Acoustic radiation contrast in magnetic resonance: detection of microcalcifications

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Introduction

Acoustic radiation contrast in magnetic resonance (ARC-MR) phase images is an innovative and non-invasive imaging technique introducing a recently developed contrast based on the viscoelastic properties of tissue [1,2].
One promising application is the detection of microcalcifications in the breast (tiny abnormal deposits of calcium) which can be first signs for breast cancer. Due to the high differences in acoustic impedance between the surrounding soft tissue and the microcalcification even a detection of very small pieces is possible.

Method and Materials

Acoustic radiation force was applied to a phantom using a custom made MR-compatible piezoelectric transducer with a resonance frequency of 2,5 MHz. The focus of the ultrasound (US) is inside the phantom. A metal free hydraulic shifting device made it possible to move the focus within all 3 dimensions of the sample volume. The thus produced displacement along the beam axis was visualized using the phase images of a displacement sensitive MRI spin-echo sequence of a 1,5 T Magnetom Avanto scanner (Siemens Healthcare, Erlangen, Germany) and a 4 channel breast coil (Noras MRI Products GmbH, Höchberg, Germany). The spin-echo sequence (T_E: 60 ms, T_R: 400 ms) had two additional monopole gradients: one before and one after the 180° pulse [3]. The gradients had a pulse duration of t = 20 ms and an amplitude of G = 20 mT/m. Therefore, movements of voxels Δy between the two gradients became visible as a phase shift $\Delta\varphi$ according to $\Delta\varphi = \gamma\, G\, t\ \Delta y$. Simultaneously, a 20 ms US pulse with an intensity of 35 W/cm² was irradiated during the second gradient pulse. The phantom consisted of an agar/de-ionized water solution with a concentration of 7 mg agar per litre of water and glass beads (Spheriglass®, concentration: 10g/1L) to achieve a tissue-like US absorption. The thus prepared phantom had a Young´s modulus of 10 kPa [4] which is a realistic value for breast tissue [5]. To simulate a microcalcification an eggshell (1mm x 1mm) was added.

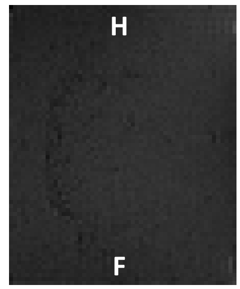

Fig. 1 T2-weighted amplitude image

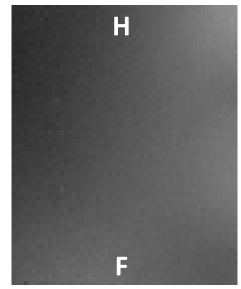

Fig. 2a Phase image without US

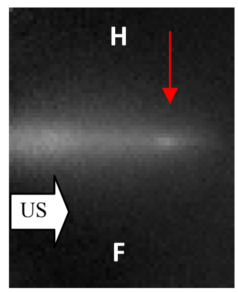

Fig. 2b Phase image with US on eggshell

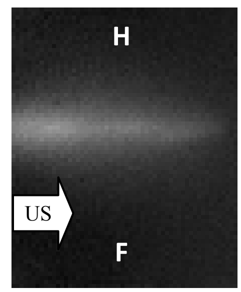

Fig. 2c Phase image with US next to eggshell

Results

Fig. 1 shows a T2-weighted amplitude image in sagittal plane where the eggshell cannot be seen. The same applies to fig. 2a which is a phase image without US. Fig. 2b and 2c are phase images with US going from A to P. In fig. 2b the eggshell is in the US beam path and is clearly visible as a bright spot (red arrow). In fig. 2c the US beam was moved upwards and the bright spot vanished. Fig. 3 shows a color encoded map of the displacement caused by the acoustic radiation force. The phantom was scanned with the US beam from H to F over a distance of about 7 cm centered around the eggshell. The line with the ultrasound beam was taken from each picture and put together to form a color encoded map of the displacement of the investigated layer. The eggshell is clearly visible as a yellow and red circle marked by the arrow.

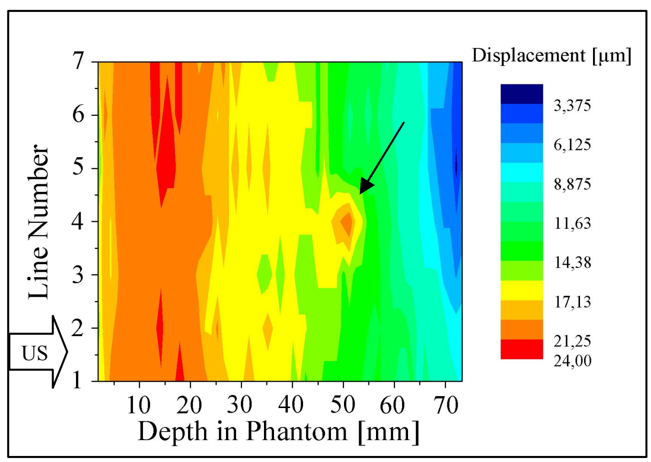

Fig. 3 2D displacement map

Discussion

Microcalcifications are detectable with the non-invasive ARC-MR imaging technique. We are developing a more convenient and faster measurement technique by combining a line-scan sequence with a synchronized movement of the ultrasound beam. This will lead to a 3D map of the displacement caused by the acoustic radiation force within a few minutes. In further measurements we expect to find even smaller pieces of eggshell and to achieve a faster data acquisition.

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