Backscattered energy for monitoring *in situ* High-Intensity Focused Ultrasound treatment

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Background, Motivation and Objective

Significant research has been conducted to develop ultrasound imaging techniques for monitoring HIFU treatments. Unlike MR-based methods, ultrasound imaging is low cost, has real-time capabilities, and is portable with the potential to increase accessibility. Ultrasound imaging techniques based on the estimation of sound speed, backscatter, attenuation, stiffness, and strain in tissue have been investigated to monitor thermal therapies. However, all of these techniques have shown major issues with temperature estimation currently limited to 55°C and tissue motion or nonlinear changes that limit their acceptance. As an alternative, we have been developing BackSscattered Energy (BSE) techniques that can be used for measuring temperature in tissues up to 70°C during HIFU treatment. In the present study, we are extending our previous work by measuring changes in BSE and comparing them with histology as a function of temperature.

Statement of Contribution/Methods

The HIFU device consisted of a 3 MHz plane transducer in order to produce a homogeneous temperature increase and ablation in liver sample with 98% duty cycle. During the off cycle, a 2.25 MHz pulse-echo transducer connected to a pulser/receiver allowed to record the backscattered signal as well as the echo coming back from an acoustic reflector placed behind the sample. A needle thermocouple was inserted just behind the region-of-interest (but not in the echo path). The BSE was estimated during heating by calculating the energy contained in the backscattered signal which was compensated by the attenuation measured at the same time. Measurements were performed at 37, 50, 60, 70 and 80°C. After treatment, Haematoxylin-Eosin-Saffron (HES) coloration was performed to correlate the number of cells and intercellular spaces to temperature and changes in BSE.

Results, Discussion and Conclusions

Ten samples were treated. A +3 dB linear increase in BSE was observed between 37°C and 70°C allowing a reliable monitoring of the temperature. The correlation between BSE and thermocouple measurements was 0.96 ($p<0.05$). Beyond 70°C, a dramatic increase in BSE of +9 dB was observed due to boiling. The increase of the BSE was also correlated to histological analyses. Intercellular spaces increased up to 175% at 60°C and then decreased up to 50% of the initial value at 80°C. This corresponds to a phase of dilatation characteristic of pure thermal effects, followed up by a contraction phase due to coagulation. The size of the cells remains constant up to 50°C and then linearly increases up to 145% of their initial diameter during the contraction phase. This increase can be also related to the agglomeration of cells during coagulation. The combination of these two tendencies may explain the increase of the BSE. This reliable temperature estimation may allow creating 2D temperature maps in real-time during HIFU treatments.