ABSTRACT
RAPID AND AUTOMATED MARGIN ASSESSMENT DURING LUMPECTOMY USING A DEEP ULTRAVIOLET FLUORESCENCE SCANNING MICROSCOPE

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Marquette University, 2022

Women with positive margins after breast-conserving surgery (BCS) or lumpectomy have a 2-fold increased risk of cancer recurrence and are recommended to undergo additional surgery. Additional surgery is associated with significant emotional, cosmetic, and financial burdens for patients and their caregivers. Although intraoperative margin assessment tools are available, their accuracy is variable and most, except radiographic examination, are time- and labor-intensive and not routinely used. Since the publication of the 2014 SSO-ASTRO guidelines, the re-excision rates have decreased but remain substantial (14-18%) with significant variation among surgeons. Because the size of BCS specimens varies significantly and positive margins often include one or multiple sites/foci, a device with both large margin coverage and microscopic resolution that can accurately and efficiently evaluate the margin status of an entire surgical specimen intraoperatively is highly desirable. While several new technologies have been proposed, no device demonstrates this capability.

In this research, a deep-ultraviolet scanning fluorescence microscope (DUV-FSM) imaging system has been developed and evaluated for rapid and accurate detection of cancer cells on the surface of fresh, unprocessed breast tissues. The DUV-FSM has achieved a spatial resolution of ~3 µm and an imaging speed of 1.0 min/cm². A total of 66 fresh human breast tissues were imaged and the fluorescence images showed excellent visual contrast in color, tissue texture, cell density and morphology between invasive carcinomas and their normal counterparts (such as adipose and stroma). Visual interpretation of the fluorescence images by non-medical evaluators was able to distinguish invasive carcinoma from normal samples with excellent sensitivity (97.62%) and specificity (92.86%). Using regional-defined nuclear-cytoplasmic ratio alone was able to differentiate patch-level (2 x 2 mm²) invasive carcinoma from normal breast tissues with reasonable accuracy. Automated tumor/normal binary classification model based on texture and other features achieved high patch-level (0.5 x 0.5 mm²) accuracy (89.8%) and sample-level accuracy (91.5%). To further accelerate the imaging speed, a dual-scanning DUV-FSM that is capable of simultaneously surveying two surfaces of a lumpectomy specimen is proposed and some preliminary results are presented. The DUV-FSM has shown great potential to be utilized for intraoperative breast margin assessment during BCS.