Real-time Thermoacoustic Imaging and Thermometry using a Linear Ultrasound Array

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Background: 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 with resolution on the mm scale. We propose the use of US arrays to obtain non-invasive, real-time temperature maps during treatment that can serve as feedback for thermal therapies and greatly improve treatment success. The goal of this study was to confirm feasibility of using a commercial US array with parallel processing for real-time imaging by correlating TA signals generated in saline, conductive gel, and porcine tissue with temperature.

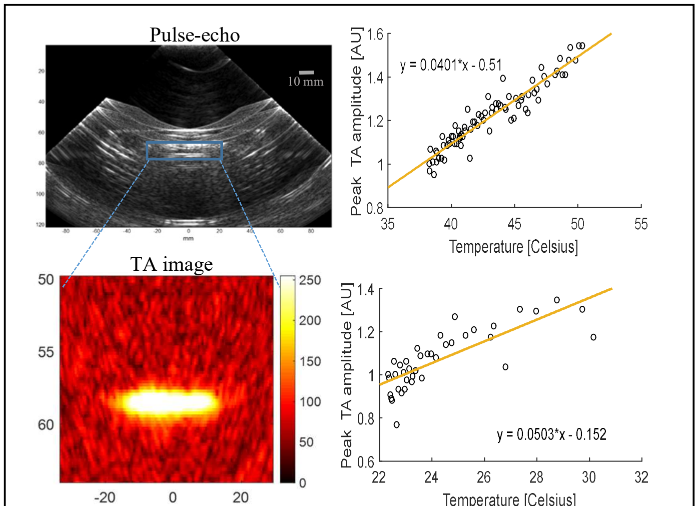

Figure 1. Pulse-echo image (top left), TA image (bottom left) from matching layer-saline interface and change in peak TA signal with temperature for saline (top right, r=0.948) and porcine tissue sample (bottom right, r=0.876). Data points (o) and fitted line (solid line).

Methods: Microwave pulses (2.81 GHz, 4 kW peak power, 340 ns pulse width, 750 Hz repetition frequency) were delivered by a microwave source (EPSCO Model PG5KB) through a WR-187 waveguide filled with mineral oil into a saline-filled tank. A matching layer improved transmission efficiency between the waveguide and sample. A 2.5 MHz linear US array (Philips P4-1) with 96 elements was used to capture TA signals, as well as pulse echo US. TA signals were recorded and processed using the Vantage 64LE (Verasonics) system. Samples were heated to 50 °C, and TA images were captured and displayed in real-time as it cooled. A Type-T thermocouple was inserted into the saline bath or into the porcine tissue to record temperatures with a thermologger. Peak TA signals and rate of change were quantified and correlated with temperature.

Results and Discussion: We observed a strong correlation between the peak TA signal and temperature for the saline and porcine samples (Figure 1) with a slope of 0.04 and 0.05 AU per °C, respectively. The strongest TA signals were near the surface of the matching layer where the microwave intensity was highest. This study demonstrates feasibility of real-time TAI using a commercially available US array. Our ultimate goal is to build an accurate, real-time and high-resolution thermal mapping system based on TA imaging and thermometry for guiding FMT during treatment of breast cancer.