ANALYSIS OF THE CAPABILITY OF TRANSURETHRAL MR ELASTOGRAPHY TO DETECT AND QUANTIFY LOCALIZED STIFFNESS CHANGES FOR PROSTATE IMAGING

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Introduction: MRI-guided transurethral ultrasound therapy is being developed as a minimally-invasive treatment for localized prostate cancer. The capability to identify target regions prior to therapy would provide an integrated diagnostic and therapeutic solution to the management of this disease. The unique location of this device offers possibilities to explore intra-capsular elastographic imaging with MRI. MR elastography is an imaging technique that is capable of characterizing tissues with respect to their mechanical properties and could take advantage of the known changes in tissue stiffness associated with prostate cancer. The technical feasibility of performing magnetic resonance elastography (MRE) with a transurethral actuator to produce stiffness maps (elastograms) of the prostate gland has been shown in vivo in a canine model [1]. The objective of this study was to evaluate the capability of this method to detect and quantify localized changes in stiffness. Agar gel phantoms with embedded inclusions of increased stiffness were used to evaluate the sensitivity of this method. The stiffness ratio between the inclusions and background gel, as well as the size of the inclusions were chosen to reflect the observed differences between normal prostate and tumours [2-4].

Methods: *Agar Inclusions:* 1.5% agar (Difco Bacto Agar, USA) phantoms were made in a 10x10x10cm box with 5 cylindrical rods traversing through them (fig.1). Once the mixture solidified all of the rods were removed and two holes were filled with 2% agar and the remaining two with 2.5% agar. Cylinders with diameters ranging from 2.33mm – 19.05 mm diameter were created using this method. Once the inclusions were set, a 6.35 mm brass rod was inserted into the centre of the agar phantom. A non-magnetic piezoceramic actuator (Physik Instruments, Germany) with maximum peak-to-peak displacement of 32 microns was used to cause the longitudinal vibration of the rod.   Imaging was performed using a standard head coil on a 1.5T MRI (Signa, GE Healthcare, USA). MR images were acquired transverse to the rod, using a gradient echo sequence with the following parameters: FGRE, FOV/TR/TE/α = 20cm/30ms/25ms/30°, 128x128/256x256. The rod was vibrated between 200 and 1000Hz, and between 1 and 20 cycles of a bipolar sinusoidal gradients were applied to encode motion. *Stiffness Maps:* Displacement images were converted to elastograms using the publicly available tool 'MREwave' [2]. *Data Analysis:* The stiffness of an inclusion was measured by taking a circular region of interest (ROI) around the center of each inclusion. Inclusion diameters were determined by assigning the average full-width at half maximum (FWHM) of 71 radial line projections about the center of each inclusion.

Results: The measured diameters for inclusions of four different sizes is shown as a function of the shear wavelength produced in the gel phantom for the 1.5% agar gel (fig 2). The calculated stiffness agreed with the actual stiffness for inclusions larger than 4.75 mm and for shear wavelengths of 3.92 mm (1000Hz) in the 2% agar phantom. In the 2.5% phantom, accurate stiffness measurements were reported for the 9.57 mm and 19.05 mm inclusions at the 3.92 mm (1000Hz) background wavelength. Inclusion diameters could be measured within 1 mm at wavelengths less than 6.5 mm (frequencies > 600Hz) for inclusions larger than 3.15mm for both inclusion stiffness values. Elastograms of the 9.57 mm and 4.75 mm diameter inclusions are shown in figure 3 for three different vibration frequencies.

Discussion/Conclusions: The results of this study suggest that shear wavelengths smaller than 4mm are required to measure the stiffness of inclusions smaller than approximately 6mm in diameter, however, accurate estimates of the size of inclusions larger than 4.75mm is possible with wavelengths smaller than 6.53mm (frequencies > 600 Hz). This implies that in prostate tissue, which has an approximate stiffness of 6kPa, frequencies of approximately 4-500Hz would be required to achieve results equivalent to what was observed in this study.

