MR Compatible Phased Array HIFU Transducer for Localized Prostate Cancer Treatment; in Vitro Validation

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Introduction

High Intensity Focused Ultrasound (HIFU) under MRI guidance may provide minimally invasive treatment for localized prostate cancer. In this study, an MR compatible multi-element endorectal HIFU transducer capable of focusing the beam at variable depths in the tissue is being investigated. Our purpose is to treat more complex anatomies as compared to existing treatment strategies using a single element transducer.

MR setup & methods

The HIFU device used consisted of 16 circular elements arranged on a truncated spherical cap (radius = 60 mm) with nominal frequency of 3 MHz. The transducer was drive by a multi-channel power generator (16W/channel) that permits individual amplitude and phase control of every channel and fast update of the phase law between the shot points. Fresh samples of porcine liver were degassed and exposed to HIFU sonication. Fast MR thermometry (PRFS method with voxel size 0.85x0.85x4.25 mm^3 , 2 s /volume) was performed in two orthogonal planes simultaneously (sagittal and transverse). The HIFU transducer was moved using a MR-compatible 3D positioning system (0.5 mm accuracy): LR and HF translations plus rotation around Bo. Different sonication sequences, chosen based on numerical simulations predicting the shape of the thermal lesion were investigated on a clinical 1.5T Philips scanner. Nine elementary lesions (Fig 1) with focal point location ranging between 32 and 69 mm were performed for in vitro tests, together with sonication sequences for lines, slices and volumes. For example, the sonication slice with maximal focal point at 69 mm, was composed of 11 multi-focal lines made at different values (-13.6º, -10.8º, -8.1º, -5.4º, -2.7º, 0, 2.7º, 5.4º, 8.1º, 10.8º, 13.6º) of the rotation angle.
Volumes of varying size that mimic the shape of typical prostate were sonicated with shots of 1 s for every point. The applied power has been varied upon the depth of the tissue layer in front of the focus. Short sonication intervals (1s) were followed by pauses of 0.1 s between different depths and 1 s between lines, respectively.

Results

No RF or susceptibility artifacts were detected on MR data. Figure 2 shows typical thermometry data obtained for multi-focal sonication slices. Temperature and thermal dose maps showed that the current sonication strategy is appropriate for inducing a homogenous lethal dose (CEM43 14400s iso-level) for the desired shape, in accordance with the numerical simulations.

Conclusions

Dynamic focusing of the HIFU beam permits to obtain lesions at variables depths and offers the possibility to treat patient-specific anatomy, i.e. larger or smaller prostates. The cumulated thermal dose within the lesion was demonstrated to be very homogeneous.

References:

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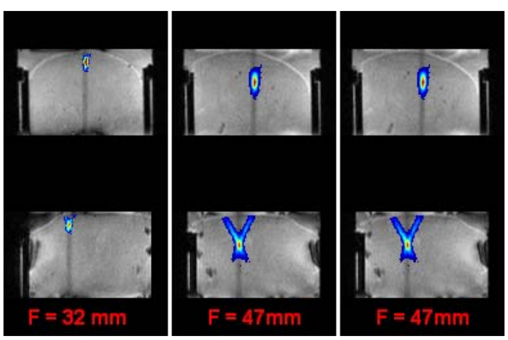

Figure1. Elementary lesions for acoustic focus positioned at 32mm, 47mm and 69 mm, respectively. In the upper row, the transducer is positioned at the top of the images and is firing to bottom. FOV=56mm^2, voxel size= 0.85x0.85x4.25 mm^3.

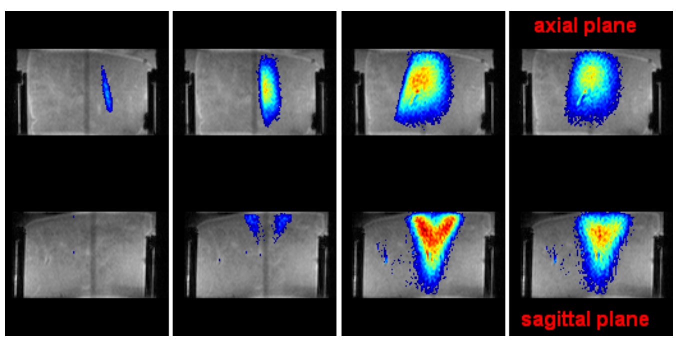

Figure 2. Temperature maps during the slice sonication sequence, at different time frames. From left to right, are being performed the first line, the fourth line, the last line. Finally the post-sonication cooling regime is shown. Minimal focus is 32mm and maximal focus is 69mm.