Original Investigation

Performance of Photon-Counting Breast Computed Tomography, Digital Mammography, and Digital Breast Tomosynthesis in Evaluating Breast Specimens

Ann-Christin Rößler, Willi Kalender, Daniel Kolditz, Christian Steiding, Veikko Ruth, Caroline Preuss, Sandra Christina Peter, Barbara Brehm, Matthias Hammon, Rüdiger Schulz-Wendtland, Evelyn Wenkel

Rationale and Objectives: This study compared a novel photon-counting breast computed tomography (pcBCT) system with digital mammography (DM) and digital breast tomosynthesis (DBT) systems. For this reason, surgical specimens were examined with all three techniques and rated by three observers.

Materials and Methods: A total of 30 surgical specimens were investigated with DM, DBT, and pcBCT; the associated images were shown to three experienced radiologists. Findings (22 microcalcifications and 23 mass lesions) were recorded and compared to the results of the pathological examination. Sensitivity and specificity for detection of microcalcifications and lesions were calculated and displayed using receiver operating characteristic curves.

Results: Sensitivity for microcalcifications was 82% for DM, 70% for DBT, and 85% for pcBCT. Specificity for microcalcifications was 71% for DM, 75% for DBT, and 83% for pcBCT. Sensitivity for lesions was 45% for DM, 62% for DBT, and 65% for pcBCT. Specificity for lesions was 76% for DM, 62% for DBT, and 76% for pcBCT.

Conclusions: pcBCT showed a comparable or superior performance compared to the clinically approved DM and DBT systems. Mass lesion detectability can be increased further by the use of contrast media.

Key Words: Breast computed tomography; digital mammography; digital breast tomosynthesis; photon-counting detector; specimen.

INTRODUCTION

Breast cancer is the most frequent solid malignant tumor among women in industrial nations. In 2012, breast cancer had an incidence of 464,000 cases in Europe and was the leading cause of cancer death in women (1). Early detection is essential to reduce the mortality rate. Each millimeter of tumor diameter is associated with a percent higher chance of death (2). For this reason, screening programs have been established in most European countries (3).

Digital mammography (DM) is the workhorse of breast imaging but weakens its effectiveness in dense breast tissue due to superposition of tissue structures. Mammographic sensitivity in lesion detection for fatty breasts rises up to 98% but drops down to 48%–30% in very dense breast tissue (4,5). On the other hand, studies reported up to a fivefold increased breast cancer risk in women with dense breast tissue (6). Sensitivity of DM has improved significantly with the additional use of digital breast tomosynthesis (DBT), which has a slightly higher radiation dose compared to conventional mammography (7). The sensitivity of DBT alone was 43% higher than mammography in clinical trials (8). Recall rates in screening programs could be reduced if DBT was conducted in addition to mammography (8–11). Unfortunately, problems occurred in the detection of calcifications and sensitivity was higher for DM than for DBT in some studies (12).

The use of dedicated breast computed tomography (BCT) for the detection and diagnosis of lesions is a novel approach in breast imaging. Several groups have developed and tested such systems in recent years (13).

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From the Institute of Medical Physics, University of Erlangen-Nuremberg, Henkestrasse 91, Erlangen 91052 (A.-C.R., W.K., D.K., C.S., V.R.); AB-CT GmbH, Erlangen (W.K., D.K., C.S.); Department of Radiology, University Hospital Erlangen, Erlangen (C.S., S.C.P., B.B., M.H., R.S.-W., E.W.); Department of Gynecology and Obstetrics, University Hospital of Erlangen, Erlangen, Germany (C.P.). Received August 25, 2016; revised September 21, 2016; accepted September 25, 2016. **Address correspondence to:** A.-C.R. e-mail: ann-christin.roessler@imp.uni-erlangen.de

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Results show a comparable performance of BCT to DM in the detection of lesions especially when contrast media are applied (14,15). Detection of calcifications, however, appears to be slightly worse using BCT systems that utilize flat panel detectors, when compared to DM systems (16). In addition, BCT systems produce images with poor spatial resolution that cannot resolve structures smaller than 290 μm; this is considered to be a reason for the lower detection rate of microcalcifications (17). Patient doses for such systems range between 6 and 16 mGy, depending on breast size (18).

