Development of an Integrated Multimodal Imaging System (IMIS) for surgical guidance

Innovation/Impact: The goal of this project is to develop a system for determination of the location and extent of primary carcinomas and lesions as well as to aid surgeons in excisional biopsy, sentinel lymph node (SLN) mapping and assessment of therapeutic response.

The IMIS is designed for in vivo imaging of tracers that are dual-labeled with radioisotopes and near infrared fluorophores. Gamma imaging is performed using a handheld silicon photomultiplier based camera with parallel hole collimation. Visible reflectance and near infrared fluorescence (NIRf) imaging are performed using two CCD cameras and a LED based excitation system, each controlled by a custom written LabView program.

A standard three bar USAF 1951 target was used to evaluate the spatial resolution of the NIRf system. Target images were acquired at a working distance (WD) of 30 cm, typical of that expected to be used during surgery. Figure 1 shows the contrast transfer function (CTF) for varying spatial frequency. This resolution is similar to that of similar developmental NIRf intraoperative imaging systems¹.

Figure 2 shows the results of a NIRf concentration study. The indocyanine green (ICG) concentration was varied, including the range of concentrations elsewhere found to provide the highest SNR (~10 µM)². In Figure 2 the concentration yielding the highest NIRf SNR is ~20 µM.

The NIRf visualization depth was evaluated using a phantom emulating the optical scattering and attenuation properties of human tissue in the NIR region³. The phantom contained a mixture of water (475 mL), Intralipid (25 mL) and india ink (12.5 µL). A simulated acrylic lesion (9.9 mm ID) filled with ICG (17.3 µM) was gradually submerged in the phantom and the NIRf SNR vs depth is plotted in Figure 3. The images were acquired with the room lights off, an LED intensity of 5.2 mW/cm² at the phantom surface above the lesion, and WD = 30 cm.

Rejection of excitation radiation is crucial for sensitive NIR fluorescence imaging⁴. In the phantom experiment during a 30 ms frame the relative magnitudes of the dark, excitation leakage, and fluorescence signal counts were measured to be 7.77, 7.79 and 9.62 ADUs respectively, indicating high rejection of excitation radiation and good target-to-background ratio.

A video of a live anaesthetized tumor-bearing mouse injected with a novel NIRf breast tumor-targeting tracer will be presented if this paper is accepted.

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1. Zhu, B et al., Technology in Cancer research and Treatment, 11 (1); 95-104, 2012
2. Ohnishi, S et al., Mol Imaging. 4 (3); 172 – 181, 2005