Multispectral open-air fluorescence-guided imaging and detection of tumors using a hands-free transnational platform with liquid crystal tunable filters (LCTF)

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Abstract

Effective detection and resection of tumors intraoperatively depends upon the surgeon’s ability to visually locate and palpate the tumors and tumor margins. Tumor nodules and residual malignant tissue may go undetected or be inadequately removed, with such cases often resulting in the need for secondary treatment or additional surgical intervention. The Solaris™ platform is an open-air fluorescence imaging system designed for translational fluorescence-guided surgery, with the advantage of real-time video-rate acquisition of fluorescence signal under ambient and surgical light conditions. Solaris supports four fixed fluorescent channels ranging from visible to near infrared (NIR), and a multispectral channel where a liquid crystal tunable filter (LCTF) is used to acquire multispectral images by sweeping across the green-to-red portion (wavelengths of 520-620 nm) of the visible spectrum. This range of imaging channels allows for single-wavelength and multispectral imaging of widely used reagents (e.g., indocyanine green [ICG] and Fluorescein isothiocyanate [FITC]), and unique NIR fluorescent dyes used for detecting and labeling tumors. While fluorescent imaging using NIR imaging agents (680, 750, 800 nm) can offer effective tumor detection, identification of tumors and tumor margins in nude mice or rats using visible (400-650 nm) reagents such as FITC present challenges concerning the presence of autofluorescence originating from tissue and chow (alpha fish). For these reagents, Solaris acquires multispectral images using the LCTF under ambient light conditions, and a spectral unmixing algorithm is applied to the multispectral data, after background correction and ambient light removal, to separate tissue and chow autofluorescence from the reagent fluorescent signal.

The unmixing algorithm uses library-based spectra or performs vertex component analysis to extract the primary pure spectra present in the multispectral images, and separate the reagent fluorescent signal from autofluorescence by non-negative least squares fitting. In vivo studies were carried out in tumor-bearing mice and rats injected with FITC-dextran and imaged at 24-hour time point. The results of these studies substantiated the ability of Solaris to spectrally unmix FITC-based agent signal tumor nodules and residual tumor tissue from normal tissue and chow autofluorescence imaging under ambient light, using LCTF-based open-air multispectral imaging, enhancing the ability to surgically resect them.

Summary

- Intraoperative tumor resection has historically relied solely on a surgeon’s ability to palpate and visually distinguish tumors.
- Fluorescence-guided surgical imaging in the FITC channel is hampered by intrinsic tissue and chow (food) autofluorescence.
- Utilizing spectral unmixing on the Solaris, metastatic liver nodules were spectrally separated from autofluorescent sources, demonstrating the unique feature of the LCTF on the Solaris imaging system.
- Spectral unmixing assists in the identification of FITC-tagged residual tumor and metastatic disease in translational preclinical cancer models.