Ultrasonic Real Time Strain Imaging: A new diagnostic Modality for the early Detection of Prostate Cancer

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Abstract
We have developed a real time strain imaging system for prostate diagnosis which can be used for the first time during the transrectal ultrasonic examination for navigation and diagnosis.
During the examination a sequence of ultrasonic images is acquired while the organ is slightly manually compressed by the ultrasound probe. Using a numerical analysis of image pairs of the acquired sequence the tissue strain is calculated which represents the spatial elasticity distribution of a specific cross-section of the organ and which are able to distinguish hard areas in the tissue.

Introduction
Prostate tumors can have a higher mechanical hardness than the surrounding tissue. During the digital rectal exam this can be used not only to detect the hypertrophy but also localized hardenings. The examination by digital palpation is inaccurate and even in combination with PSA-value and a transrectal ultrasonic examination the result is often not reliable. Ultrasound strain imaging is able to measure and visualize the elastic properties of a tissue region and hence is an adequate supplement for commonly used diagnostic procedures.
We present new results from several patients, which show, that real time strain imaging is able to detect tumor-like areas which are inconspicuous in the B-mode image. The results correspond to the histological specimens. In a clinical trial with 150 patients strain imaging reached a sensitivity of 76 % and a specificity of 84 %.
Most of the tumors could not be recognized in the B-mode image alone.

Methods
Our system operates with a 7.5 MHz transrectal probe connected to a Combison 330 scanner from Kretztechnik AG/Austria. The rf-data are directly sampled into the PC-memory by a PC-card (GaGe™) with a sampling frequency of 25 MHz and 12 bit resolution. Using the transrectal probe 20 frames per second are acquired and processed. Within a region of interest of approximately 2.5 cm x 3.6 cm the real time strain images are calculated and displayed. The rf-data of two successive frames in the PC-memory are used as pre- and post-compression images. The absolute value of the strain is displayed color-coded or gray-scaled on the PC monitor side by side with the b-mode image including a real time scan conversion of the b-mode image and the strain image. The strain is evoked by compressing and releasing the tissue with the hand held transducer itself. Only the magnitude of the strain is displayed. The strain images prior to scan conversion are stored in ringbuffers for additional off-line processing. For the calculation and the display a Dual Pentium 800 MHz Desktop PC with 384 MB RAM is used. A strain image has the approximate size of 100 x 90 pixels. The rf-data are acquired and evaluated continuously in real time. This is possible because the most time consuming part, which is the estimation of axial displacements between the rf-data of two ultrasound images, is done by the phase root seeking technique described in [Pesavento, et al 1999].

The Figure presents an in vivo image of a prostate with carcinoma which prospectively recognized prior to prostatectomy:

Strain Image   conventional B-mode image   histological cross-section

Discussion

We presented a new system for real time strain imaging based on a conventional desktop PC connected to a conventional ultrasound machine. The system was used for *in vivo* real time examinations of the prostate with the aim to improve conventional ultrasonic diagnosis of prostate carcinoma. Prostate carcinoma is most often not recognizable by the b-mode image, but can often be detected by the combination of digital palpation and PSA value. It is well-known that prostate carcinoma most often comes along with a hardening of the prostate tissue. Therefore the use of strain imaging, which is the equivalent to a two-dimensional representation of the elasticity distribution of tissue, seems a good method to support cancer detection in its early stage. The findings described above show that very often hardenings can be localized by strain imaging and estimated in their true dimensions where b-mode imaging can not.

Technically we implemented the World's first real time strain imaging system. We used a conventional PC platform which allows an easy scaling of speed and memory with improving PC technology. At the moment our system is able to calculate and display up to 30 images per second with approximately 10000 pixels each. The resulting real time strain images are displayed after scan conversion with the PC monitor.

The implementation of real time strain imaging shows the high potential of PC based imaging technology. Now it is also possible to implement other real time imaging techniques in the same way which could reduce significantly the development cycle of high end ultrasound systems.

The problem of lateral motion correction which was reported by other groups was overcome by the use of a high frame rate. At this frame rate decorrelation of the rf-data due to the lateral motion is negligible and hence stable images can be obtained without any correction schemes.

In the future we will turn our efforts towards the application of real time strain imaging in other areas of ultrasound diagnosis such as the female breast, IVUS, imaging of the thyroid, imaging of liver, kidney and other abdominal organs.

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