Digital breast tomosynthesis

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The development of digital detectors for mammography has permitted the development of tomosynthesis for breast evaluation. Digital Breast Tomosynthesis (DBT) has been developed in an effort to improve on the major success of mammography. DBT is a new embodiment of a technique that was first described over thirty years ago. It was developed for breast imaging because the normal structures of the breast can obscure a lesion (structure noise) or appear to be a lesion when none is present, both complicating the interpretation of conventional mammograms (analog as well as digital). Early results suggest that DBT may have major advantages over standard two-dimensional mammography (analog as well as digital), for example in reader studies, cancers are more conspicuous on DBT than on conventional mammography, and DBT results so far have shown a major decrease in the false positive rate.

Not all tomosynthesis techniques being applied to the breast are the same. There are different ways of acquiring the images and differing ways of processing the images to “synthesize” slices through the breast. Consequently, it is important to not think of tomosynthesis of the breast as a single monolithic technique. One approach may be quite different and have different results from another approach. It remains to be seen which technique is superior. The fundamental technology involves acquiring projection images of the breast from different angles and using the parallax shift of structures in the projection images to “synthesize” slices through the breast. Our approach at the Massachusetts General Hospital was the first to permit whole breast imaging by moving the X-ray source while keeping the detector and breast stationary. Acquisition images can be obtained by moving the tube and the detector in various combinations. It would even be possible to move the breast with or without tube and detector motion.

Since 1990, and for the first time in over 50 years, the death rate from breast cancer has decreased in the United States by 27 percent. This is primarily due to mammography screening with a small portion attributable to improved therapy.

It is still not certain what the best combination of projection images is nor is it clear what angles are best for collecting these images. Another unknown factor is how much of the total dose to be used should be used at which angle. There have been no good comparisons of the results obtained by varying the composition of the X-ray source (focal spot type), and it remains to be seen if one detector technology is better than another. It is fairly certain that it is better to collect the images over a shorter time rather than a longer time since motion of the breast produces blur and misregistration, but the contribution of motion to the degradation of the synthesized images is not clear. Speed of acquisition is directly related to the speed at which the information can be read from the detector, and how quickly the detector can collect the next image. Since some detectors lack sufficient readout speed at high resolution, they have to “bin” the pixels (averaging the data from four or more pixels together). This will, of course, reduce the spatial resolution of the system. Other factors that will influence the image quality are the various elements of noise contributed by the system and the breast, and how that noise is handled.

Once the projection images have been collected there are already a number of ways that have been developed to “synthesize” the slices. The original approach that was first described is “shift and add”. This electronically “aligns” the images so that structures in a designated plane align on all the projection images. These are then added so that the plane of interest is reinforced by the number of acquired images while structures out of plane are misregistered and not reinforced and fade into the background. Then the images are shifted and added again to synthesize the next plane through the breast, and so on. More complex algorithms have been developed that reduce the contributions of structures that are out of plane. Algorithms devised for computed tomography have also been applied.
The simplest way to compute the slices through the breast is to know the location of the X-ray tube at the time of exposure and the angle at which the beam passed through the tissues. One variation in data processing is based on the method used to understand the direction in which X-rays passed through the breast. Tuned Aperture Computed Tomography (TACT) uses fiducials in the X-ray beam, and uses the locations and projections of these known fiducial references, included in the images, to permit the calculation of the location of the X-ray source and the direction that the rays traveled through the tissues so that precise, direct measurement of the angle is not necessary. TACT has been used for imaging small portions of the breast, but I am unaware of its use for imaging the entire breast.

Borrowing on the approach used for computed tomography, some breast tomosynthesis studies are processed using filtered back projection, which has the advantage of speed. It enhances high frequency data such as calcifications, but masses are not handled as well by filtered back projection. The physics suggests that some form of iterative maximum likelihood algorithms are best at reproducing both calcifications and masses.6 Others have developed algorithms to reduce the repetitive out-of-plane artifacts that are most prominent when only shift and add approaches are used.

Reader studies
In our preliminary experience, based on current results in studies using DBT in women who volunteered to have standard film/screen imaging and a concurrent DBT study, blinded readers were better able to differentiate benign lesions from malignant lesions using DBT.7 Based on the same studies blinded readers also called back fewer patients for pseudo-lesions that were subsequently shown to be of no consequence.8 We have corroborated the latter in a screening study of over 2,500 women where the callback rate has been reduced by up to 40 percent using DBT as a screening study. Perhaps the most important indication so far is that, by reducing the structure noise of the normal breast tissues, lesions are more conspicuous using DBT than they are on conventional mammography.

Visualizing calcifications
Some have suggested that calcifications are not as well seen on DBT as they are on standard two-dimensional mammography. This has not been our experience. Since the detector for DBT is, essentially, the same as for conventional digital mammography, the spatial resolution should also be the same. As long as the detector elements are not “binned,” decreasing the spatial resolution of the detector, and as long as motion does not blur the image, there is no reason to believe that calcifications are seen more clearly on two-dimensional imaging versus DBT. It has been our experience, based on studies so far, that calcifications are often more clearly seen on tomosynthesis studies by reducing the structure noise of the normal breast tissues. In a review of over forty cases of groups of calcifications in a direct comparison between DBT and digital mammograms, the vast majority of calcifications were more clearly seen on DBT than on 2D digital.

