Comparison of Carbon Nanotubes and Microbubbles as Contrast Agents for Thermoacoustic Imaging by Computational Studies

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Microwave-induced thermoacoustic imaging (TAI) is a promising hybrid modality for breast cancer detection. Reliable diagnosis of breast carcinoma by TAI depends on the contrast in the microwave dielectric properties between the abnormal and surrounding normal tissues. However, the insufficient (merely 10%) endogenous dielectric contrast between the malignant and healthy glandular tissues, from which breast tumors usually originate, greatly challenges the feasibility of TAI in clinical applications, especially for discriminating early-stage breast malignancies.

To overcome this downside, exogenous contrast agents have been proposed to assist TAI. These agents, which can be targeted to specific tumor cell receptors, modify the local dielectric properties of the tumor and enhance the conspicuity of the tumor in reconstructed thermoacoustic images. This strategy is referred as contrast-enhanced TAI (CETAI). Some experimental results have been reported that demonstrate the effectiveness of CETAI involving contrast agents such as carbon nanotubes, microbubbles and magnetic nanoparticles. A computational study employing realistic numerical breast phantoms containing a tumor and single-walled carbon nanotubes (SWCNTs) as the contrast agents has been performed by our group, which substantiates the potential of CETAI for breast cancer detection.

This work further presents a computational investigation comparing SWCNTs and microbubbles as contrast agents for breast cancer detection. SWCNTs have been demonstrated to be able to strengthen the thermoacoustic signal of the targeted tumor due to their high microwave absorptions. On the other hand, microbubbles exhibit very small microwave absorption and corresponding weak thermoacoustic signal compared to background. The effects of both contrast agents on CETAI are exploited via a differential imaging technique using images obtained pre- and post-contrast. Several key parameters governing the performance of differential-imaging-based CETAI for breast cancer detection, including signal-to-noise ratio, scan time and spatial resolution, are dependent on the extent to which the contrast agents modify the dielectric properties of the breast tumor. Different concentrations of the two contrast agents are examined to evaluate these parameters and the obtained results are useful for the translation of this technology to the clinic. With regard to the accuracy of CETAI, using microbubbles is a little inferior to using SWCNTs, as can be seen from their three-dimensional (3-D) differential images shown in Figs. 1 and 2 (the transparent cyan spheres represent the actual tumor). This is largely ascribed to the local electromagnetic field distributions around the tumor in each case.

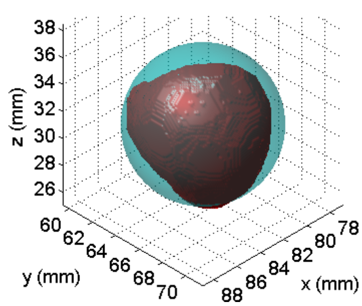

Fig. 1. 3-D differential image of a tumor using SWCNTs.

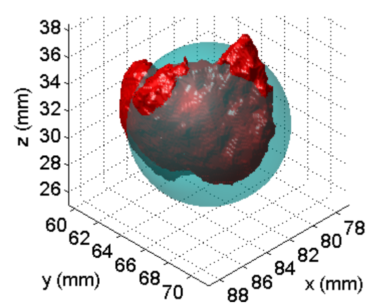

Fig. 2. 3-D differential image of a tumor using microbubbles.