Spectral mammography using a photon counting detector provides a unique method for measurements 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.

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sense and simplicity

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

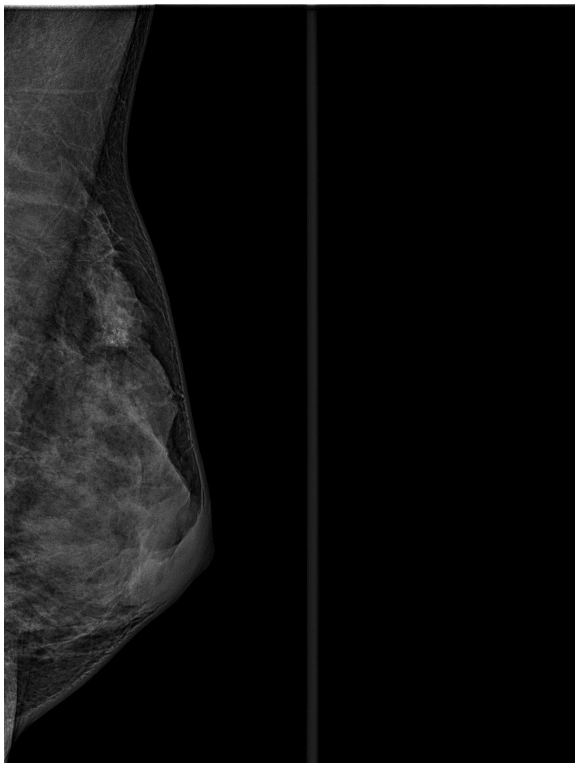
During data acquisition, all photons whose energies were above the noise floor were recorded in the total image. At the same time, photons whose energies were higher than the splitting energy were recorded in the high-energy image. The low-energy image was obtained by subtracting the high-energy image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



X-ray image of a dense breast. Breast density has been associated with a higher risk of cancer.

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

1. Boyd NF, Guo H, Martin LJ, Sun LM, Stone J, Fishell ER, Jong RA, Hislop G, Chiarelli A, Minkin S,and Yaffe JA. Mammographic density and the risk and detection of breast cancer. *New England Journal of Medicine*. 2007 356:227-236.
2. Boyd NF, Greenberg C, Lockwood G, Little L, Martin L, Byng J, Yaffe M, Tritchler D. Effects at two years of a low-fat, high-carbohydrate diet on radiologic features of the breast: Results from a randomized trial. *J Natl Cancer Inst*.. 1997 89:488-496.
3. Wolfe, JN. Risk for Breast-Cancer Development Determined by Mammographic Parenchymal Pattern. *Cancer*. 1976 37:2486-2492.
4. Wolfe JN., Breast Patterns as an Index of Risk for Developing Breast-Cancer. *American Journal of Roentgenology*. 1976 126:1130-1139.
5. Saftlas AF, Szklo M. Mammographic Parenchymal Patterns and Breast-Cancer Risk. *Epidemiol Rev*. 1987 9: 146-174.
6. Heine JJ, Malhotra P. Mammographic tissue, breast cancer risk, serial image analysis, and digital mammography part 1. Tissue and related risk factors. *Academic Radiology*. 2002 9:298-316.
7. Heine JJ, Malhotra P. Mammographic tissue, breast cancer risk, serial image analysis, and digital mammography part 2. Serial breast tissue change and related temporal influences. *Academic Radiology*. 2002 9:317-335.
8. Goodwin PJ, Boyd NF. Mammographic Parenchymal Pattern and Breast-Cancer Risk - a Critical-Appraisal of the Evidence. *Am J Epidemiol*. 1988 127:1097-1108.
9. Boyd NF, Byng JW, Jong RA, Fishell EK, Little LE, Miller AB, Lockwood GA, Tritchler DL, Yaffe MJ. Quantitative Classification of Mammographic Densities and Breast-Cancer Risk - Results from the Canadian National Breast Screening Study. *J Natl Cancer Inst*. 1995 87:670-675.
10. Byrne C, Schairer C, Wolfe J, Parekh N, Salane M, Brinton LA, Hoover R, Haile R. Mammographic Features and Breast-Cancer Risk - Effects with Time, Age, and Menopause Status. *J Natl Cancer Inst*. 1995 87:1622-1629.
11. Byrne C, Schairer C, Brinton LA, Wolfe J, Parekh N, Salane M, Carter C, Hoover R. Effects of mammographic density and benign breast disease on breast cancer risk (United States). *Cancer Cause Control*. 2001 12:103-110.
12. Harvey JA, Bovbjerg VE. Quantitative assessment of mammographic breast density: Relationship with breast cancer risk. *Radiology*. 2004 230:29-41.
13. McCormack VA, Silva IDS. Breast density and parenchymal patterns as markers of breast cancer risk: A meta-analysis. *Cancer Epidemiology Biomarkers & Prevention*. 2006 15:1159-1169.
14. Byng JW, Boyd NF, Fishell E, Jong RA, Yaffe MJ. The Quantitative-Analysis of Mammographic Densities. *Physics in Medicine and Biology*. 1994 39:1629-1638.
15. Sivaramakrishna R, Obuchowski NA, Chilcote WA, Powell KA. Automatic segmentation of mammographic density. *Academic Radiology*. 2001 8:250-256.
16. Zwiggelaar R, Denton ERE. Texture based segmentation. *Lect Notes Comput Sc*. 2006 4046:433-440.
17. Highnam R, Pan X, Warren R, Jeffreys M, Smith GD, Brady M., Breast composition measurements using retrospective standard mammogram form (SMF). *Physics in Medicine and Biology*. 2006 51:2695-2713.
18. Highnam R, Jeffreys M, McCormack V, Warren R, Smith GD, Brady M. Comparing measurements of breast density. *Physics in Medicine and Biology*. 2007 52:5881-5895.
19. Kaufhold S, Dohrmann R, Ufer K, Meyer FM. Comparison of methods for the quantification of montmorillonite in bentonites. *Applied Clay Science*. 2002 22:145-151.
20. Pawluczyk O, Augustine BJ, Yaffe MJ, Rico D, Yang JW, Mawdsley GE, Boyd NF. A volumetric method for estimation of breast density on digitized screen-film mammograms. *Med Phys*. 2003 30:352-364.
21. Alonzo-Proulx O, Tyson A, Mawdsley G, Yaffe MJ . Effect of Tissue Thickness Variation in Volumetric Breast Density Estimation, *Digital Mammography*. 2008 5116:659-666, edited by E. Krupinski (Springer Berlin / Heidelberg).
22. Ducote JL, Molloi S. Quantification of breast density with dual energy mammography: A simulation study. *Med Phys*. 2008 35:5411-8.
23. Ducote JL, Molloi S. A Quantification of breast density with dual energy mammography: An experimental feasibility study. *Med Phys*. 2010 37:793-801.
24. Ding H, Molloi S. Quantification of breast density with spectral mammography based on a scanned multi-slit photon-counting detector: A feasibility study. *Phys Med Biol*. 2012 57:4719–4738.

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