I suspect that some have confused the conspicuity of calcifications with the perception of their presence. Since tomosynthesis provides cross sections through the breast, the radiologist may not appreciate the “clustering” of the calcifications because, as the radiologist “pages” through the images, one calcium particle may appear and then disappear while two or more are in the next slice and then

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they are gone with another in the next slice and so on. The radiologist may not appreciate the clustered distribution even though the particles are quite conspicuous. Various methods have been developed including passing a thick reconstruction “slab” through the breast using a maximum intensity projection within the slab to aid the radiologist in appreciating the clustering. We have developed additional approaches that should overcome the perception problem.

Current results indicate that DBT could alter the approach to X-ray imaging the breast by reducing the need for “Diagnostic Mammography”
The results of the studies so far suggest that the confusion caused by structure noise (normal breast tissue) superposing on conventional two-dimensional images, could be eliminated using tomosynthesis. If further results prove conclusive, this could greatly alter the diagnostic sequence of events following the screening study. On this basis, if DBT becomes the screening study, the need for recalling patients for diagnostic evaluation may be markedly decreased in the following fashion.

The first reason that a patient is recalled from conventional mammographic screening for additional (diagnostic) evaluation is because the radiologist has seen something on the screening study that he/she is not certain is even real.

In fact, in our experience, 25 percent of the women recalled from screening are found to have superimposition of normal tissue that forms a “summation shadow” that looks like a lesion, but is normal superimposed tissue structures. With conventional imaging, the patient is recalled and several (and sometimes many) additional images are obtained to try to determine if there is a real lesion in the breast or if it was merely summation of normal structures, however, if tissues are no longer superimposed using DBT there cannot be “summation shadows”.

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The next reason to recall a patient from screening for diagnostic evaluation is because the radiologist is convinced that there is a real abnormality, but can only see it in one of the two screening projections. If it is only seen in one view, then its three-dimensional location within the breast is not known, and if it is a finding of concern, the patient must be recalled to obtain additional imaging to determine its three-dimensional location in the breast. Since DBT is cross sectional, the location of a lesion is never in doubt. Its x and y coordinates are measurable on the slice on which it is seen, and its “z” location is calculated by knowing the slice number on which it is best seen, how thick the breast is while the acquisition images were obtained, and how many slices were needed to go from one side of the breast to the other. For example, if a lesion is best seen on slice 33, and it took 66 slices to go through the breast, the lesion is clearly in the center of the breast (33/66). The “z” location is easily calculated from the slices so that the radiologist knows how far the slice is above the plane of the detector.
Finally, the radiologist recalls women from screening to get a better look at the shape and margins of masses, and the morphology and distribution of calcifications. If it can be shown that the use of DBT eliminates the need for magnification mammography, then the only reason to recall women from screening would be because they should have an ultrasound or an imaging guided biopsy. If ongoing results continue as expected, the use of DBT for screening could eliminate the need for most “diagnostic” mammography.

Some have suggested that there is a long learning curve to learn to interpret breast DBT. My experience is that there is little or no learning curve. The “rules” for mammographic interpretation apply to breast tomosynthesis. There are some structures that DBT shows that are frequently hidden on standard mammography. Biopsy scars following surgery with benign results are usually not evident on standard mammography, but they are often seen on DBT. This is not a problem since the history of a biopsy clarifies the observation. Hopefully new signs will be discovered that will help increase the cancer detection rate. At the present time, most of the “learning” has to do with using the workstations. As these become “user friendly”, the interpretation of breast tomosynthesis will also be facilitated.

**Does DBT require increasing the dose for mammography?**

It is clear that radiation risk to the breast is related to the age at which the individual is exposed. By the time a woman reaches the age of 40, and the recommended start of routine screening, the breast has matured and is, essentially, resistant to radiation. Not only do the data from previous situations where women were exposed to much higher than mammographic doses show no increased risk of developing breast cancer, but, mammography has been applied to millions of women over the past 20 years. If the radiation from mammography was causing cancer the incidence of breast cancer would be increasing, but, in fact, it is decreasing. The research studies so far have utilized a dose for the DBT study, which is at least equivalent to the combined dose for the standard 2 view (MLO and CC) screen-film mammogram.

**Conclusion**

The development of digital detectors for mammography has opened up new opportunities to use X-ray imaging to improve our ability to detect and diagnose breast cancer. The preliminary results so far suggest that DBT should help to increase the sensitivity of mammography as well as the specificity. There is great hope for the development of new and improved therapies and ways to prevent breast cancer. Mammography is here and has been shown to be decreasing deaths today. We expect DBT to build on this major success.
References


