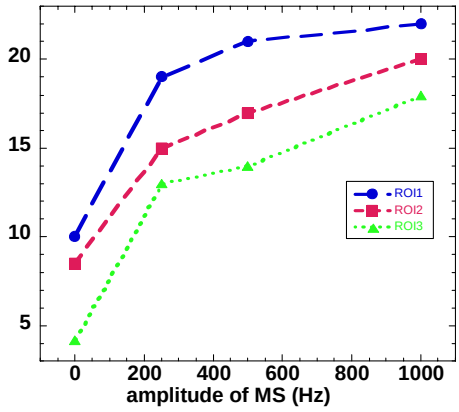

Figure 2. MSE relaxation time for three distinct ROI's is plotted as a function of burst pulse amplitude. The ROI's are shown in Fig. 1(A)

Conclusions:

The MSE technique can be applied to visualize the highly organized tissue micro architecture in Achilles tendon. Based on the MSE dispersion characteristics, one can optimize the burst pulse amplitude in order to refocus the residual dipolar interaction efficiently in tendon. This can be exploited for improved sensitivity for the detection of tendon pathology, which is currently limited by low sensitivity to early disease.

References: 1) Xia Y, Invest. Radiology, (2000), **35,** p 602-621, 2) Young IR, and Bydder GM, Physiol. Meas. (2003), **24**, R1-R23, 3) Rhim WK, et al Phys. Rev.B (1971), **3**, p684-695. 4). Matsui S, Chem. Phys. Lett. (1991), **179**, p 187-90. 5) Grenier D, et al JMR (2000) **147**, P 353-6.

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