Localized Application of Shear Waves to Tissue for MR Elastography via a Needle Device

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Introduction

Magnetic Resonance Elastography (MRE) is an MRI-based method for imaging the mechanical properties of tissue [1, 2]. The technique has been shown to be capable of depicting the spatial distribution of tension in skeletal muscle [3, 4]. The purpose of this work has been to adapt the MRE method to study hypotheses relates to physiologic basis of acupuncture, and specifically whether the introduction of a needle causes local reactive changes in the viscoelastic properties of muscle. In most MRE studies [1-5], shear waves are generated by applying mechanical motion to the body surface. With the introduction of an acupuncture needle, it is possible to introduce shear motion directly to adjacent muscle by vibrating the needle. The specific objective of this work was therefore to conduct an *in vivo* test of the feasibility of applying and imaging shear motion induced by a vibrating acupuncture needle inserted deep in the muscle.

Methods

This study was carried out in with a 1.5 T MRI system (Signa Horizon Echo Speed with version 5.51 software, General Electric Medical Systems, Milwaukee, WI, USA). A piezoelectric bending element was used as the driver device capable of attaching to a standard silver acupuncture needle and generating cyclic longitudinal motion along its axis. The needle was 0.4mm diameter, 50mm long and the cyclic longitudinal displacement 250-350um. The device was tested with a tissue-simulating gel phantom, a bovine muscle specimen, and in rat and rabbit leg muscles *in vivo*. Data acquisition parameters for the MRE studies were: TR 100-150ms, TE min full, flip angle of 30°, 256x64 acquisition matrix using a 14-20cm axial field of view. The acquisition time for each scan was 76.8-115.2s. The tested excitation frequencies were 50Hz, 100Hz and 150Hz. Wave images were Gaussian filtered to remove noise. Quantitative measurement of the shear stiffness was performed in regions of interest adjacent to the needle. Shear stiffness was calculated using the following equation: $\mu=\rho f^2\lambda^2$, where ρ is the density of the material, f is the excitation frequency and λ is the shear wave wavelength determined from the wave images. The density ρ was assumed to be 1.0g/cm^3 for tissue-equivalent gels and 1.1g/cm^3 for muscle.

Results

Figure 1 and 2 show the wave images of the gel phantom at 50Hz and 100Hz respectively. The estimated stiffness at 50Hz and 100Hz are 3.3 (SD: 0.9) kPa and 3.9 (SD: 1.6) kPa respectively. Shear waves induced by the needle in ex vivo bovine muscle at 100Hz are shown in Figure 3. Figure 4 shows a wave image in a rat leg at 150Hz. Wave images at 50Hz and 100Hz in the leg of an anesthetized rabbit are shown in Figure 5 and 6. The estimated stiffness at 50Hz and 100Hz are 6.1 (SD: 0.6) kPa and 6.3 (SD: 0.8) kPa respectively. Figures 1-6 show that shear waves are well depicted, without artifacts from the vibrating acupuncture needle.

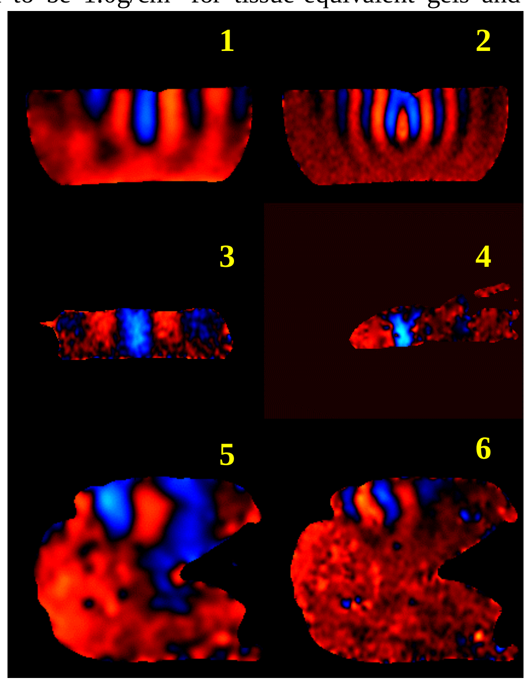

Figure 1-6 Wave image of (1) bovine gel phantom at 50Hz; (2) bovine gel phantom at 100Hz; (3) ex vivo bovine muscle and 100Hz; (4) in vivo rat thigh muscle at 150Hz; (5) in vivo rabbit thigh muscle at 50Hz; (6) in vivo rabbit thigh muscle at 100Hz

Discussion

The results show that shear waves can be locally generated deep in tissue by embedded acupuncture needles and that the waves are readily imaged with the MRE sequence without significant artifacts from the silver metal of the needles. The estimated stiffness values were consistent at various frequencies in the gel phantom and rabbit leg muscle. No heating effects were observed with the embedded needles during *ex vivo* and *in vivo* imaging. The results are a preliminary step toward applying the technique in the future to study the postulated local effects of acupuncture on the viscoelastic properties human muscle *in vivo*.

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