In the present study, a novel photon-counting breast computed tomography (pcBCT), using a photon-counting cadmium-telluride detector, with a three-dimensional imaging technique is used. This technique achieves a high spatial resolution and is to detect structures down to 100 μm at a dose below 5 mGy, which gives the ability to delineate microcalcifications clearly (19). The purpose of the study presented here is to compare detection statistics between images produced from pcBCT, DM, and DBT.

MATERIALS AND METHODS

In total, 30 surgical specimens were evaluated for the present study from November to December 2015. Specimens of women who had a Breast Imaging Reporting and Data System (BI-RADS (20)) 4, 5, or 6 (one case) lesions were included. Fourteen women underwent lumpectomy and 16 women underwent mastectomy. The mean age of the examined patients was 58.6 years (range: 41–79 years). Ethical approval was confirmed and informed consent was obtained from all patients.

All specimens were investigated directly after surgery by DM, DBT, and pcBCT before pathological examination. DM and DBT examinations were performed on two standard clinical systems made by two different manufacturers (Siemens Mammomat, Siemens Healthcare GmbH, Erlangen, Germany; and Hologic Selenia Dimensions, Hologic, Bedford, MA). Specimens were investigated with standard clinical settings at a tube voltage of 26 kV for DM and 27 kV for DBT. Spatial resolution of the systems was better than 100 μm for DM, DBT (only in-plane), and pcBCT (all directions, isotropic resolution). The examination systems for DM and DBT were chosen randomly for each specimen. pcBCT scans were performed with a tube voltage of 60 kV at an experimental scanner equipped with a photon-counting high-resolution cadmium-telluride detector. The scan was made in spiral mode. A filtered backprojection was used for image reconstruction. Average glandular dose was kept below 5 mGy (21).

The evaluation of images was performed by three radiologists with 12, 5, and 3 years of breast imaging experience, respectively. The software ImpactView (AB-CT GmbH, Erlangen, Germany) was used for image viewing on a dedicated workstation. Observers were allowed to change window settings and to slice through the data sets independently. For pcBCT exams, all views (transversal, coronal, and sagittal) were recorded and used. Images were grouped according to imaging modalities and shown in a random order to the observers without knowledge of the results of the pathological examination or the other imaging modalities. First, DM then DBT and pcBCT images were shown to the observers in different random orders. The time it took the physicians to evaluate the images was recorded.

DM scans were used for determining breast density according to American College of Radiology BI-RADS density categories as follows: (a) almost entirely fatty, (b) areas of fibroglandular tissue, (c) heterogeneously dense, and (d) extremely dense (20).

In each specimen, two different kinds of findings were interpreted for all modalities: microcalcifications and mass lesions.

Microcalcifications and mass lesions were reported as being present or not by the three observers. Each observer stated the certainty of his or her answer on a scale from 1 (not certain) to 5 (completely certain). The most experienced observer classified the findings analogously to the BI-RADS descriptors for the diagnostic DM images.

The results between the observers were averaged. Sensitivity and specificity were calculated for each modality and compared to each other and to the results of the pathological examination. Differences in sensitivity and specificity between lumpectomy and mastectomy specimens were calculated.

Receiver operating characteristic curves were constructed with the help of certainty values for DM, DBT, and pcBCT and were classified into microcalcifications and lesions. Areas under the curves (AUCs) were calculated.

RESULTS

Pathology revealed 16 invasive carcinomas with an average size of 20.3 mm (range: 2–84 mm). Seven of these carcinomas were associated with microcalcifications. Twelve carcinomas were additionally associated with ductal carcinoma in situ. Seven pure ductal carcinomas in situ were found pathologically from which six were associated with microcalcifications. Additionally, one case of atypical ductal hyperplasia without microcalcifications and five cases of fibrocystic changes (three associated with microcalcifications) were detected. In one of the specimens, a BI-RADS 6 case, none of the previously mentioned carcinomas were found after the patient underwent neoadjuvant chemotherapy. An overview of the pathological findings separated into lumpectomies and mastectomies is shown in Table 1.

Twenty-two of the specimens contained radiologically detected microcalcifications. In six of the specimens, microcalcifications were not explicitly described in the pathological report but were clearly visible in all three imaging techniques and were defined as true positive.

Breast tissue was classified as rather dense in mammography with a density of b–c. Lumpectomy specimens were rated denser (averaged c) than mastectomy specimens (averaged b).

A characterization of findings was made by observer 1 in DM images according to the BI-RADS classification standards and is shown in Figure 1. If the finding was not visible