Acoustic radiation contrast to visualize viscoelastic properties in human breast

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Introduction

Combining ultrasound (US) and MRI offers a new contrast based on the differences in the viscoelastic properties of the investigated tissue. Breast cancer diagnostic is expected to benefit from detailed knowledge of these properties. This innovative and recently developed method is called acoustic radiation contrast in magnetic resonance (ARC-MR) [1,2]. It visualizes lesions and microcalcifications non-invasively in MR phase images [3,4]. After successful trials on self manufactured and commercially available breast phantoms, first *in vivo* measurements on three healthy volunteers (age 44, 50 & 65) were performed.

Method and Materials

US was generated by a custom made MR compatible piezoelectric transducer with a diameter of 5 cm and a resonance frequency of 2.5 MHz. The US was focused with a PMMA lens to achieve a focal length of 22 cm. This setup led to a unidirectional acoustic radiation force in the direction of propagation and therefore to a displacement along the beam path. The US focus was movable in three dimensions by means of a computer controlled, metal free hydraulic shifting device in order to investigate the whole sample volume. The displacement Δy became visible as a phase shift $\Delta\varphi$ according to $\Delta\varphi = \gamma \, G \, t \, \Delta y$ using a displacement sensitive MRI spin-echo sequence with two monopolar gradients [5] (sequence parameters: T_E/T_R: 41/500 ms, no fat saturation, gradient length and amplitude: 20 ms and 20 mT/m, voxel: 1.1 mm x 1.1 mm x 4 mm). The measurements were performed at a 1.5 T Magnetom Symphony scanner (Siemens Healthcare, Erlangen, Germany) with a 4 channel breast coil (Noras MRI Products GmbH, Höchberg, Germany). US was applied synchronously with the second gradient, it had a pulse duration of 20 ms and an intensity of 3.95 W/cm^2. This US intensity was far below the FDA limits concerning the mechanical and thermal indices. The measurements presented in this abstract were taken from the 44 year old female volunteer.

Results

Figure 1 shows a T2-weighted image of a transversal plane of the investigated breast without US. Apart from the ordinary structures of the breast, a lighter area in the center is visible which corresponds to a lesion. The reflector as a part of the shifting device can be seen at the bottom. It redirects the US from the horizontal into the vertical plane. Figure 2 shows a phase image with the same FOV (direction of displacement sensitivity for all pictures: A → P). Neither the lesion nor any other details are visible. Figure 3 shows a phase image with US incident from the bottom. The displacement caused by the acoustic radiation force is clearly visible as a lighter gray area up to a depth of about 5 cm. Since the US propagates next to the lesion the signature decreases uniformly with increasing depth. In Figure 4 the lesion is in the beam path and clearly visible as a very light gray region. The influence of the US ends abruptly in the area behind the lesion.

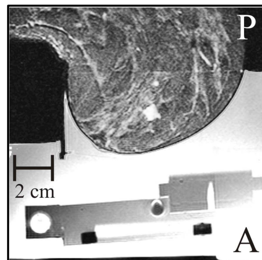

Fig. 1 T2-weighted amplitude image

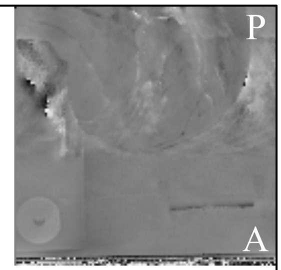

Fig. 2 phase image

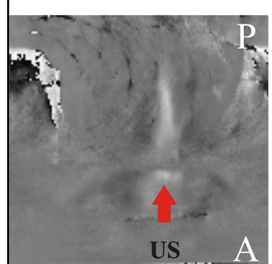

Fig. 3 phase image with US next to lesion

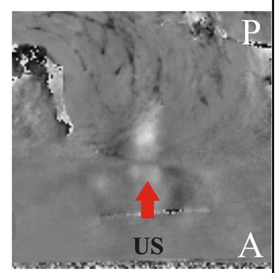

Fig. 4 phase image with US on lesion

Discussion and Outlook

The physical and experimental know-how collected in several phantom studies [3,4] was transferred to *in vivo* measurements. It turns out that phase images of human breasts without US are homogeneous and thus make the use of ARC-MR possible. The influence of the US can be seen clearly in the phase images. In healthy breast tissue the US is uniformly absorbed. The lesion found was identified as a cyst with conventional MRI. The liquid characteristic of the cyst causes a larger displacement which explains the brightening. The signature in the area behind the lesion cannot be interpreted by the presence of the cyst alone. The transition between the cyst fluid and breast tissue is comparable to the transition between water and tissue at the front side of the breast. Hence an undisturbed US transmission is expected. The explanation is a drastic change in the viscoelastic properties in the area behind the cyst. Based on the fortuitous finding a DCE-MRI was performed and validated the presence of a small tumor behind the cyst. In general tumors are significantly harder which explains the abruptly decreased displacement. A study on healthy volunteers and volunteers with well known lesions is the next step. Using this method it is expected to characterize lesions based on their viscoelastic properties. In addition finite element simulations will lead to a better understanding and interpretation of the measurements.

[1] M. Radicke *et al.*, Hyperfine Interact **181** (2008) 21-26
[2] N. McDannold and S. E. Maier, Med. Phys. **35** (2008) 3748-3758
[3] M. Radicke *et al.,* „ARC in MR Images for Breast Cancer Diagnostics – Initial Phantom Study'' in Ultrasound in Medicine and Biology (2010) (accepted)
[4] J. Mende *et al.,* „ARF contrast in MRI: detection of calcifications in tissue-mimicking phantoms'' in Medical Physics (2010) (accepted)
[5] E. O. Stejskal and J. E. Tanner, J. Chem. Phys. **42** (1965) 288-292