3D MR ELASTOGRAPHY OF IN-VIVO PROSTATE CANCER AND CORRELATION WITH HISTOLOGY: PRELIMINARY RESULTS

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Introduction

Mechanical properties of tissue are important indicators of disease potential. Viscoelastic properties of the prostate have been shown to correlate with prostate cancer for ex-vivo specimens using MR elastography (MRE) [1], and several in-vivo studies using ultrasound elastography techniques [2]. In addition, one feasibility study compared results from in-vivo prostate cancer MRE with biopsy samples [3]. This work is a follow up of our elastography method with trans-perineal excitation [4]. We report a much improved data acquisition sequence that will enable fast multi-frequency volume acquisition and, using this technique, we acquire and report what is, to the best of our knowledge, the first in-vivo prostate cancer patient images that are correlated with full mount histology. The aim of our study is to identify the cancerous tumors in the elasticity images and correlate them to the whole mount histopathology marked with the Gleason score.

Methods

Ethics board approval and informed consent were obtained from a patient (first in study of N=20) of age 61 scheduled for radical prostatectomy.

MRI/MRE: We performed the experiments on a 3T Achieva (Philips Inc., Netherlands) scanner. A standard cardiac coil was used. The vibrations were applied to the perineum over the patient's undergarment (in supine position) using a custom-made electromagnetic driver. A sagittal scout image (Figure 1) was performed to ensure that the transperineal exciter is properly positioned. For the anatomy image a standard axial T2 weighted FSE sequence (TE/TR = 80/1850ms, FOV 140mm×140mm×72mm with 0.5mm in-plane resolution and 4mm slice thickness) was perfomed. The MRE images were acquired in the axial plane using a novel fast-field echo sequence named eXpresso [5], with TE/TR = 9.2/344ms and flip angle 25º. The wave images were acquired on a 128×128×24 matrix with 2mm isotropic voxel size, which covered the entire prostate. Eight vibration phases were encoded the mechanical excitation of 70Hz. The entire MRE acquisition lasted approximately 8 min for the 3D wave field including a reference scan. Images were processed offline similarly to the approach described in [6]. The approach was validated on commercial elasticity phantoms (CIRS Inc., USA).

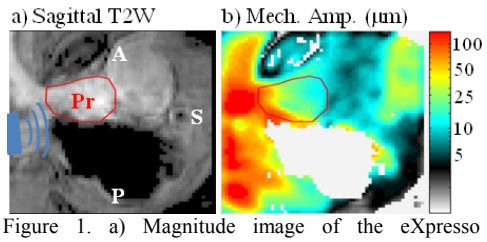

Figure 1. a) Magnitude image of the eXpresso sequence. b) The amplitude of the mechanical excitation shows that the waves are present in the entire prostate gland (Pr).

Histology: Following the surgery, the whole prostatectomy specimen (~50g) was sliced using a custom made slicing device [7] to ensure that the T2W and MRE images are aligned with the histology samples. Haematoxylin and eosin stained whole mount sections were prepared. The outline of the tumour along with its Gleason score were delineated manually on the histology slide by an experienced pathologist.

Results

Mechanical waves were transmitted effectively into the prostate via the perineum, as seen Figure 1. The peak amplitude of the mechanical wave was 130μm with a mean of 25μm in the prostate. No patient discomfort was reported when specifically asked. The displacements were successfully encoded using the eXpresso sequence in all three dimensions for the entire prostate gland. In the axial plane, the prostate gland is outlined in the (a) T2W, and the reconstructed shear modulus (b) G' and (c) loss modulus G". The histology is shown in Figure 2(d) where the outline of the large (Gleason score of 4+3) and smaller (3+3, i.e., the lowest form of prostate cancer) tumors are shown. A very promising correspondence between reconstructed shear and loss moduli G' and G" and the matching histology slide can be observed. The mean values of G' were {3.0, 1.6, and 0.8kPa} for Gleason scores of {4+3, 3+3, and healthy tissue}, respectively. Also, the mean values for G" were {1.7, 0.8, and 0.4kPa} for the same regions of interest, respectively.

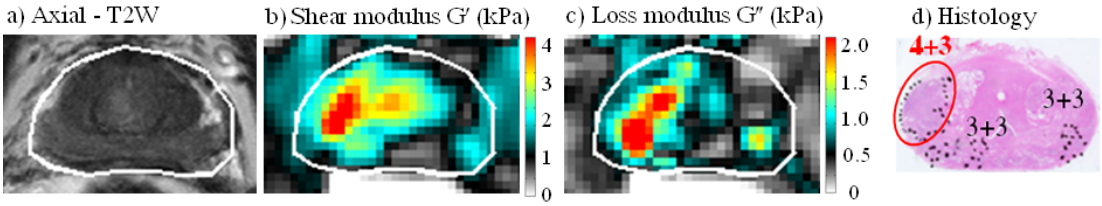

Figure 2. a) Standard axial T2W anatomy. b) and c) show the reconstructed maps of the shear modulus G' and loss modulus G". d) The histology slide shows the outline of the tumors (marked by Gleason score) from a patient following radical prostatectomy. The larger tumor can be distinguished with ease in the viscoelastic images. Even the smaller 3+3 tumors can be identified in these maps - notably in G".

Conclusion

A novel pulse sequence (eXpresso) was applied for acquiring a 3D displacement field which enables fast imaging times of the entire prostate gland. In-vivo MRE of the prostate with the driver applied to the perineum is feasible at 70Hz. The results in Figure 2 confirm previously known results [1], [2], [8] that cancerous tissue in prostate specimens has higher stiffness compared to healthy tissue, and that the values are consistent with those reported previously. The tumor with Gleason score 4+3, and even the smaller 3+3 tumors, can be visually identified in the viscoelastic maps. These results further strengthen the case for MRE techniques which promise to improve staging of prostate cancer tumors. We are presently accruing patients to obtain sufficient images to carry out a meaningful statistical analysis of this prostate imaging method alone and in combination with multi-parametric MRI protocols developed at our centre [7].

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