Technical Report

Artifacts Caused by Breast Tissue Markers in a Dedicated Cone-beam Breast CT in Comparison to Full-field Digital Mammography

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Rationale and Objectives: The purpose of this ex vivo study was to investigate artifacts in a cone-beam breast computed tomography (CBBCT) caused by breast tissue markers.

Materials and Methods: Breast phantoms with self-made tissue pork mincemeat were created. Twenty-nine different, commercially available markers with varying marker size, composition, and shape were evaluated. A dedicated CBBCT evaluation of all phantoms was performed with 49 kVp, 50 and 100 mA, and marker orientation parallel and orthogonal to the scan direction. The resultant images were evaluated in sagittal, axial, and coronal view with a slice thickness of 0.5 mm. Additionally, measurements of all markers in the same directions were done with full-field digital mammography.

Results: All markers were visible in full-field digital mammography without any artifacts. However, all markers caused artifacts on a CBBCT. Artifacts were measured as the length of the resulting streakings. Median length of artifacts was 7.2 mm with a wide range from 0 to 48.3 mm (interquartile range 4.3–11.4 mm) dependent on composition, size, shape, weight, and orientation of the markers. The largest artifacts occurred in axial view with a median size of 12.6 mm, with a range from 0 to 48.3 mm, resulting in a relative artifact length (quotient artifact in mm/real physical length of the marker itself) of 4.1 (interquartile range 2.3–6.1, range 0–8.7).

Conclusions: Artifacts caused by markers can significantly influence image quality in a CBBCT, thus limiting primary diagnostics and follow-up in breast cancer. The size of the artifacts depends on the marker characteristics, orientation, and the image plane of reconstruction.

Key Words: Artifacts; markers; phantoms; cone-beam breast CT; breast.

INTRODUCTION

The dedicated cone-beam breast computed tomography (CBBCT) designed by Koning Corporation (West Henrietta, NY) is the first commercially available breast CT scanner. First studies reported that CBBCT can significantly improve the detection of breast masses and microcalcifications (1–7). This is owing to its high spatial and contrast resolution, and the potential of reconstruction of three-dimensional (3D) information from a series of two-dimensional images (1–3,7–9).

The CBBCT system is a new and promising diagnostic technique for breast imaging and CT-guided interventions. The CT-guided system is an add-on device for the diagnostic CBBCT. All lesions requiring an image-guided biopsy not visible on magnetic resonance imaging (MRI) or ultrasonography can be biopsied under CT guidance instead of stereotactic biopsy.

As imaging-guided biopsy possibly removes most parts of the suspected lesion, the remaining parts fall under the limit of detection. Therefore, it has become standard practice to place a breast tissue marker at the site of the initial percutaneous core needle biopsy for future definitive surgical excision in cases with malignancies or atypical histology (10–14). This is especially relevant in findings that need a wire localization for planned consecutive surgical intervention owing to any malignancy (15,16).

High absorption and the beam hardening effect of markers can cause streak artifacts (13,17) in a cone-beam CT. These artifacts can alter the images and obscure malignant lesions, thus leading to misinterpretations. Thus, further assessment of artifacts and their potential impact on diagnostic imaging is mandatory. The method of digital tomosynthesis with typically existing out-of-plane blurring artifacts was excluded from the evaluation.

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To our knowledge, there are currently no studies that have systematically and directly compared the different breast imaging modalities concerning the impact of streaking artifacts caused by markers. The purpose of this ex vivo study was to quantitatively evaluate the artifacts from different commercially available breast tissue markers and compare it to full-field digital mammography (FFDM) and CBBCT.

MATERIALS AND METHODS

Breast Tissue Markers and Breast Phantom

Institutional review board approval was not necessary for this study because no human subjects were used. The breast tissue phantoms were created using pork mincemeat. All breast tissue markers were provided by the respective manufacturer upon request.

