Digital systems aim to reduce breast imaging radiation dose

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Photon-counting, the method used in Sectra's detector, for example, minimizes patient exposure to radiation. In a 2006 analysis, the British National Health Service Breast Screening Programme reported that the Sectra MicroDose Mammography system achieved significant dose savings over screen-film mammography. The average mean glandular dose of the MicroDose System in this analysis was 0.57 mGy, a level that was 75% lower than average dose levels in film imaging systems.

A Swedish study1 confirms that clinical performance in terms of cancer detections rate and recall rate can be improved, while decreasing the radiation dose.

"The secret to the dose reduction possible with Sectra MicroDose Mammography is a high detective quantum efficiency (DQE) and contrast transfer, which basically translates to very low noise in the system and absorption and use of all incident x-rays with high efficiency," said Prof. Mats Danielsson, a professor of physics at the Royal Institute of Technology in Stockholm and cofounder of Sectra Macroa. "The photon-counting system, in fact, rejects all electronic noise that would otherwise blur the image."

Manufacturers of digital mammography systems are seeking to reduce radiation dose to patients by other means as well. One approach involves changing the way in which x-rays are generated. By going to a higher kV, the average x-ray energy will be higher, which means it will penetrate the breast and hit the detector more efficiently, said Dr. Andrew Smith, principal scientist for Hologic of Bedford, Massachusetts.

"For the same amount of signal hitting the detector, there is less signal being absorbed in the breast," Smith said. "That is something that could not be done with screen-film imaging because screen-film systems must operate in a very limited kiloelectron volt range to provide a high-quality image. But digital detectors are capable of imaging over a wide range of exposures and incident kV energies. So changing x-ray generation is the strategy by which people are further reducing dose."

The focus of change is on composition of the x-ray tube and x-ray filters. The gold standard for analog imaging has been a molybdenum x-ray tube and a molybdenum x-ray filter. However, the x-rays emitted from a tungsten tube have higher energy.

"Tungsten generates higher energy, which penetrates the breast better, so less radiation is absorbed in the breast and more goes to the imaging plate itself," said Jonny Eser, mammography product manager in the U.S. for Siemens. "Because of the higher current used to excite the electrons, there is better penetration-particularly in dense breasts-and a reduction in the patient dose."

The most common molybdenum form of x-ray tube operates at approximately 35 kV constant potential and produces peaks of radiation at 18 keV and 20 keV. That is the narrow x-ray spectrum of a molybdenum anode target and filter. X-ray tubes with tungsten targets operate at 30 kV, and they generate a large proportion of characteristic radiation at 8 keV and 10 keV. In combination with a rhodium filter, both molybdenum and tungsten x-ray tubes improve the depiction of glandular tissue, pectoral muscle, skin, and subcutaneous tissue for all types of breasts. The tungsten/rhodium combination provides a better depiction of glandular tissue in dense breasts, however, according to various studies.

Siemens Medical Systems has used tungsten tube technology in its mammography units since it first released the Mammomat 3000 Nova analog product line. In phantom studies2,3 of its amorphous selenium full-field digital Mammomat Novation system, investigators have shown that tungsten/rhodium preserves image quality while reducing radiation dose. Dose reductions ranged from 28% for an average 4-cm breast to 66% for a thick, fatty breast. Signal-to-noise ratios in...
average breasts nevertheless increased by 28% for calcifications and 48% for masses, and they were up to three times higher in fatty breasts, in a study by Duke University in Durham, North Carolina.

A 2006 European study found that the mean glandular dose for the tungsten/rhodium combination used in the Novation mammography system was 49% lower than the molybdenum/molybdenum tube/filter configuration and 33% lower than the molybdenum/rhodium combination. Sectra has a rotating tungsten anode, and Hologic is planning to add a tungsten alternative to its Selenia system.

Although Siemens recommends using tungsten for imaging breasts of all sizes and tissue compositions, its digital mammography system offers both molybdenum and tungsten to suit customers' preferences.

GE Healthcare's digital mammography system has an x-ray tube with a rhodium as well as a tungsten track. Depending on breast density and compression thickness, the filtration of the x-ray system can be changed by means of automatic optimized protocols, which adjusts the energy spectrum of the x-ray beam to try to get the best dose performance, said Mike Barber, the company's chief technology officer.

