MR elastography of the prostate using an endorectal coil for actuation: feasibility in a phantom and porcine prostate

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Introduction/Purpose

Functional information on water diffusion, tissue perfusion and metabolite concentrations may improve MR diagnostics of prostate cancer (PCa). MR elastography (MRE) is an emerging modality that measures the propagation of mechanical waves in the tissue to noninvasively determine its viscoelastic properties. While previous work was devoted to other regions of the body [1], in particular breast and liver, MRE also holds promise to improve PCa diagnostics. However, it is difficult to generate shear waves inside the prostate gland that are appropriate for MRE [2]. This work describes a potential concept for prostate MRE and presents preliminary results using the endorectal coil for both MR imaging and elastography.

Materials and Methods

The basic setup for MRE was adapted from a previous implementation at a different institution [3] and is shown in Fig. 1. A commercial endorectal coil (ERC, Medrad) was modified to dynamically generate mechanical stress in terms of expansion and contraction (Fig. 2) in a multi-modality prostate phantom (model 053-MM, CIRS, Norfolk, VA) and in a porcine model. The endorectal actuator will induce shear waves in the object under examination that propagate orthogonal to the compression direction. The resulting tissue displacements were measured in a 3.0-T scanner (Magnetom Trio, Siemens Healthcare) with a motion-sensitive EPI sequence (FOV 181 × 181 mm², TR/TE=3,000/150 ms, slice thickness 5.0 mm, spatial resolution 1.5 × 1.5 mm², acquisition time 2 min) at actuation frequencies of 50–200 Hz. Viscoelastic parameters were calculated from the obtained phase differences of the shear-wave patterns.

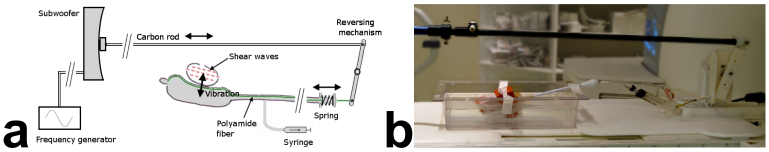

Figure 1: Schematic drawing **(a)** and actual setup **(b)** for endorectal MRE in a standard cylindrical scanner (3.0 T, Magnetom Trio). A frequency synthesizer is triggered by a motion-sensitive EPI sequence and generates electromagnetic oscillations that are transformed into mechanical vibrations of a subwoofer located in the MR room. These oscillations are then transferred to a reversing mechanism via a telescopic carbon rod and coupled into the modified endorectal coil (see Fig. 2 for details).

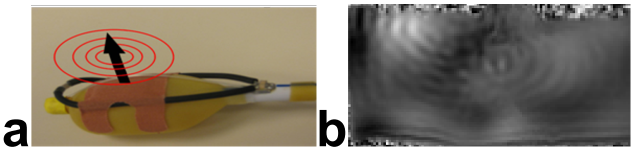

Figure 2: **(a)** A 1.0-mm diameter plastic cord is placed at the surface of the inner balloon of the ERC, fixed at the distal end of the device and connected to the reversing mechanism (Fig. 1) via the standard supply channel of the coil. Expansion and dilation of the balloon (arrow) will generate spherical shear waves that propagate in a plane perpendicular to the vibration direction (red circles). **(b)** Preliminary MR images in an isotropic gelatine phantom indicate that shear waves can be generated and propagate as expected.

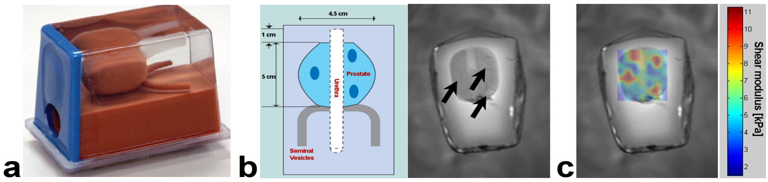

Figure 3: **(a)** Prostate phantom. The plastic housing was removed to avoid reflections of the shear waves. **(b)** Schematic longitudinal section of the phantom (left) and corresponding T2w MR image (right) show locations of 6-mm diameter inclusions (dark blue ellipses and arrows, respectively). **(c)** Overlay of the computed color-coded map of shear modulus G (acquired at 200 Hz) onto coronal T2w MR image clearly shows local stiffening at corresponding positions.

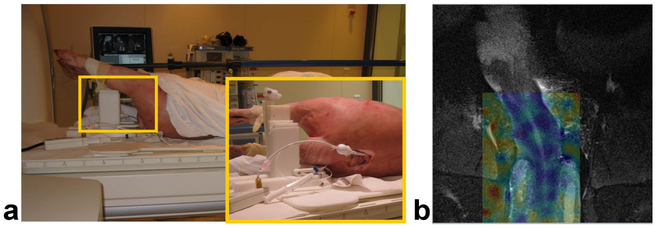

Figure 4: **(a)** Setup of porcine cadaver experiment. The modified endorectal coil (inset) was blocked with 50 ml of perfluorocarbon. The pig was examined in supine position and the add-on components for elastography (see Fig. 2) were mounted on the table. **(b)** Map of shear modulus G (obtained at 150 Hz) overlaid onto corresponding coronal T2w image of the porcine urogenital tract (see Fig. 3 for scale).

Results and Discussion

Map of shear modulus G (Fig. 3c) clearly allows identification of embedded 6-mm large "phantom lesions" against the background (bkg). Measured absolute values of G_{les} (8.2±1.9 kPa) and G_{bkg} (3.6±1.4 kPa) were substantially different. Both G values were systematically lower than those reported by the vendor (13.0±1.0 and 6.7±0.7 kPa, respectively). In the porcine model, shear waves could be generated and anatomical structures like prostate, bladder, bulbourethral gland and surrounding (muscle) tissues could be clearly identified on the shear modulus map (Fig. 4). Measured average shear moduli for muscle (7.1±2.0 kPa), prostate (3.0±1.4 kPa), and bulbourethral gland (5.6±1.9 kPa) were substantially different.

Conclusion

The close proximity of the actuator to the prostate permits the application of high mechanical excitation frequencies, which are required to achieve high spatial resolution. A main advantage of this design is the simultaneous use of the modified ERC for MR imaging and elastography. The presented approach for endorectal MRE is technically feasible. Clinical application, however, requires further optimization and validation.

Acknowledgements

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