

Comparison of a Stationary Digital Breast Tomosynthesis System to Magnified 2D Mammography Using Breast Tissue Specimens

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Rational and Objectives: The objective of this study was to compare the stationary digital breast tomosynthesis (s-DBT) system to a conventional mammography system in a study of breast specimens. Radiologist evaluation of image quality was assessed in a reader study. This study represents the first human tissue imaging with the novel carbon nanotube-based s-DBT device.

Materials and Methods: Thirty-nine patients, with known breast lesions (Breast Imaging Reporting and Data System 4 or 5) by conventional mammography and scheduled for needle localization biopsy, were recruited under an institutional review board-approved protocol. Specimen images were obtained using a two-dimensional (2D) mammography system with a $\times 1.8$ magnification factor and an s-DBT system without a high magnification factor. A reader study was performed with four breast fellowship-trained radiologists over two separate sessions. Malignancy scores were recorded for both masses and microcalcifications (MCs). Reader preference between the two modalities for MCs, masses, and surgical margins was recorded.

Results: The s-DBT system was found to be comparable to magnified 2D mammography for malignancy diagnosis. Readers preferred magnified 2D mammography for MC visualization ($P < .05$). However, readers trended toward a preference for s-DBT with respect to masses and surgical margin assessment.

Conclusions: Here, we report on the first human data acquired using a stationary digital breast tomosynthesis system. The novel s-DBT system was found to be comparable to magnified 2D mammography imaging for malignancy diagnosis. Given the trend of preference for s-DBT over 2D mammography for both mass visibility and margin assessment, s-DBT could be a viable alternative to magnified 2D mammography for imaging breast specimens.

Key Words: Mammography; digital breast tomosynthesis; CNT X-ray; s-DBT; specimen imaging.

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Malignant lesions in the breast can be difficult to visualize using full-field digital mammography (FFDM) when significant tissue overlap is present. Tissue overlap is most apparent in breast tissue that is thick and radiographically dense. Digital breast tomosynthesis (DBT) uses a small number of angular projections to reconstruct a pseudo-three-dimensional (3D) volume. Recent studies have shown an increase in the area under the curve (AUC) when using a combination of DBT and FFDM compared to FFDM alone (1,2). Recall rates for benign cases significantly decrease when using a combination of DBT and FFDM (1–4). However, for cases with microcalcifications (MCs),

the use of DBT along with an FFDM image has shown no significant improvement in the AUC (2).

Current DBT systems use a single X-ray source which is translated over an angular span that typically covers between 15° and 50° (5–9). Larger angular spans sample more of the Fourier domain which reduces out-of-plane reconstruction artifacts. Translating a source over a larger angular span requires longer acquisition times, which leads to patient motion artifacts (10). These single-source systems also suffer from poor spatial resolution because of focal spot blurring from the tube motion (11). We have developed a stationary digital breast tomosynthesis (s-DBT) technology that uses a novel multiple focal-spot X-ray source array with carbon nanotubes (CNTs) as the field emission electron source (12). This stationary approach can increase acquisition speed and eliminate the focal spot motion. It has been shown that the s-DBT device offers significant improvement in image quality, including improved modulation transfer function (MTF) and lesion conspicuity in breast phantom studies (11,13).

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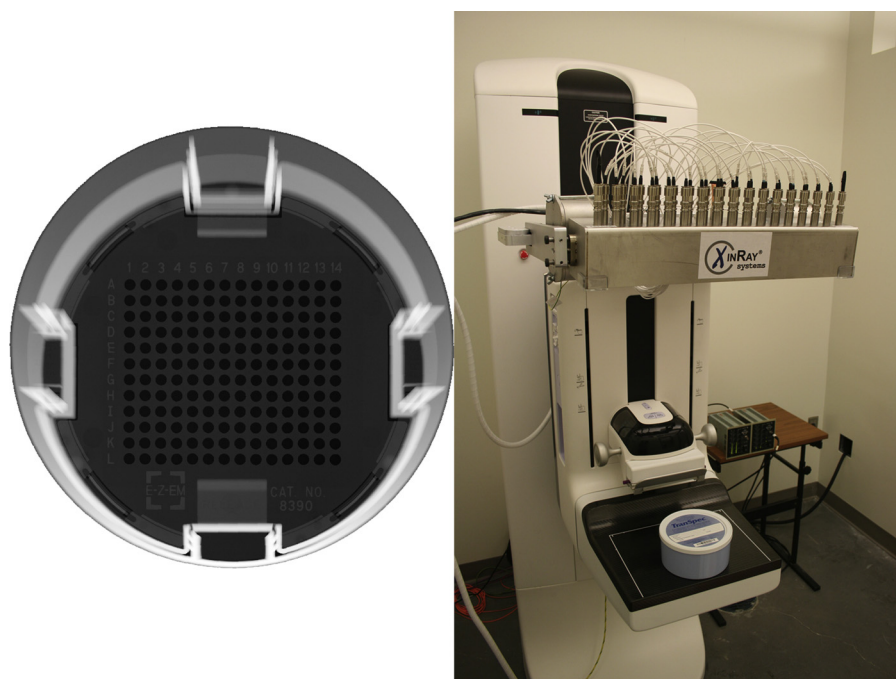


