Real-Time Thermoacoustic Thermometry for Focused Microwave Therapy

Chandra Karunakaran[(1)], Srishti Saraswat [(2)], Jinpil Tak[(2)], Hongbo Zhao [(2)], Hannah Schmitz[(1)], Waleed Ahmad[(2)], Hao Xin[(2)], Russell S. Witte [(1)]

(1) Dept. of Medical Imaging, University of Arizona, Tucson, AZ, 85724

(2) Dept. of Electrical and Computer Engineering, University of Arizona, Tucson, AZ, 85721

Thermal therapies, such as focused microwave therapy (FMT), have potential advantages over more aggressive methods for cancer treatment with reduced systemic side effects, but lack adequate control or temperature feedback for optimizing thermal dose and minimizing effects on surrounding healthy tissue. Thermoacoustic (TA) imaging, based on the absorption of a short microwave pulse and conversion of heat to US pressure, can be used for noninvasive temperature monitoring at depth with resolution on the mm scale. We propose integrating FMT with TA thermometry and imaging for real-time feedback of tissue properties during ablation therapy for breast cancer. The goal of this study was to demonstrate feasibility of a prototype system that combines FMT with TA imaging and thermometry towards a closed-loop, image-guided system for accurate and local heating of the breast.

A 3 cm thick saline gel slab (0.9% NaCl and 1.5% agarose) was placed in the center of a 3D-printed FMT-TAI chamber (Fig. 1a). The sample was placed above a matching layer and short microwave pulses (1.2 GHz, 1 µs, 5kW peak power, 1 KHz repetition rate) were delivered for thermoacoustic imaging. The chamber was filled with deionized water and a focused single element ultrasound transducer (0.5 MHz) was scanned linearly every 5 minutes to generate cross sectional TA images during FMT. For heating, microwaves (915 MHz, 40W) were delivered continuously (with 30s off period every 5 minutes for imaging) through four patch antennae placed at right angles on the side of the chamber and focused on the sample center. Thermocouples were placed in the sample to measure temperatures at several locations. The average TA-temperature slope was then used to predict temperature at each location during 70 minutes of FMT heating.

The largest temperature increase during FMT occurred at the center of the gel slab (+19.58 °C at 0.28 °C/min). Average slope (TA signal vs. temperature) was 2.5±0.47% per °C. TA thermometry predicted temperatures at the five thermocouple locations with an error of 3.79±1.23 °C (17%/°C). For the 2D temperature prediction maps (Figs 1b & 1c), the final predicted temperature change at the center of the gel was +14.98 °C and +27.13 °C at 35 minutes and 70 minutes respectively, implying that the method overpredicted temperature in the center of the gel by 7.5°C. This study demonstrates feasibility of integrated TAI-FMT platform for breast cancer ablation with real-time TA thermometry. More robust processing techniques need to be implemented to reduce the temperature prediction errors.

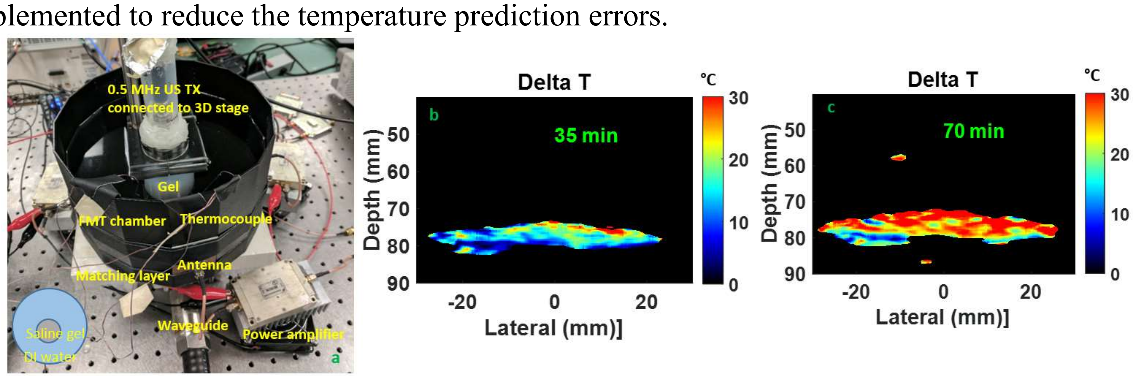

Figure 1: Experimental setup (a) and temperature prediction maps during 35 (b) and 70 (c) minutes of FMT heating.