3.0-T MRI-guided focused ultrasound ablation versus MRI-guided needle-wire placement for the pre-operative localization of non-palpable breast tumors: an experimental study

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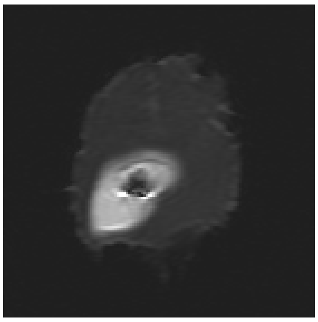
Introduction: In the past decades, screening programs and developments in breast imaging techniques have led to an increased detection of early stage and non-palpable breast cancer. The insertion of a needle wire under image guidance is the standard method to localize these tumors. Although it is a relatively simple procedure, it is not without shortcomings, i.e. positive tumor margin are found in around 40% of patients. Magnetic resonance imaging (MRI)-guided focused ultrasound (MRI-guided FUS) causes tissue necrosis by heat. Instead of tumor ablation, MRI-guided FUS can potentially be used to mark a non-palpable breast tumor by creating a palpable and visible template caused by necrosis.

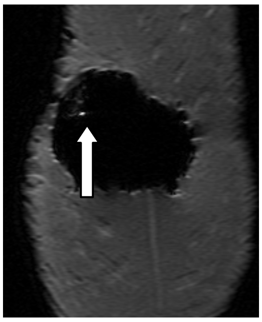
Purpose: To compare the accuracy of MRI-guided FUS ablation with MRI-guided needle-wire placement (MRI-gNW) for the localization of non-palpable breast tumors.

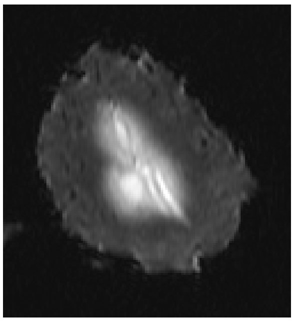
Methods and Materials: Sixteen turkey breasts were used for this experiment. In each turkey breast an artificial non-palpable tumor was created by injecting an aqueous gel containing a 1:200 dilution of gadopentetate dimeglumine. Both localization techniques were performed in a 3.0T MRI imaging unit (Signa,GE Medical Systems) by using a circular 4 inch surface coil (Invivo/MRI Devices Corp.). MRI-gFUS localization (n=8) was performed on the ExAblate 2000 system (Insightec) using the Insightec breast cancer protocol. The tissue and lesion were evaluated by a localizing sequence, followed by 3D gradient echo sequence (TR/TE 12.1/2.4; flip angle 20º; bandwidth 15.63 kHz; 512 x 192 matrix; FOV 20; section thickness 1.5 mm; 32 slices per volume) and a 3D IDEAL sequence (TR/TE 7.6/5; flip angle 20º; bandwidth 41kHz; 512 x 192 matrix; FOV 20; section thickness 1.5 mm; 32 slices per volume). For treatment planning with the Insightec FUS system T1-weighted spin-echo images were acquired in the sagittal, transverse, and coronal planes (TR/TE 300-400/14; 256 x 128 matrix; FOV 20 in coronal plane; 24 in axial and sagittal; slice thickness 3 mm; skip 1 mm) and transferred to the focused US workstation. Multiple ablation spots were created with sonications at therapeutic levels (Focused US Power up to 60 W/ 1000 Joule) around the non-palpable tumor in the coronal plane, each spot 5mm apart, to create a visible and palpable template. Position of each sonication to the predetermined target point was verified by using MR imaging phase maps that depicted temperature-dependent changes in resonance frequency. MRI-gNW localization (n=8) was performed by placement of a 20G-MRI compatible wire centrally through the tumor under MRI guidance. After both localizations, the tumor was surgically excised. MR images were provided to the surgeon, indicating the position of the lesion and the outcome of the used localization technique in correlation with the tissue. In both techniques the surgeon attempted to achieve a tumor free margin of ≥ 5mm. MR images were used to evaluate tumor-free margins (neg/pos), minimum tumor-free margin (shortest distance (mm) in coronal plane) and the excised tissue volume (length x broad (both coronal plane) x height (transverse plane) in cm³).

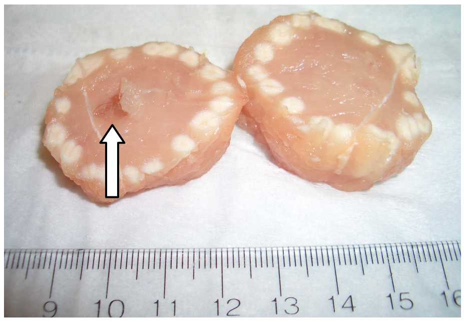
Results: There were no technical problems in treating the turkey breast with either MRI-gFUS or MRI-NW. The template created by MRI-gFUS could be felt on the outside of the turkey breast and seen from the inside by the surgeon and was used as guidance for excision (figure 4). In the FUS-group there was no case (0%) with positive tumor margins. In the NW-group 2 cases (25%) with positive margins were found (P=0.5). The mean minimum tumor-free margin ±SD in the FUS-group was significantly larger (5.5 ± 2.4mm), than the NW-group (0.9 ± 1.4mm) (p<0.001). The mean volume ±SD of excised tissue was slightly higher in the FUS-group (44.8±9.0cm³) than in the NW-group (39.5 ± 10.7cm³), but there was no significant difference (P=0.3). One case of the MRI-gFUS localization was excluded because of diffusion of the aqueous gel containing gadolinium after treatment. This was not observed in the any of the other cases.

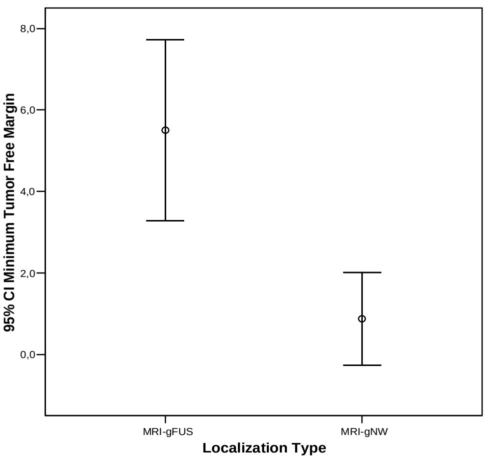
Conclusion: The results of this experimental study indicate that MRI-gFUS is as accurate as MRI-gNW for localization of non-palpable breast tumor in turkey breasts. One of the main advantages of FUS over NW is that FUS is completely non-invasive.











Figures:
1) MR image of the excised tissue after MRI-gNW-localization. The needle wire is placed centrally trough the tumor. The smallest tumor-free margin is 1mm.
2) MR image of 1 case treated with MRI-gNW where tumor of 1.0 x 1.0 mm was left behind in turkey breast (arrow).
3) MR image of excised tissue after MRI-gFUS-localization. The smallest tumor-free margin is 6.8mm.
4) Photo of resected tissue after MRI-gFUS-localization (cut into half). Notice the template of multiple ablations (cigar-shaped, white color) around the created gadolinium tumor in the centre (arrow).
5) Graph (Error bar) showing significant difference (95% Confidence Interval) for minimum tumor-free margins between MRI-gFUS (left bar) and MRI-gNW (right bar).