127d Optical/Thermal Enhancers for Seamless Optical Detection of Breast Cancer and Hyperthermic Treatment

Hanzhu Jin and Kyung A. Kang

X-ray mammography, the method commonly used for breast cancer detection, has low sensitivity for younger women (<40 years) due to their dense breast tissue. If a tumor is suspected from an X-ray mammogram, invasive removal of tissue is needed from the suspected region for a biopsy, which usually turns out to be benign tumors. This process usually generates a physical and mental suffering for those who went through X-ray mammogram. Optical Mammography, which uses near infrared (NIR) light, is an effective detection approach especially for younger women. Tumors have unorganized vasculature, and therefore, tend to accumulate hemoglobin – one of the chromophores in tissue, resulting high absorption of NIR. In the same way, contrast agents such as metal nanoparticles can also be accumulated in the tumor site when they are injected, and help detecting a small and deeply seated tumor. Low heat (45^{o}C) hyperthermia can induce slow death of the tumor by deactivating some enzymes in the tumor with little side effects.

In this study, metal nanoparticles were tested as optical contrast agents for optical mammography and cancer specific heat-guide for hyperthermic treatment as well. Gold nanoparticles were tested in the size range of 5~250 nm for the contrast enhancement. They are inert and also strong NIR absorbers. 150 nm gold showed the highest absorption of 0.3 Optical Density (OD) at 0.01 wt% at 780 nm, one of the wavelengths for optical mammography. For experimental studies, an experimental model (24x14x5 cm) with the similar optical properties of breast tissue was constructed. Gold nanoparticles were mixed with the same ingredients of breast model at concentration of 0.01 wt% and added to an empty Vitamin E capsule (1.5x1x1 cm), and placed in the breast model at various depths between 1 and 2.5 cm. The surface of the breast model was scanned with NIR at 780 nm. At 1 cm deep, gold nanoparticles showed the maximum contrast of 3.5 dB, greater than by a usual tumor model (2.5 dB), which is approximately 4 times higher absorption than that of breast model. Even at 2.5 cm deep, the contrast was 1.0 dB, indicating gold nanoparticles are very good contrast agents.

Magnetic nanoparticles can be heated by alternating electromagnetic (AEM) field. Fe3O4, one of the most frequently used magnetic nanoparticles, at sizes of 10~20 nm were tested. Frequencies of 0.45, 5, of 9.2 MHz (generated by an induction heater) were tested to select the frequency that heats the nanoparticles only. Tissue components, hemoglobin, 0.9% NaCl solution, and ground beef were tested at above frequency ranges. 0.45 MHz was selected because of the minimum tissue heating effect. At 0.45 MHz, 1% of Fe_3O_4 nanoparticles were heated by 60~65^{o}C after 2 minutes, providing sufficient energy to perform a low heat hyperthermia. These nanoparticles were also added to the tumor model (2.5x1.5x1.5 cm), and the tumor model was placed at 1 cm deep in the cylindrical breast model. With a pancake shaped coil with 3 cm diameter, the temperature of the tumor model was increased by 16.8^{o}C after 2 minutes, demonstrating non-invasive heating of tumor. Therefore, a gold coated magnetic nanoparticle can be a contrast agent because of its high NIR absorption and its heating by AEM field, becoming an optical/thermal enhancer.

Authors acknowledge the U.S. Army Medical Research and Materiel Command under DAMD17-03-1-0572 for funding.