

## COMMENTARY

# Advances in mammographic imaging

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**ABSTRACT.** Breast imaging in the UK is currently undergoing a major change, with the widespread implementation of full-field digital mammography (FFDM) equipment. This article looks at some of the advanced imaging techniques that have become possible following the development of FFDM units. These techniques may prove to be useful additions to standard mammography for some groups of women.

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Despite major recent advances, mammography remains a very technically demanding imaging procedure. This is partly because the breast is exclusively soft tissue and that normal and abnormal tissues have very similar radiographic properties. In addition, the appearance of “normal” breast tissue varies enormously from woman to woman. Estimates of the sensitivity of mammography vary widely, with one recent study giving a figure of 78% [1]. Sensitivity varies with age and breast density, with figures as low as 48% being reported for the most dense breasts [1]. However, despite these limitations, mammography remains the main modality for breast screening.

Until the late 1960s, when the first dedicated mammography unit was developed, breast imaging was carried out using standard radiographic X-ray systems. As a result, the image quality was poor and radiation doses were high. Over the years, units with smaller focal spots, better optimised tube voltages and target-filter combinations and automatic exposure control (AEC) systems have been introduced. Further refinement took place with the development of more sophisticated AEC systems in which the beam quality selected by the unit depends on the properties of the breast being imaged. The use of different tube voltage and target and filter materials allowed the mammographic examination of larger breasts to be carried out at a lower mean glandular dose while maintaining (as much as possible) an adequate level of contrast in the image. On the image acquisition side, the move away from direct exposure film to dedicated high-resolution intensifying screens for mammography lowered radiation doses significantly. However, the era of film–screen imaging is drawing to a close and the main developments are now in digital mammography. Significant advantages are associated with digital mammography, including the separation of image acquisition and display, improved dynamic range,

the elimination of film processing and the ability to perform advanced imaging techniques.

The first direct digital imaging in mammography was in small-field digital systems used for stereotactic localisation. Such units were, by definition, small-area devices that could not be used for general mammography. Nevertheless, they provided useful advantages over conventional stereotactic systems, particularly reducing the period of time the procedure took to complete. Over the past few years, there has been a surge in the number of full-field digital mammography (FFDM) units on the market. These systems use a number of different image detector technologies, such as amorphous selenium and CsI/amorphous silicon; more novel systems include photon counters.

Despite these great technical advances in the production and detection of X-ray photons, mammography still suffers from the fundamental problem of representing a three-dimensional object by a two-dimensional image. Since the radiographic image is a summation of the radiographic attenuation present along a particular beam path, a low-contrast object can be completely masked by the presence of dense tissue above or below it. Also, the superimposition of different layers of normal tissue can mimic an architectural distortion or lesion. This can be a particular problem when the breast is very dense (more common in younger women), and the detection of lesions in the glandular part of the breast is very difficult. As the target age range for the NHS Breast Screening Programme (NHSBSP) is extended to include younger women, the number of examinations falling into this category will increase significantly. The superimposition and masking of tissue in the image will contribute to the number of false-positives and false-negatives associated with mammography. While most mammography results in a screening programme are true-negatives, false-positives result in significant anxiety for women who may be recalled for further investigations. False-negatives give a false sense of security and can delay diagnosis. The discovery of false-negative cases can also lead to legal action by patients and to reduced confidence in a

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screening programme. For these reasons, any development that reduces error rates is to be welcomed. A large multicentre study [2] demonstrated that digital mammography was more accurate than film–screen imaging in the screening of younger women and women with radiographically dense breasts. Digital mammography was also as good as film–screen mammography for older women. At present, there is a major procurement exercise in the NHSBSP to replace existing film–screen imaging systems with FFDM units.

The use of contrast agents in breast imaging, other than in MRI, is not widespread. Several mammographic techniques that use iodine contrast agents have, however, been proposed to improve the visualisation of malignant lesions in the breast. It is known that a tumour needs to develop its own blood supply in order to grow beyond a few millimetres in size. This angiogenesis provides a potential method of improving the conspicuity of malignant lesions through differential uptake of contrast agent. It might even be possible to characterise lesions by looking at contrast enhancement kinetics. The advent of FFDM systems has allowed the investigation of some of these techniques for breast imaging.

Temporal subtraction imaging has been around for many years in the general radiology environment, and digital subtraction angiography has become a commonplace procedure that is available even on many mobile fluoroscopy systems. An image is taken before the administration of a contrast agent (the mask image), a quantity of iodine-based contrast agent is then injected and a series of (post-contrast) images taken over a period of time. Weighted logarithmic subtraction of the mask from each image is then carried out, resulting in the suppression of the anatomical background. This technique, using a fluoroscopic imaging system, was applied to imaging breast cancers in the mid-1980s [3]. More recently, a dedicated FFDM system has been used to carry out contrast-enhanced digital mammography (CE-DM) examinations [4, 5]. Images taken over several minutes have demonstrated the uptake of contrast agent in lesions, but the results from these feasibility studies suggest that the enhancement kinetics do not consistently show different patterns for benign and malignant lesions [4, 5]. In some cases, however, uptake curves did show similar patterns to those found in contrast-enhanced MRI.

In standard mammography, the breast is compressed in order to reduce movement blurring, scatter and breast radiation dose. The issue of compression poses a problem for CE-DM in that, if significant compression is applied, the pressure in the breast can be great enough to reduce blood flow and cause poor uptake of contrast agent. Less compression could be applied during the procedure, but this would reduce geometric sharpness and could lead to excessive movement between the acquisition of the mask image and subsequent images, resulting in misregistration artefacts. Alternatively, the compression could be released following the pre-contrast image to allow the injection of contrast agent and then reapplied, although it is likely that this method would lead to even greater misregistration artefacts. In order to maximise the contrast of the iodine, photons in the X-ray beam should have an energy just above that of the K-edge of iodine. A high kV and significant additional filtration is required to achieve this with standard mammography equipment. This extra

filtration will, by necessity, reduce the X-ray tube output, requiring tube loadings that are greater than those used in standard mammography. This may have implications for X-ray tube life.