The breast tissue phantoms consist of a cubic plastic container with a volume of 500 mL and measuring 6 cm in height, 13 cm in length, and 8 cm in width. Wall thickness was 0.3 cm. The plastic container was filled with pork mincemeat (180 g) to simulate the female breast with similar attenuation and scattering of X-rays. All markers were positioned within the central third of the tissue depth into the breast tissue phantom with a tweezer and examined one after another. Each marker was examined individually in both directions (orthogonal and parallel) with a CBBCT, followed by FFDM.

Every marker has certain invariable characteristics: marker group, material composition, shape, weight, length, and width. Some markers had coatings of different composition around their markers. The maximum length and width of the different markers, without coating, were gauged by a caliper with an electronic display. The weight of the markers was measured with an analysis scale, after removing the coating of the marker. Additionally, the analysis of the material composition of the different markers was conducted at the Institute for Material Physics by using energy-dispersive X-ray spectroscopy. All markers are presented in Figure 1.

Assessment of Samples

All markers were individually examined in a breast tissue phantom with a dedicated CBBCT system (Koning Corporation). The system consists of a horizontal CT gantry, incorporating a mammographic X-ray tube (Rad 70, Varian Medical Systems) with a focal spot size of 0.3 mm, an X-ray flat panel detector (PAXScan4030CB, Varian Medical Systems) mounted on the CT gantry, and an ergonomically designed examination table. CBBCT scans were performed at 49 kVp, tube currents of 50 and 100 mA, with a pixel pitch of 0.388 mm (2×2 binning), resulting in a scan duration of 10 seconds for a 360° rotation. During acquisition, the flat panel detector acquired 300 two-dimensional projection images ($1024 \times 768 \times 14$ bits/projection) (Fig 2). The data sets from the CBBCT system are loaded into a specialized 3D visualization software (Visage CS Thin Client/Server, Visage Imaging, Richmond, Australia) and evaluated on a computer workstation.

The resultant 3D image sets were assessed in three orthogonal orientations (sagittal, axial, and coronal) with a slice thickness of 0.5 mm (Fig 3). During image postprocessing, a standard reconstruction mode with a soft tissue filter and a voxel size of 0.273 mm^3 was used. The measurement for each marker was conducted parallel and orthogonal to the scan direction of the CBBCT. In addition, measurements in the same directions were done with FFDM (Senographe Essential CESM, GE Healthcare, Milwaukee, WI).

Assessment of Artifacts

The artifacts caused by the different markers were quantitatively evaluated using a standard digital measurement technique. All available images were reviewed by a radiologist with 10 years of experience in radiological imaging, using a 5-megapixel monitor and the 3D visualization software (Visage CS Thin Client/Server). The quantitative analysis of the artifacts around the different markers using a CBBCT was measured under 12 different conditions: marker orientation orthogonal and parallel to the scan direction, different imaging planes (sagittal, axial, and coronal), and tube currents of 50 and 100 mA. The measurements with FFDM were conducted immediately afterward in the exact same marker orientation.

Sizes of markers' artifacts relative to the real physical length of the marker itself were compared to each other. This technique has already been used in similar studies in MRI (18–20) and is useful in comparing different implants to another.

Moreover, the images showing the largest artifacts were analyzed in all three imaging planes (sagittal, axial, and coronal) for exact analysis. All imaging parameters (eg, window size, zoom) were chosen individually to adequately assess the artifacts.

Statistical Analysis

This study is a pilot study for the generation of hypotheses. Therefore, no confirmatory but only descriptive analyses were performed and the *P* values are used as descriptive measures. Because the distribution of the absolute as well as of the relative length of the artifacts is skewed, the median, interquartile range (IQR), and the range (minimum to maximum) are reported as descriptive measures. For categorical variables, absolute and relative frequencies are provided. The association between the relative length of the artifacts and the categorical predictors is illustrated using boxplots and scatterplots. For the comparison of independent variables, the Mann-Whitney *U* test (for two groups) or the Kruskal-Wallis test (for more than two groups) was used. The Wilcoxon signed rank test was used for the comparison of dependent groups. Spearman correlation coefficient was calculated for the assessment of the association of the relative length of the artifacts and metric predictors.

RESULTS

Study Collective

All of the 29 breast tissue markers were visible in the images of the breast tissue phantom taken with the diagnostic