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A novel technique for breast lesion targeting under ultrasound-guidance and positron emission mammography localization

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Purpose: Targeting small, breast lesions with high accuracy is critical for early stage diagnosis, treatment planning, and improving patient prognosis. Current imaging methods to target and sample breast lesions are limited in sensitivity and targeting accuracy. We propose using a breast-specific nuclear medicine imaging technique, positron emission mammography (PEM) to improve detection and target localization of breast lesions. To be useful for biopsy, anatomical detail and needle visualization are necessary, but not possible with nuclear imaging. We present a mechatronic guidance system integrating an ultrasound (US) guided biopsy method for improved visualization to target and sample breast lesions detected with PEM.

Methods: A mechatronic guidance system was developed to operate with an advanced PEM and US system. The system features a manually actuated, mechatronic arm with ability to access the breast between PEM detector plates. The end-effector biopsy device contains an US transducer and biopsy gun with its needle focused on a remote-center-of-motion. Kinematics of motion were implemented, and custom software modules were developed to dynamically track, display, and guide the biopsy device. Guiding the needle to calibration fiducials on a simulated PEM detector plate registered the world coordinate system to PEM using landmark-based registration. Validation was performed with fiducials at various locations within the targeting volume of a breast, simulating PEM detected breast lesions. Fiducial Registration Error (FRE) and Target Registration Error (TRE) was quantified to evaluate accuracy. Within 95% confidence intervals, 3D principal component analysis assessed directional trends.

Results: Registration and validation resulted in an FRE of 0.23±0.20mm (N=8) and TRE of 0.70±0.20mm (N=72). Tracking accuracy is <1mm in each axis. A 3D prediction ellipsoid centered on the mean error, such that any future observation has 95% probability of targeting within the volume was determined.

Conclusions: We demonstrate a novel system with the ability to guide with sub-millimeter accuracy in 3D space within targeting region of a breast between simulated PEM detector plates. When a lesion is detected with PEM, this accuracy is within the resolution and imaging uncertainty, demonstrating feasibility to improve targeting accuracy during image-guided breast biopsy.

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