By Prof Sabee Molloi

Spectral mammography using a photon counting detector: a unique method for the measurement of breast density

BREAST DENSITY AND CANCER RISK

Breast density, defined as the percentage of fibroglandular tissue (stroma and epithelial tissue) over the whole breast, has been associated with a higher risk of cancer. In fact, it has been suggested that women with a mammographic breast density higher than 75% have a four- to six-fold higher risk of developing breast cancer than women with little or no dense tissue [1].

Improved methods of measuring breast density could potentially help clinicians more accurately quantify breast cancer risk, and monitor changes in risk over time. This is especially significant because breast density changes with external factors, such as alcohol use, hormonal agents, diet, and other factors. The advantage of using a precise density assessment has been suggested by Boyd *et al.*, who reported that for every 1% increase of mammographic breast density, there is a 2% increase of the relative risk for breast cancer [2].

CURRENT METHODS OF ASSESSING BREAST DENSITY

The positive association between a qualitative classification of mammographic breast density and breast cancer risk was first reported in 1976, and has since been confirmed by many studies [1,3-13]. However, qualitative methods of assessment aren't reproducible, because different reviewers can perceive density differently. Thus, several quantitative methods have been developed. The first of these entailed reviewing 2D projection images of compressed breasts, and segmenting the breasts according to different X-ray attenuation properties [14,15,16]. This method required each pixel in the image to be classified as either purely adipose or purely fibroglandular tissue, making the measurements inaccurate. In addition, because the measurement relied on a 2D projection, it didn't take into account variations in breast thickness.

More recently proposed methods attempt to measure the fibroglandular and adipose thicknesses in each pixel, further increasing accuracy.

These include:

- Using the total estimated compressed breast thickness between the compression and the support plates, along with a system calibration
- Segmenting the fibroglandular tissue in the column above each pixel, so that a measurement of the volumetric breast density can be acquired from mammograms – either by using a standardized, quantitative representation of the breast [17,18] or using a volumetric method to measure breast density using calibrations from breast tissue-equivalent materials of known thicknesses and compositions [19,20].

While these methods represent improvements, they still depend on knowledge of thickness, which is compromised by using a shape model or because of the mechanical precision of the compression paddle. In fact, these two variables can lead to a two- to three-fold increase in measurement error for volumetric breast density [21].

FEASIBILITY PHANTOM STUDY SHOWS HIGH ACCURACY FOR SPECTRAL IMAGING BREAST DENSITY MEASUREMENTS

Studies have shown that accurate measurement of breast density can be achieved via dual energy imaging, which uses a standard mammogram as a low-energy image, and then acquires an additional, high energy image. By measuring the dual energy decomposition of adipose and fibroglandular tissues, accurate measurements of both density and thickness can be obtained [22,23]. However, the additional, high energy image increases mean glandular dose (MGD). In addition, if the patient moves between the acquisition of the two images, misregistration artifacts can result.

Spectral imaging with a photon counting detector, which sorts photons into low- or high-energy categories, eliminates the need for two exposures. We recently performed a phantom study on a mammography system that uses photon counting technology to determine the feasibility and accuracy of this technology to quantify volumetric breast density with just a standard mammogram [24].

PHOTON COUNTING TECHNOLOGY

The photon counting detector system consists of a large number of crystalline silicon strip detectors, with the strips tapered to point back to the X-ray source. To overcome silicon's relatively weak attenuation due to its low atomic number (Z=14), the strip detectors are in edge-on geometry, with their long axis parallel to the direction of the X-ray beam. This creates a sufficient absorption length to result in high quantum efficiency for the full energy spectrum used in mammography.

Our study consisted of two parts:

- Simulation studies to predict the optimized imaging protocol for the specific system, by maximizing the dual energy SNR with respect to mean glandular dose (MGD)

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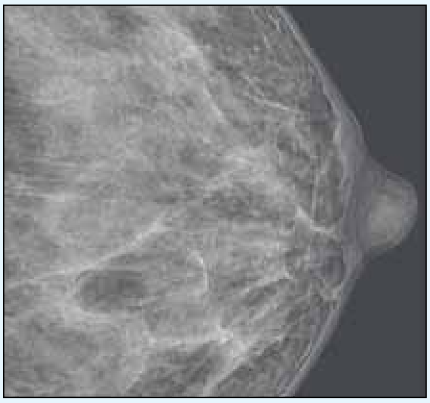

Clinical image from Philips MicroDose SI including Spectral Breast Density Measurement

• A comprehensive phantom study to characterize the accuracy in breast density measurement with the specific system

During data acquisition, all photons whose energies were above the noise floor were recorded in the total image. At the same time, photons whose energies were higher than the splitting energy were recorded in the high-energy image. The low-energy image was obtained by subtracting the high-energy image from the total image.

CONCLUSION

The results of the phantom study suggest that photon counting spectral mammography systems may potentially be implemented for an accurate quantification of volumetric breast density; the study resulted in a root-mean-square (RMS) error of less than 2%, using the proposed spectral imaging technique [24].

The advantages of using a photon counting spectral mammography system include:

1. Dual-energy data acquisitions, realized by means of multiple energy thresholds, can be obtained simultaneously with a single exposure, so patients are not exposed to radiation dose from second exposures

2. There is no spectra overlap in dual-energy decomposition

3. Motion artifacts that could result from acquiring low- and high-energy images sequentially are avoided

4. The electronic readout noise can be effectively eliminated by proper selection of the background threshold, which dramatically improves detection efficiency, especially for low-dose applications

5. The scanning multi-slit technique helps to eliminate scattered radiation

PRESENTATION AT RSNA 2013

On Tuesday 3rd December, in session SSG 15-07 commencing at 10.30 am in room S04AB of RSNA 2013, Dr Molloi and his team will be presenting their latest data on the use of spectral mammography for the quantification of breast density.

After an introduction describing the risk factor of breast density in developing breast cancer and the large inter-observer variability between radiologists in establishing BI-RADS categories, Dr Molloi will describe a study involving four-view mammograms for 93 women from a previous study using a Philips MicroDose Mammography SI system. All images were arranged in a random order for a blind comparison study. .Four-category BI-RADS rankings were assigned independently by 10 radiologists. Area-based breast density measurements were also performed by a physicist using Cumulus 4 and by an automatic image segmentation method based on a fuzzy C-mean clustering (FCM) technique. Volumetric breast density was calculated with a dual energy decomposition technique using the available spectral information. For all four techniques, linear regression analysis was performed to investigate the correlation of the breast densities from the right and left breasts. The breast densities from the right and left breasts showed a reasonably good linear correlation. The normalized variance about the best-fit line, which reflects the precision of the techniques, was estimated to be 8.4, 13.4, 6.1, and 1 for BI-RADS, Cumulus, FCM, and dual energy decomposition, respectively. This indicates that the variability in estimation of breast density is substantially lowerusing spectral mammography as compared with using BI-RADS, Cumulus and FCM in conjunction with standard mammography.

The data lead to the conclusion that spectral mammography can offer quantification of volumetric breast density with excellent precision during standard screening mammography and could eliminate the inter- and intra-observer variability in the currently used BI-RADS ranking.

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For more information on photon counting detector technology, see www.philips.com/MicroDoseSI