References:
1) Arani et al. Proc. ISTU, 2008.
2) Man Zhang et al. Proc. 15th, 2007
3) Dresner et al. Proc. 11th ISMRM, 2003
4) Pallwein et al. BJU Int., 100, 42-46
5) Manduca et al., SPIE **2710,** 616-623, 1996

Figure 1: Schematic of the inclusion preparation setup. The fifth cylinder was not included in the animation for visual purposes only
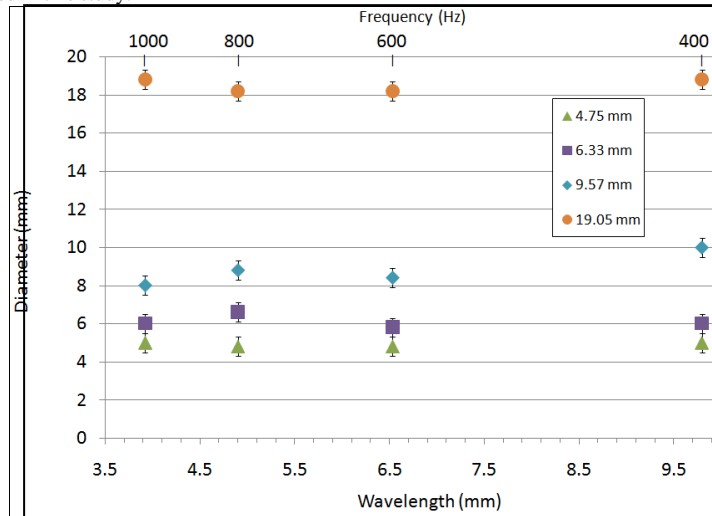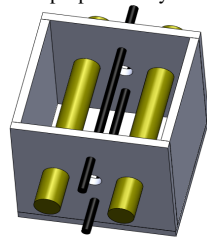

Figure 2: Measured diameter as a function of shear wavelength. The stiffness of the inclusion was 32 kPa.
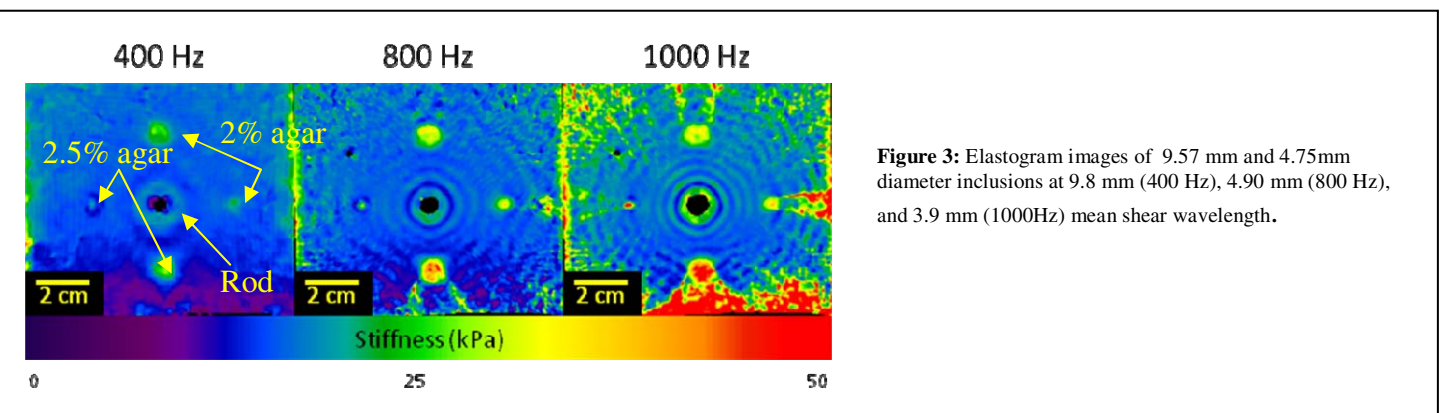

Figure 3: Elastogram images of 9.57 mm and 4.75mm diameter inclusions at 9.8 mm (400 Hz), 4.90 mm (800 Hz), and 3.9 mm (1000Hz) mean shear wavelength.