Figure 1. Segmented two-dimensional radiograph of container used to hold specimens (*left*). Image of a stationary digital breast tomosynthesis system with specimen container on the detector housing (*right*).

The clinical standard of care for surgical breast biopsies requires that each specimen be imaged using magnified FFDM for surgical margin assessment before the surgery is ended. Because of the limitations of FFDM, including superimposition of tissues, surgical margin assessment for some lesions can be impossible. FFDM is also incapable of visualizing margins which are parallel to the detector. If more accurate surgical margin assessment could be achieved, the surgical biopsy recall rate could be reduced. For this study, we sought to compare the CNT-based s-DBT system to an FFDM system in a study of breast specimens. Radiologists' evaluation of image quality was assessed through a reader study. This study represents the first human tissue imaging with the novel CNT-based device. We hypothesized that in using the s-DBT system, we will generate clinically useful tomographic images of breast specimens that are of comparable quality to conventional high-magnification two-dimensional (2D) specimen radiographs.

MATERIALS AND METHODS

Informed consent was obtained for 39 patients with known breast lesions (Breast Imaging Reporting and Data System [BIRADS] 4 or 5), as determined by conventional screening and diagnostic mammography and scheduled for needle localization biopsy under an institutional review board–approved protocol. After excision from the patient, the specimen was placed in a standard quasiradiolucent specimen container and compressed using the container's own compression mechanism with enough pressure to prevent the tissue from sliding in the container using a perforated grid. [Figure 1 \(left\)](#) shows a 2D radiograph of an empty specimen container. An average

specimen thickness of 16 mm after compression was observed. Specimens were imaged using a Senographe Essential FFDM system (General Electric, Fairfield, CT) using 26 kVp, $\times 1.8$ radiographic magnification, and a dose proportional to the specimen's size. After standard of care clinical imaging, all specimens were transported to our research facility and reimaged using an s-DBT system. The specimens were then transported to the Department of Pathology in the hospital for standard clinical pathology evaluation. All specimens were returned to the Department of Pathology within 1 hour after excision (cold ischemia time). Of the 39 patients, 25 were later determined to have malignant lesions excised through pathologic analysis.

The s-DBT system consists of a linear array of CNT-based X-ray sources retrofitted to a Selenia Dimensions DBT system (Hologic, Bedford, MA). [Figure 1 \(right\)](#) shows an s-DBT system with a specimen container on the detector housing. The array contains 31 equiangular-spaced X-ray sources covering a total span of 30° with a 1-mm thick aluminum window. Specimens were imaged using 15 projection images distributed over 28° , $\times 1.08$ radiographic magnification, 26 kVp, 100 mAs, and a detector pixel size of $70\ \mu\text{m}$. The spatial resolution of this system is 30% higher (4 cycles/mm compared to 3 cycles/mm) than that of a continuous-motion DBT system (11). Projection images were reconstructed into a 3D volume using a back-projection filtering method developed by Real Time Tomography (LLC, Villanova, PA) (14). Images were reconstructed using a 0.5-mm distance between slices and a pixel size equivalent to that of a $\times 1.8$ magnified image (the magnification used for the 2D radiograph).

A reader study was performed with four breast fellowship-trained radiologists over two separate sessions; all images were viewed in each session. During the initial session, half of the

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