Breast Density Evaluation Using Spectral Mammography, Radiologist Reader Assessment, and Segmentation Techniques:

A Retrospective Study Based on Left and Right Breast Comparison

Sabee Molloi, PhD, Huanjun Ding, PhD, Stephen Feig, MD

Rationale and Objectives: The purpose of this study was to compare the precision of mammographic breast density measurement using radiologist reader assessment, histogram threshold segmentation, fuzzy C-mean segmentation, and spectral material decomposition.

Materials and Methods: Spectral mammography images from a total of 92 consecutive asymptomatic women (aged 50–69 years) who presented for annual screening mammography were retrospectively analyzed for this study. Breast density was estimated using 10 radiologist reader assessment, standard histogram thresholding, fuzzy C-mean algorithm, and spectral material decomposition. The breast density correlation between left and right breasts was used to assess the precision of these techniques to measure breast composition relative to dual-energy material decomposition.

Results: In comparison to the other techniques, the results of breast density measurements using dual-energy material decomposition showed the highest correlation. The relative standard error of estimate for breast density measurements from left and right breasts using radiologist reader assessment, standard histogram thresholding, fuzzy C-mean algorithm, and dual-energy material decomposition was calculated to be 1.95, 2.87, 2.07, and 1.00, respectively.

Conclusions: The results indicate that the precision of dual-energy material decomposition was approximately factor of two higher than the other techniques with regard to better correlation of breast density measurements from right and left breasts.

Key Words: Mammography; breast density; dual-energy; breast imaging; cancer.

Mammographic breast density is an important risk factor in the development of breast cancer (1–7). Previous reports have shown that women with the highest mammographic density (75%–100%) have 4- to 5-fold increased risk of developing breast cancer compared to the lowest density (0%–25%) (8–10). Furthermore, it has been shown that the sensitivity of screening mammography is lower among women with dense breasts (9,11–18). Therefore, improved methods of measuring breast density could potentially be helpful in more accurately quantifying breast cancer risk and monitor changes in risk over time. This is especially important because breast density can change with external factors such as hormonal agents and diet. The importance of quantitative breast density assessment has been highlighted by a previous report indicating that for every 1% increase of mammographic breast density, there is a 2% increase of the relative risk for breast cancer (19).

Qualitative classification of mammographic breast density is the current clinical standard. However, subjective classification of breast density is limited by its considerable intra reader and inter reader variability (20–22). Therefore, there have been previous reports of more automated methods using area-based and volume-based techniques to measure breast density (8,23). The area-based techniques essentially use a histogram of image gray levels for segmentation of fibroglandular and adipose tissues (8,23). These techniques are limited by the segmentation process and the fact that the three-dimensional nature of the breast is not taken into account. The current volume-based techniques use paddle position and a shape model for estimation of breast thickness, which is used in breast thickness calculation (24,25). However, these

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From the Department of Radiological Sciences, University of California, Medical Sciences I, B-140, Irvine, CA 92697 Received January 21, 2015; accepted March 18, 2015. This work was presented at 2012 RSNA Annual Meeting. Funding sources: This work was supported in part by National Institutes of Health/National Cancer Institute grant R01CA13687. **Address correspondence to:** S.M. e-mail: symolloi@uci.edu

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techniques are limited by the assumptions required in the breast shape model and the errors associated with the paddle position measurement, which can lead to a 2-to 3-fold increase in measurement error in volumetric breast density (26).

Spectral material decomposition can exploit the differences between the effective atomic numbers of fibroglandular and adipose tissues to provide separate quantitative thickness measurements for each tissue. It does not require any assumption for breast density measurement because glandular and adipose thickness measurements are based on two separate physical measurements using low- and high-energy image data. Previous studies have shown that accurate breast density measurements can be made using dual-energy mammography (27–29). However, slightly higher radiation dose is required for dual-energy mammography (27–29), and misregistration artifacts can result if the patient moves between acquisition of low- and high-energy images.

Recent introduction of spectral mammography, which uses energy-resolved photon counting detectors, eliminates the need for two exposures by providing the energy information using a single exposure (30–33). This addresses the previous limitations associated with radiation dose and misregistration artifacts associated with dual-energy mammography. A previously reported phantom study using spectral mammography has shown that accurate volumetric breast density measurements can be made using just a single exposure (34). Previous studies have also validated the accuracy of the dual-energy mammography technique for breast density measurement using chemical analysis in postmortem breasts as the reference gold standard (29,35). The postmortem breast studies have also shown excellent correlation of breast density between right and left breasts (29,35). The purpose of this retrospective study was to compare the precision of breast density measurement using reader assessment, histogram thresholding segmentation, fuzzy C-mean segmentation, and dual-energy material decomposition. The breast density correlation between left and right breasts was used to assess the precision of these techniques to measure breast composition relative to dual-energy material decomposition.

MATERIALS AND METHODS

Image Acquisition

Spectral mammography images from a total of 92 consecutive asymptomatic women (aged 50–69 years) who presented for annual screening mammography were retrospectively analyzed for this study where the requirement of informed consent was waived under institutional review board approval. One of the patients was excluded from this analysis because of an obvious breast cancer that changed the mammographic density in one of the breasts. The remaining 92 women were included in this study. The digital mammograms were previously acquired with a spectral mammography system (MicroDose L30, Philips Healthcare, Stockholm, Sweden). For the 92 women, bilateral, craniocaudal (CC), and mediolateral–oblique (MLO) views were analyzed. The processed (for presentation) images were used for radiologist reader assessment, histogram threshold segmentation, and fuzzy C-mean segmentation, whereas the raw (for processing) images were used for performing dual-energy material decomposition. A total of 368 digital images were thus available for density analysis in this study. The breast density correlation between left and right breasts was used to assess the precision of these techniques to measure breast composition relative to dual-energy material decomposition.

Breast Density Measurement

Radiologist Reader Assessment. All the images from the 92 patients were read (August 2012 to September 2012) by 10 board-certified radiologists with a range of 1–25 years of mammography experience. The CC and MLO views of each breast were read together, but the right and left breasts for all the patients were read in a random order blinded from the reviewers. The radiologists were asked to rank the breasts into 4 density categories of 1) fatty, 2) scattered densities, 3) heterogeneously dense, and 4) extremely dense. The averaged categorical ranking for the ten readers was also converted into percentage values by using linear interpolations, which assumed rankings of 1–4 as 12%, 37%, 62%, and 87%, respectively. This allows a more direct comparison of reader assessment with other breast density measurement techniques.

Histogram Threshold Segmentation. A previously reported histogram threshold segmentation method (Cumulus, version 4.2; Sunnybrook Health Sciences Center, Toronto, Canada) was used for segmentation of glandular and adipose tissues (36). In this method, each digital mammogram was adjusted by the reader to a window and level to optimize the display. This was followed by application of a manually determined intensity threshold to identify and subsequently exclude background air and to identify the breast edge. The pectoral muscle edge was then manually delineated and excluded from subsequent analyses. The remainder of the image was designated as the breast tissue region of interest, and the total breast area was computed automatically by the software. After identification of the total breast tissue area, a second gray-level intensity threshold was interactively chosen by the reader to segment the fibroglandular tissue from the remaining adipose tissue. The dense tissue area was then computed automatically by the software. The breast density was finally calculated by taking the ratio of the dense tissue area to the total breast area. Before the reading study, the order of the images was processed with an automated script written in Matlab (The MathWorks, Inc. Natick, MA), so that the CC and MLO views of the same breast were grouped together but the right and left breasts for all the patients were presented to the reader in a random order. Two medical physicists performed the reading independently without the knowledge of the image