An alternative approach to CE-DM is contrast-enhanced dual-energy mammography [6]. In this technique, instead of acquiring a mask image and a series of post-contrast images over a period of time, the contrast agent is injected and two exposures taken in quick succession using different beam energies (one above the iodine K-edge and one below in order to maximise the contrast of the injected iodine). Again, a weighted subtraction of the two images is performed that will effectively remove areas that have not taken up the contrast agent from the image areas. As there is no need for a “pre-contrast” image, compression can be applied after the injection to reduce the potential for movement artefacts and retain the degree of image detail associated with standard mammography. A further advantage over CE-DM is that no registration of pre- and post-contrast images is necessary, and so image pairs can be acquired in any projection and the subtraction carried out.

Although the use of iodine contrast agent together with image subtraction will reduce the appearance of “background”, the problem of superposition of unrelated anatomical structures still exists. Cross-sectional imaging, such as computed tomography (CT) and MRI of the breast, has been used for several years to alleviate this problem. Although the contrast resolution of these techniques is very good, their poor spatial resolution limits their usefulness. In addition, the radiation dose associated with CT is significantly higher than standard “mammographic” techniques and the cost (both financial and in scanner time) is significant for MRI.

Using multiple radiographic projections to create isolated image planes at different “depths” is not a new idea [7], but this process would be impractical with analogue mammography equipment. With the advent of full-field digital units, this idea has been re-investigated. Digital breast tomosynthesis (DBT) uses multiple low-dose projection images of the breast taken during a single scan. From these images, it is possible to reconstruct slices through the breast at discrete depths. The technique therefore has the potential to reduce the uncertainty produced by overlying tissue masking or mimicking abnormal areas. Although still a relatively new technology, many manufacturers now offer DBT as an option on their FFDM equipment or are able to provide a dedicated unit. Because of the nature of the technique, a large number of images is produced. The electronic storage of these images will need to be considered, as will the change in reporting method for radiologists. It has been shown that soft-copy reporting is more time-consuming than film reporting. Moreover, the production of many more images per patient is likely to increase the demand on the radiologist’s time even further.

More recently, work has been carried out to investigate the use of iodine contrast agents in combination with DBT [8–10]. These studies have investigated both temporal [8] and dual-energy subtraction methodologies [9] in further attempts to extract as much information as possible from the imaging technique. A paper published in this issue of the *British Journal of Radiology* reports on the clinical feasibility of dual-energy subtraction DBT [10] and

provides information on both the lesion morphology and enhancement kinetics of a known malignancy.

Although still very much in the feasibility stage of development, these exciting techniques may prove to be useful additions to standard mammographic imaging for particular groups of women. It is timely that these techniques are being studied in a period when the NHSBSP is embarking on the procurement of large numbers of digital units. Any risk–benefit calculation for examinations using these techniques would need to take into account the additional risk associated with the injection of contrast agent. The techniques may, however, provide information on the classification of lesions and demonstrate the extent of lesions more effectively than standard mammography. Furthermore, they may achieve this relatively cheaply and without the radiation dose associated with CT imaging.

## References

1. Kolb TM, Lichy J, Newhouse JH. Comparison of the performance of screening mammography, physical examination, and breast US and evaluation of factors that influence them: an analysis of 27,825 patient evaluations. *Radiology* 2002;225:165–75.
2. Pisano ED, Gatsonis C, Hendrick E, Yaffe M, Baum JK, Acharyya S, et al. Diagnostic performance of digital versus film mammography for breast-cancer screening. *N Engl J Med* 2005;353:1773–83.
3. Watt AC, Ackerman LV, Windham JP, Shetty PC, Burke MW, Flynn MJ, et al. Breast lesions: differential diagnosis using digital subtraction angiography. *Radiology* 1986;159:39–42.
4. Jong RA, Yaffe MJ, Skarpathiotakis M, Shumak RS, Danjoux NM, Gunsekara A, et al. Contrast-enhanced digital mammography: initial clinical experience. *Radiology* 2003;228:842–50.
5. Dromain C, Balleyguier C, Muller S, Mathieu M-C, Rochard F, Opolon P, et al. Evaluation of tumor angiogenesis of breast carcinoma using contrast-enhanced digital mammography. *AJR Am J Roentgenol* 2006;187:W528–37.
6. Lewin JM, Isaacs PK, Vance V, Larke FJ. Dual-energy contrast-enhanced digital subtraction mammography: feasibility. *Radiology* 2003;229:261–8.
7. Miller ER, McCurry EM, Hruska B. An infinite number of laminagrams from a finite number of radiographs. *Radiology* 1971;98:249–55.
8. Chen SC, Carton A-K, Albert M, Conant EF, Schnall MD, Maidment ADA. Initial clinical experience with contrast-enhanced digital breast tomosynthesis. *Acad Radiol* 2007;14:229–38.
9. Carton A-K, Lindman K, Ullberg C, Francke T, Maidment ADA. Dual-energy subtraction for contrast-enhanced digital breast tomosynthesis. In: Hsieh J, Flynn MJ, editors. *Physics of Medical Imaging. Proc of SPIE Vol 6510*, San Diego, CA: SPIE, 2007: 651007-1–651007-12.
10. Carton A-K, Gavenonis SC, Currivan JA, Conant EF, Schnall MD, Maidment ADA. Dual-energy contrast-enhanced digital breast tomosynthesis — a feasibility study. *Br J Radiol* 2010;83:347–353.