MR monitoring of focused ultrasound surgery (FUS) in a breast tissue model - in vivo study

C. Bohris, R. Rastert, J. Jenne, I. Simiantonakis, J. Spo0, M. Hlavac, P. Huber, G. Brix, J. Debus

German Cancer Research Center (dkft), Heidelberg, Germany
Institute of Radiation Hygiene, Federal Office for Radiation Protection, Neuherrberg, Germany

Introduction
Focused ultrasound surgery (FUS) is a potential tool for cancer therapy. Particularly, breast tumors, which are well accessible by ultrasound, may be an important future application for non-invasive FUS. It was the aim of this study, to investigate this approach within the framework of an experimental animal study. MR-monitoring during in vivo treatments included the acquisition of images for FUS planning, temperature monitoring of FUS, and the visualization of the induced necrosis.

Materials and Methods
Experiments were performed on a conventional 1.5. Tesla MR system (Siemens Vision, Erlangen, Germany). In total, the mammary glands of 8 sheep (2 years old, ~ 70 kg weight, not lactating) were each treated twice. The animals were in supine position with the applicator attached to the mammary gland from above (see Fig. 1). The applicator contained a spherical focused MR-compatible transducer (prototype, Siemens, focal distance = 68mm, focus diameter = 1.1mm, length of the focal zone = 8.7mm). The focus position could be varied in x,y,z-directions by an MR-compatible hydraulic tripod system (prototype, DLR, Oberpfaffenhoven, Germany). This offered the possibility to destroy extended targets by a scanning technique. The standard eye-ear-coil (ring coil with 11.5cm diameter) was used for data acquisition.

The target volume was planned on T2-weighted TSE images [a]. It was covered by numerous single ultrasound applications (9sec duration) with varying focal positions. At the end of each ultrasound sonication, temperature sensitive T1-weighted Saturation Recovery TurboFLASH (SRTF) images were acquired [b]. Quantitative temperature maps were calculated online using the temperature related signal reduction relative to a reference image [1]. The focus could be visualized and compared with the planned focus coordinates within the time interval between two successive ultrasound applications (50sec).

To visualize induced tissue changes, pre- and post-contrast T1-weighted 3D-FLASH images [c] were acquired (contrast agent: Prohance, Bracco-Byk Gulden, Konstanz, Germany, dose 0.2ml/kg).

Results and Discussion
Figure 2 represents a contrast enhanced T1-weighted image which was acquired after the treatment. The sonicated 'L'-shaped target is clearly depicted as hypointense area and surrounded by a bright boundary zone. The pre-contrast T1-weighted images had shown the 'L' as hyperintense area. In this treatment, all 41 focus positions could be detected by temperature mapping. The evaluated positions agreed very well with the hypointense area. With respect to the defined target the sonicated 'L' was slightly tilted and shifted. Sources of error were presumably an inaccurate relationship between the coordinates of the MR and the ultrasound applicator system and a 2mm shift of the mammary gland during the treatment.

In the second half of our study, the quota of foci, which could be visualized, varied between 70-100%. Also in adipose tissue the focus could be well visualized. This T1-based approach thus offered an alternative to proton resonance frequency methods, whose application is hampered in fatty tissues.

Conclusion
The results of this study show that FUS treatments can be planned and controlled by MRI. Since the tissue properties of the mammary glands of sheep are very similar to those in the human breast, the results demonstrate that MR monitoring of FUS in the breast is feasible.

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References: