Imaging of the prostate with vibro-elastography: preliminary patient results

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Introduction

Prostate brachytherapy has been widely used for treating prostate cancer. Transrectal ultrasound (TRUS) is the primary imaging modality providing the guidance for brachytherapy. However, imaging and detection of the prostate with conventional B-mode TRUS still remains a challenging task due to the poor contrast between the prostate and surrounding tissues. Because prostate is a firm organ with respect to surrounding tissues, ultrasound elastography would be a potential candidate. This abstract extends [1] and presents further patient results from imaging of the prostate using a dynamic elastography technique called vibro-elastography (VE) [2].

Materials and Methods

A TRUS VE imaging system has been constructed. The system utilizes a Sonix RP ultrasound machine with a biplane endorectal TRUS probe. Both B-mode images and digitized radio-frequency (RF) signals can be acquired simultaneously from the machine. The TRUS probe is mounted on a shaker, which is used to apply compression waves to the rectal wall, typically band-pass filtered white noise. The probe and shaker are mounted on a stepper, as shown in Fig. 1. With the stepper, the probe and shaker can be rotated about the longitudinal axis of the probe at different angles, and sagittal images that contain the longitudinal axis of the probe are acquired at each angle.

Every RF data frame consists of many scan lines. For VE, each RF scan line is divided into a series of short segments with equal length and overlap at different depths. Tissue motion due to the shaker compression and relaxation is determined by the time domain cross-correlation with prior estimates (TDPE) method [3]. With the time sequences of tissue displacement estimates, transfer functions (TFs) between different spatial locations in tissue are estimated using Welch's periodogram method with accumulative windows [1]. The average magnitude of the TF over the excitation frequency range is equivalent to a "displacement" image of tissue. Tissue strain is obtained by the least squares estimation of the gradient of the "displacement" field. Alternatively, the L_2 norm of the differences between TFs at different locations is computed to approximate tissue compliance [1]. Finally, 2D median filtering, histogram equalization, and thresholding are applied to smooth and enhance the result VE images.

Experiments and Results

So far there are 14 patients preoperatively imaged by the TRUS VE system in the British Columbia Cancer Agency, Vancouver Centre, including the 3 cases previously done in [1], 9 patients recently done during the volume study, and 2 patients recently done in the OR prior to the brachytherapy. Table 1 summarizes of the data acquisition protocols during the volume study and OR study, respectively. Fig. 2 presents the prostate VE and B-mode images of three patients, in the sagittal scan plane, when the probe was manually rotated. The VE images obtained show good delineation of the prostate by comparison to B-mode images. One can also see the urethra in the middle VE image in Fig. 2. Fig. 3 shows the average normalized correlation (NC) curve for tissue displacement estimation and the average coherence function (CF) curve for TF estimation in the patients at different rotation angles. The TFs and CFs were calculated with respect to the motion estimates of the tissue elements along the middle row in the sagittal scan plane.

Conclusions

We presented the preliminary patient results of imaging of the prostate using VE. This approach provides the ability to visualize the stiffness difference between the prostate and surrounding tissues. While only a few patients have been imaged so far, the results are encouraging. Further research is required to improve the accuracy of tissue motion and TF estimation and to determine the potential usefulness and accuracy of the VE technique for prostate segmentation.

Table 1: Summary of the data acquisition (DAQ) protocols during the volume study and OR study

	RF data frame rate	Excitation amplitude	Excitation freq range	Angular range	Angular increment	DAQ duration
Volume study	20 Hz	0.4 – 0.5 mm	0.5 – 4.5 Hz	$-45^0 – 45^0$	5^0	10 sec
OR study	36 Hz	0.4 – 0.5 mm	2 – 10 Hz	$-45^0 – 45^0$	1^0	1 sec

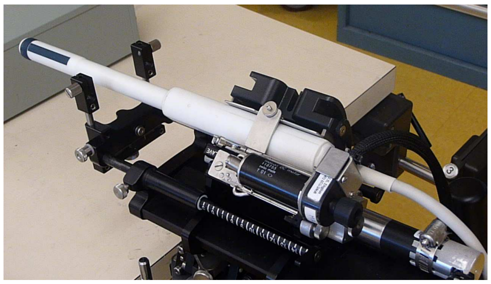

Figure 1: The TRUS probe, shaker and stepper

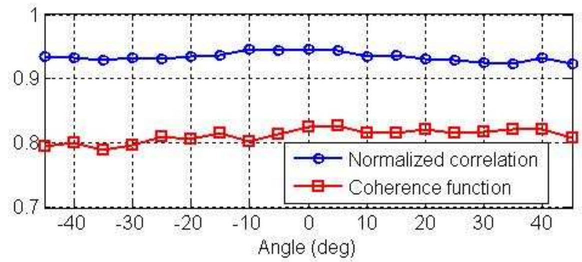

Figure 3: Average NC and CF curves for tissue motion and TF estimation at different angles

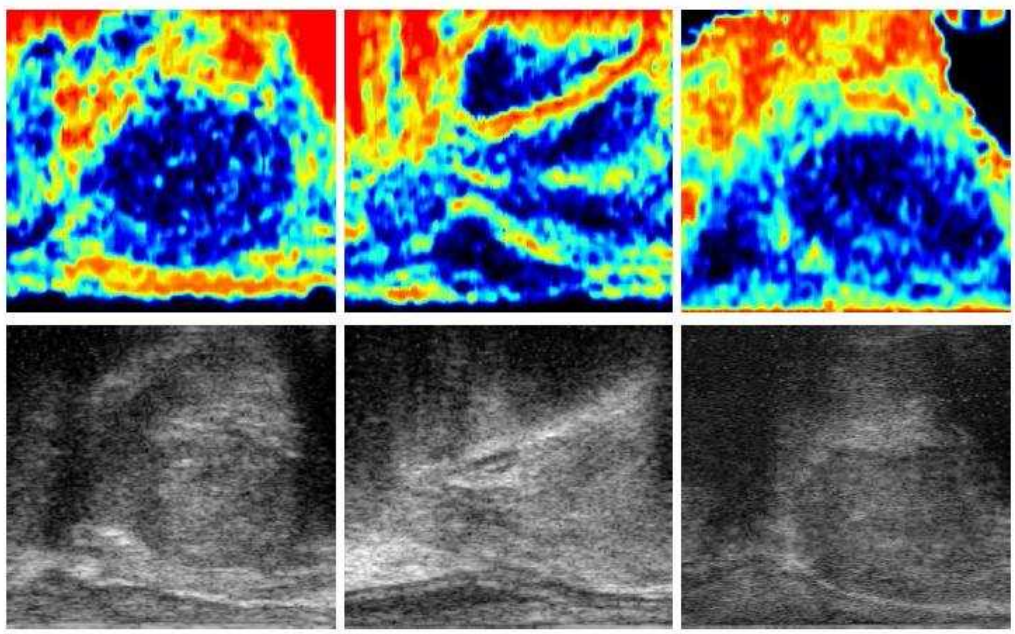

Figure 2: Prostate VE images (top row) and B-mode images (bottom row) of three patients, in the sagittal scan plane, when the probe was manually rotated

References

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