Feasibility study of integrated pulsed microwave ablation and thermoacoustic monitoring

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Microwave ablation (MWA) is a promising thermal therapy technique for the treatment of diseases such as liver and lung cancer. A minimally invasive interstitial antenna radiates electromagnetic energy, which is absorbed by and rapidly heats tissue in the immediate vicinity. The goal is to raise the temperature of the diseased tissue to cytotoxic levels to induce coagulation necrosis. Real-time monitoring of the evolution of the ablation zone and verification of completeness of ablation is essential for minimizing the risk of over- or under-treatment. Existing real-time monitoring approaches, i.e. MRI, CT, and ultrasound, suffer from a number of weaknesses, including high cost, vulnerability to artifacts caused by gas formation, and radiation exposure. Accurate, safe, and low-cost real-time monitoring of the progress of the ablation is currently an unmet need.

In this work, we propose a novel integration of microwave ablation and thermoacoustic monitoring techniques. The thermoelastic effect yields ultrasound waves that are generated by the absorption of pulsed electromagnetic waves in tissue. The ultrasound waves can be detected at the tissue surface and utilized for imaging. Our proposed system takes advantage of the existing MWA antenna and uses the energy that it is providing to the tissue for ablation—in this case, in pulsed form—as the source of thermoacoustic signals. Conventional microwave-induced thermoacoustic imaging systems utilize an externally positioned horn antenna or open waveguide to supply pulses to the tissue, but this results in significant energy loss by means of pulse reflection and attenuation before the pulse can reach the imaging region of interest. The use of the MWA antenna itself as a pulse emitter ensures excellent energy transfer between the pulse microwave source and region of interest, improving SNR and reducing the need for more costly, higher-power pulse sources.

We investigate the feasibility of combined pulsed MWA and thermoacoustic monitoring. We first establish the feasibility of producing thermal lesions using high-power pulsed microwaves. The ablation zones generated in egg white using an X-band floating-sleeve dipole antenna excited with a peak power level of 25 kW, a pulse duration of about 1 microsecond, and a pulse rate of 900 Hz are comparable in size to those produced using the same antenna but with a continuous wave source (20 W) at the same frequency. Further, we investigate the thermoacoustic signal characteristics in the context of reference liquid heating and egg white ablations to elucidate the fundamental properties of thermoacoustic signal generation in the ablation environment.