MR IMAGING OF TRANSIENT SHEAR WAVES INDUCED BY ULTRASONIC RADIATION FORCE

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Background

Magnetic Resonance Elastography (MRE) is a technique for quantitatively imaging the elasticity of tissue [1]. MRE utilizes motion encoding gradients (MEG) to image shear waves. The waves are typically induced by a vibrating driver in contact with the skin. The waves are heavily attenuated and may not reach the structure of interest. An alternative approach is to use the radiation force of a focused ultrasonic transducer to induce transient shear waves directly inside the body [2,3]. However, the use of focused ultrasound is associated with thermal effects that must be evaluated in order to design a safe MRE sequence.

Aim

Our aim is to estimate of the acoustic energy required to induce transient shear waves that are detectable by MRE, and to assess the corresponding thermal effects.

Methods

Transient shear wave images were acquired using a modified gradient echo sequence with an additional bipolar MEG. The sequence was implemented in a Siemens Symphony MR scanner equipped with a body coil. Typical acquisition parameters were TR=67 ms, 256x256 matrix, 20x20 cm field of view, slice thickness 10 mm, and TE varying between 14 and 25 ms depending on the duration of the MEG. The MEG direction was aligned with the acoustic axis of the transducer, and MEG amplitude was 18 mT/m. The radiation force was generated using a spherical shell air-backed transducer operated at 2.4 MHz (diameter 70 mm, focus 90 mm), with peak intensities in the range 180-2200 W/cm^2 and push duration in the range 5–17 ms. We tested the MRE sequences in five porcine liver samples. Finally, we assessed the thermal effect of the sequence using an EPI MR thermometry sequence [4].

Results

Figures 1 and 2 show typical transient shear wave images for push duration 8 ms and peak intensity 1500 W/cm^2. In these images, the wave was detectable in a 6x4 cm region in longitudinal view and 4x4 cm in coronal view, and the temperature rose by 6-8 °C during the acquisition of one phase image (figure 3). The shear wave velocity was approximately 1.2 m/s, corresponding to a shear modulus of 1.4 kPa.

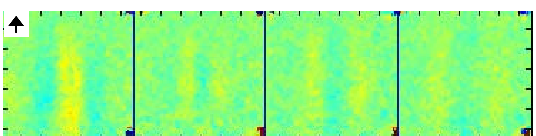

Fig. 1: Phase (displacement) images acquired at 4 ms interval (longitudinal view). The arrow indicates the MEG direction (phase range +/- π/4, each tick =1 cm)

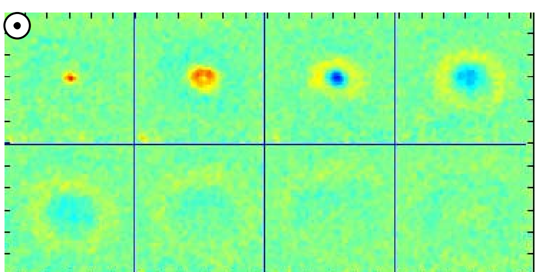

Fig. 2: Phase (displacement) images acquired at 4 ms interval (coronal view, phase range +/- π/4, each tick =1 cm)

Conclusion

The results confirm that MR imaging of transient shear wave induced by ultrasonic radiation force is possible, provided that heat accumulation is reduced to an acceptable level. The temperature measurements suggest that the number of ultrasonic pushes must be decreased by a factor of 10-20 to keep temperature increase below 1 °C. This objective is likely to be achievable using an EPI MRE sequence.

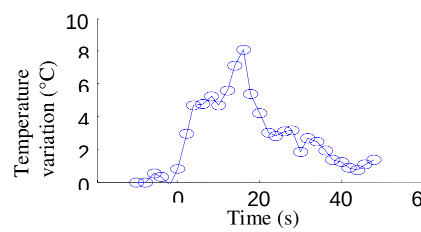

Fig. 3: Temperature variation at the focus of the transducer. Time 0–17 s corresponds to the acquisition of the wave image, and time 17–50 s to cooling.

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