"The automatic optimized protocols determine-based on a number of parameters such as kV or mA settings as well as breast compression thickness-what is the right energy spectrum," Barber said. "And the way you get that different energy spectrum is by switching between rhodium and tungsten."

Dose might be reduced further, at least theoretically, by eliminating the scatter-absorbing grid. This grid has long been a standard element in mammography and radiography to counteract the loss of contrast due to scattered radiation, according to Eser.

Grids have been especially important in mammography because of the need for high contrast to distinguish between malignant and normal tissues, which often have nearly the same densities. After researchers removed the antiscatter grid in one study, image quality improved when breast phantoms were smaller than 5 cm, and contrast detail with and without the grid was similar when breast thickness was between 5 cm and 7 cm, leading investigators from the University Medical Center of Nijmegen in the Netherlands to suggest that a grid might not be necessary when imaging compressed breast thicknesses of 1 to 7 cm.

Researchers from Siemens reported last year that an antiscatter grid improved image quality only when breast tissue was 5 cm or greater. The investigators recommended removing the grid for imaging breast thicknesses less than 5 cm because the amount of scatter radiation in such tissue samples is low.

Danielsson contends, however, that the research does not indicate that removing the grid leads to dose reduction for average or thicker breasts.

"Instead, the situation, from image quality and dose point of view, is equally bad in both cases, with or without the grid, and far away from the performance of the Sectra multislit scanning technique," he said, citing a peer-reviewed paper.

A multislit system, such as the Sectra MicroDose, maintains the contrast that would be reduced by use of a bucky grid and still rejects scattered radiation without compromising primary radiation. As a result, it operates at radiation doses below those associated with detectors that have a grid. Removing the grid for those detectors would not reduce dose for an average breast since the fraction of scattered radiation would increase.

Research published in the April 2006 issue of Medical Physics summarizes the effect of removing the grid. For thinner breasts, its removal is advantageous, while for thicker breasts, the penalty in terms of increased scatter is too high. In all cases, the performance of the scanned-slit photon-counting technique was found to be superior to the other techniques, according to the investigators.

GE is working to further improve dose performance by increasing the sensitivity of the amorphous silicon flat-panel detector to leverage every photon that reaches the scintillator, according to Barber, who could not divulge the specific strategies the company is following at this point.

**OTHER METHODS**

Future dose-reduction strategies may not have much to do with digital detector technology, according to Smith.

"With selenium detector technology, we are already stopping almost 100% of the x-rays, so there's not much to do in terms of making the detector more radiation-efficient," he said. Absorption, however, is only one of several factors affecting DQE and, thus, dose and image quality. In terms of noise, there is much room for improvement.
In a study conducted by researchers from Lausanne, Switzerland, DQE for all available technologies for digital mammography was measured, and it was found that, depending on detector, improvements of 40% to 80% are possible. At low doses, the potential improvement is even higher.8 Sectra’s photon-counting technique comes out on top in this comparison, and the reason is the absence of electronic noise.

The way to get improvement, according to Smith, is by moving to 3D imaging. Volumetric data capture through tomosynthesis does not improve the dose efficiency of the digital detector, nor does it improve the resolution of images. But it does provide a clearer depiction of anatomic structures and abnormalities by expanding beyond the standard 2D views of the breast. Tomosynthesis also may contribute to dose reduction by requiring only two views rather than the four views of each breast in a standard screening exam, Eser said.

"There need to be some studies to actually prove that you could eliminate two of the regular views with tomosynthesis," he said. "But if it proves true, that will also be a reduction of dose to the patient."

A potential breakthrough for the future is the introduction of active x-ray filters in terms of x-ray optics fabricated using advances in nanotechnology, according to Danielsson.

"These active lenses would shape the x-ray beam to enable further dose reduction by tuning it to the optimum energy, an energy that could potentially be changed for different breast sizes," he said. "Research is actively going on in this area at a number of universities and companies, but it is hard today to guess when this might become a clinical reality."

It is interesting to note, however, that mammography, the last field to switch from screen-film to digital, is now already using photon-counting systems in clinical praxis, a technique that is still in the laboratories for use in next-generation CT systems, Danielsson said.

References


Ms. Sandrick is a freelance writer based in Chicago.

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