Reducing the radiation dose in molecular breast imaging

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Enhancements to semiconductor gamma cameras have reduced radiation exposure 3 to 5 fold.

Many studies have shown that screening mammography saves lives by detecting breast cancer early, when it is still curable. However, for the thousands of women who have dense breast tissue, the ability of this x-ray technique to detect cancer is greatly reduced. Consequently, many researchers are evaluating alternatives. We have been working on a new technology for this sub-population called molecular breast imaging (MBI). It uses cadmium zinc telluride (CZT) gamma cameras (see Figure 1) to detect the uptake of the radiotracer Tc-99m sestamibi in breast tumors. Results with MBI in a large study of 1000 women with dense breast tissue showed that it could detect 2 to 3 times as many cancers as mammography. However, a drawback to MBI is that current techniques use an administered dose of 20 to 30 mCi Tc-99m sestamibi, which results in an effective dose to the body of 6.5 to 10 milliSiverts (mSv). This is about 2 to 3 times the annual exposure from natural background radiation in the US (~3mSv) and is about 5 to 10 times that of mammography. The goal of our study was to reduce the radiation dose by a factor of 5 to 10, while maintaining image quality.

To achieve a dose reduction of this magnitude, we had to look at every aspect of the MBI technology to determine where improvements could be made. We evaluated a total of four different dose-reduction schemes. The first was development of improved collimation. The current lead collimation had been designed for conventional nuclear medicine studies and was not optimal for breast imaging. Second, we looked at improved utilization of the energy spectrum. Normally only gamma rays close to the radioisotope’s primary energy are used, but CZT detectors possess some unusual characteristics that may enable better use of information at lower energies. Third, we considered the development of an adaptive geometric mean algorithm for combining images from opposing detectors. The dual-head MBI system obtains opposing views of the same breast tissue, and it may be possible to combine these images, thereby reducing image noise and improving the ability to detect breast lesions. Fourth, we studied the implementation of special noise-reduction techniques such as a non local means filter (NLMF) for noise reduction and image enhancement. We initially validated these schemes using breast phantoms with various tumors and activity matched to that observed in clinical studies. We then confirmed this validation in patient studies.

We had previously developed a model of the optimum collimation for MBI that we used to construct a tungsten collimator where each hole is matched to an individual pixel in the CZT detector (see Figure 2). Theoretical calculations indicated that this would yield a 2.1 to 2.9 gain in system sensitivity. Figure 3 shows images from a clinical study performed both with the original collimation and the new tungsten collimation. We saw Continued on next page
Figure 2. A CZT detector with optimized tungsten collimator. Each hole in the collimator is matched to an individual pixel in the CZT detector.

Figure 3. Mediolateral oblique images in a patient with invasive ductal carcinoma. A) Image obtained using a conventional hexagonal hole collimator. B) Image obtained using an optimized tungsten collimator. A three-fold sensitivity improvement with no spatial-resolution loss.

A number of methods are being studied to improve the use of gamma rays detected at energies lower than the photopeak of Tc-99m (140keV). Figure 4 compares patient images acquired using a standard energy window (126keV to 154keV) and an asymmetrical wide window (110keV to 154keV). The wider window resulted in a 1.5 to 2.0 gain in sensitivity with minimal contrast loss. Work is ongoing to optimize the adaptive geometric mean algorithm that will allow us to combine images from both detectors. We expect this will yield a 1.4 reduction in image noise while retaining contrast. More refinements to the NLMF algorithm should yield another small image-quality improvement.

To date, we have been able to reduce the administered dose of radiotracer from 20 to 30mCi down to 6 to 8mCi for patient studies. We expect additional work on the various filter techniques will allow a further reduction to 2 to 4mCi. This lower dose range from MBI is comparable to that from mammography. This will be important as we consider using MBI in an environment where annual or biennial screening will be performed. Further work is also needed to confirm that the improved ability of MBI to detect breast cancer compared to mammography is retained at these low doses.

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Continued on next page
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