Microwave Hyperthermia for Breast Cancer Therapy Monitored by Compressive Thermoacoustic Imaging

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Breast cancer is a major threat to women due to its high morbidity and mortality. Microwave hyperthermia has been shown to be a promising technology to treat breast cancer and researched extensively in the past years. It applies microwave energy to heat breast tumors and elevate temperature at the tumor to above 42°C that can cause apoptosis of the malignant cells. Different modalities of microwave hyperthermia have been investigated for breast cancer therapy. The one that is referred to as focusing microwave hyperthermia has attracted lots of attention. This configuration can focus the radiated microwave signals at the breast tumor while keep moderate level of microwave energy in the rest healthy parts of the breast, which thus embraces the merit of high accuracy in treatment and holds promises to be applied in clinical applications.

However, there still lacks an efficient way to provide real-time monitoring of the microwave focusing effect inside breasts during the hyperthermia process. Thermometers have been applied to directly measure the temperature at the tumor and some other points in the breast. But this method is obviously invasive and can only monitor temperature at a few points in the breast. Ultrasound imaging has been examined to fulfill this task, but the low sensitivity of ultrasound to the variation of temperature in human tissues limits its accuracy. Microwave imaging is another possible way, but its inadequate spatial resolution and complicated imaging algorithm are problematic for practical applications.

Microwave-induced thermoacoustic imaging (TAI) has been extensively investigated and exhibits great potentials for breast cancer detection. A thermoacoustic image essentially represents a distribution of the microwave power absorption in the object to be imaged. To be specific, if a location has a higher conductivity or receives stronger microwave power, it will emanate stronger acoustic waves and accordingly appear more apparently in the image. Therefore, this work proposes applying TAI to monitor the microwave power distribution for breast hyperthermia and check if the microwave focuses at the tumor location.

For practical applications of microwave hyperthermia, a fast real-time monitoring mechanism is desired. But the conventional TAI configuration cannot meet this requirement due to long scanning time. Compressive sensing (CS) based TAI can address this challenge owing to its high time efficiency. It has been shown that applying CS to TAI can significantly decrease the scanning time by a factor of more than 20. This work further improves this technique by reducing the number of ultrasound transducers or locations of spatial measurements to about 20, which is very favorable for time efficient applications of TAI.

This work employs a realistic 3D human breast phantom with a 1-cm large tumor to implement the proposed mechanism. A phased array antenna with 12 elements circulating the breast phantom radiates pulsed microwave signals into the breast. An optimization algorithm is used to iteratively tune the phase of each antenna in the array to finally achieve acceptable focusing of the microwave at the tumor. About 120 iterations have been used. 20 ultrasound transducers are also evenly distributed around the breast to detect the acoustic signals for each time of iteration. CS algorithm is used to obtain thermoacoustic images. The resulting images show very good agreement with the microwave power distribution inside the breast and thus can successfully monitor the hyperthermia process.