Large aperture transducer designed for MR-HIFU treatment of breast tumors

C. Mougenot1, M. Köhler1, M. Tillander2, C. Moonen3, W. Bartels1, and G. Ehnholm2

1Philips Healthcare, Suresnes, France, 2Philips Healthcare, Vantaa, Finland, 3IMF / Univ. Bordeaux 2, Bordeaux, France, 4University Medical Center Utrecht, Utrecht, Netherlands

Introduction

The treatment of breast tumors by MR-guided HIFU has recently been shown to hold great potential [1]. However, widespread clinical acceptance has been hampered by the considerable risk of undesired tissue damage to the thoracic cage, the heart, and the lungs, which are all located in the far field of the commonly vertical ultrasound beam axis. To reduce the associated risks, a dedicated large aperture MR-HIFU breast transducer with a lateral principal ultrasound beam direction [2] is here proposed. This transducer is designed to minimize heating in the far field of the beam path while also minimizing near-field energy density and heating of skin and subcutaneous tissues.

Materials and Methods

The proposed large aperture transducer consists of a circular structure with focal length of 13cm that surrounds the breast. The active surface of the transducer is slightly tilted to allow the focal point to be located slightly above the transducer, as illustrated in figure 1. This design enables sonication of any position within the breast, including areas close to the thoracic cage. This phased array operates at 1.45 MHz. Due to manufacturing constraints of such large aperture transducer design, it is composed of 12 separate modules that each consists of 32 elements. To compensate the possible assembling inaccuracies, phase calibration of the acoustic signal of each element at the focal point was performed to improve the focal point quality. The phase calibration and focal point shape measurements were performed in degassed water with a 3D hydrophone scanning system. The transducer was integrated in a MR compatible table top including a 3D mechanical positioning system and a dedicated MR breast coil. This Philips Sonalleve breast MR-HIFU platform was tested in a 1.5T Achieva scanner. A sonication of 150 acoustic watts with duration of 20s using 256 of 384 channels was performed inside a breast shaped absorbing phantom. The resulting heating was monitored using PRF thermal maps acquired with a gradient echo sequence (TE=20ms, resolution 1.5×1.5×5mm), overlaid on a spin echo image for clarity.

Results

The normalized pressure distribution displayed in figure 2 shows the very sharp focal point of this transducer with a small FWHM size of 0.4×0.6×3.3mm. As a consequence, the heating measured by the MR thermal maps (Figure 3) was located predominantly in a spherical shape mostly due to thermal diffusion effect from the central narrow focal point. Assuming an initial temperature of the 37°C for the phantom, the induced thermal dose above 240 equivalent minutes covers a volume of 8×10×12mm. No temperature rise higher than 2°C was observed 1cm below or above the ablated volume.

Discussion/Conclusion

The large transducer aperture and the lateral orientation of the beam induces a low energy density at skin surface and an abruptly decreasing far field that will aid in avoiding excessive heating of the rib cage. This transducer design is expected to improve significantly the treatment safety as well as ablation efficiency by allowing large volumetric ablations with a narrow transition zone to healthy tissue. This Philips Sonalleve breast MR-HIFU platform will be used for initial clinical evaluation of breast tumor ablation in 2011.

References