Acoustic radiation contrast in magnetic resonance to visualize viscoelastic properties in human breast - preparation of clinical trial

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Purpose

The early detection of breast cancer has severely improved during the past 20 years, but there is still room for improvement like considering a more comfortable examination or a better clarification of indications without using ionizing radiation. Recent research showed that DCE-MRI has the highest sensitivity (~85%) of standard breast cancer diagnostic methods. But the comparably high clarification rate (~17%) causes many women to be insecure and to have extra examinations (e.g. biopsy). The evaluation of biopsy data showed that about 80% of women diagnosed with cancer after the different types of imaging do not have cancer [1]. Our investigations target on improving this surprisingly high percentage by improving the specificity by measuring the elasticity of lesions.

Methods

To produce acoustic radiation contrast in magnetic resonance (ARC-MR), Ultrasound (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 parallel displacement (in an area of Ø = 1cm, length of 5cm) 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 (sequence parameters: TE/TR: 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 with a pulse duration of 20 ms and an intensity of 3.95 W/cm². This US intensity was far below the FDA limits concerning the mechanical and thermal indices. The preliminary measurements presented in this abstract were taken from a 44 year old female volunteer.

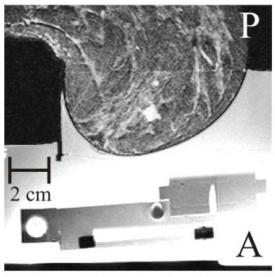

Fig. 1 T2-weighted amplitude image

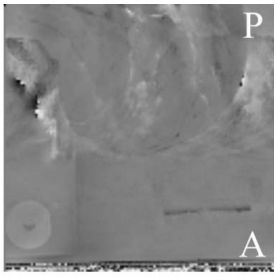

Fig. 2 phase image

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.

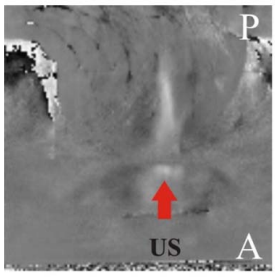

Fig. 3 phase image with US next to lesion

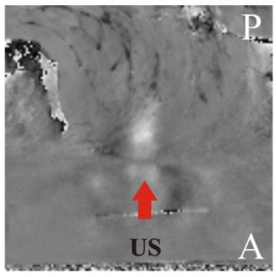

Fig. 4 phase image with US on lesion

Conclusion

The physical and experimental know-how collected in several phantom studies [2,3] was transferred to *in vivo* measurements. The first measurement is represented in this abstract. It is shown that phase images of human breasts without US are homogeneous and thus make the use of ARC-MR plausible. 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, however, 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 that validated the presence of a small (Ø = 2 mm) tumor behind the cyst.
This first measurement and the random finding already show the capability of this novel technique. Measurements on 10 volunteers with well known lesions will provide an important step towards seeing if ARC-MR is capable to improve the specificity of standard breast cancer diagnostic during the next six months.

[1] Current evaluation of data collected by the German Consortium for Hereditary Breast and Ovarian Cancer.
[2] M. Radicke *et al.,* „ARC in MR Images for Breast Cancer Diagnostics – Initial Phantom Study'' Ultrasound in Med. & Biol. 37(2), pp. 253–261, 2011
[3] J. Mende *et al.,* „ARF contrast in MRI: detection of calcifications in tissue-mimicking phantoms'' in Med. Phys. 37 (12), pp.6347-6356, 2010