High Frequency Mode Conversion Technique for Stiff Lesion Detection in Magnetic Resonance Elastography

Y. K. Mariappan[1], P. J. Rossman[2], A. Manduca[2], A. Romano[3], R. L. Ehman[2]

[1]Mayo Clinic college of Medicine, Rochester, Minnesota, United States, [2]Mayo clinic college of medicine, Rochester, Minnesota, United States, [3]Naval Research Laboratory, Washington, DC, United States

Introduction:

Dynamic Magnetic Resonance Elastography (MRE,1) is a technique for quantitatively mapping the stiffness of tissues by imaging propagating shear waves. One of the most prominent potential applications is for detecting and characterizing breast disease such as cancer (2-4). Typically, shear waves of frequency 50-200 Hz are induced (by either shear or longitudinal transducers) and are imaged as they propagate through the breast. However, with shear drivers, high frequencies result in strong attenuation and shallow wave penetration, while low frequencies result in poor resolution. With longitudinal drivers, better wave amplitude throughout the breast through mode conversion into shear waves at boundaries and interfaces is achievable, but it remains difficult to characterize stiff inclusions such as tumors because of the long shear wavelength in such materials at these frequencies. To address this issue, we investigated the use of much higher frequency longitudinal waves. We hypothesized that if a high frequency longitudinal wave is induced, shear waves would be present only in the stiffer regions (since they would be heavily attenuated elsewhere), and would have a shorter wavelength in the stiffer regions, allowing more accurate stiffness determination.

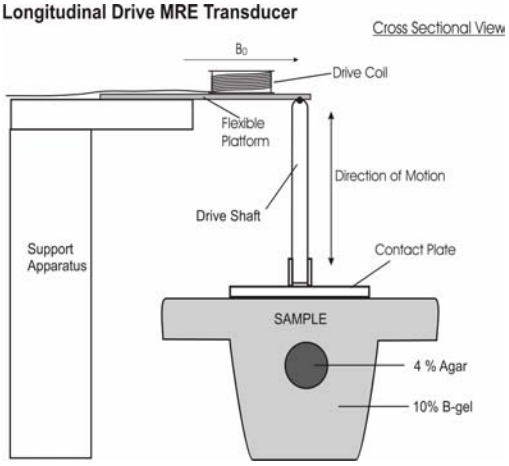

Fig 1. Schematic of the experimental setup showing the longitudinal transducer, the breast tissue simulating phantom of 10% B-Gel and the tumor simulating 4% agar gel inclusion

Materials and Methods:

A 1.5 T whole body scanner (GE Signa, Milwaukee, WI) and Helmholtz surface coil were used for the experiments. A breast tissue simulating phantom of dimensions 22 cm X 12 cm X 12 cm was made with 10% bovine gel (B-Gel) around a cylindrical inclusion made up of 4% agar, similar to tumor in stiffness, to mimic a breast lesion. A tapping electromechanical driver with a resistance of 6 ohms was coupled to the sample by a contact plate and induced longitudinal waves in the phantom. The experimental setup with the electromechanical transducer and phantom is shown in Fig. 1.

Results and Discussion:

Fig. 2A shows one phase image of shear wave propagation in the sample at a frequency of 200 Hz. At this conventional frequency, shear waves are visible throughout the sample and have a very long wavelength in the stiff inclusion. Fig 2B shows one phase image of the wave propagation at a frequency of 900 Hz. Here, since the frequency is higher, the shear waves in the soft background are highly attenuated. In the stiffer region the mode converted shear waves created at the inclusion interface are readily visible and we can detect the presence of a stiff region in the soft background. The wavelength of the shear wave in the stiff inclusion is also clearly depicted, and the stiffness calculated from this wavelength is close to the expected value of 150 kPa for this gel.

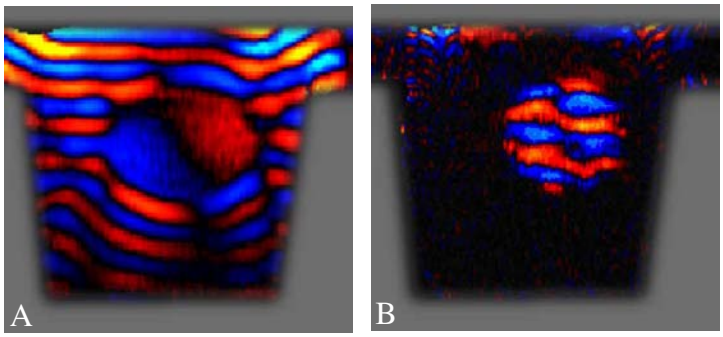

Fig 2. A. Wave image with the transducer driving at a frequency of 200 Hz. B. Wave image with the transducer driving at a frequency of 900 Hz. In this image we can selectively visualize the stiff inclusion due to the presence of shear waves. Sensitization is to motion in the left-right direction in both images.

Conclusion:

The result confirms the hypothesis that the stiff regions in a soft background can be detected by exciting with a high frequency longitudinal wave and imaging the mode converted shear waves that are present only in the stiff regions. The shear wave in the inclusion at high frequencies also has a much shorter wavelength than at conventional frequencies, which should allow more accurate stiffness determination.

References:

(1) Muthupillai et al., *Science* 269: 1789-1936, 1995. (2) Mcknight et al., *A J Roentgenology* 178:1411-1417, 2002. (3) Van Houten *JMRI* 17:72-85, 2003. (4) Sinkus et al., *Mag Res Med* 53:372-387, 2005.