Commentary

Computer-assisted mammographic imaging

Caroline RM Boggis and Susan M Astley*

South Manchester University Hospitals (NHS) Trust and *Manchester Medical School, Manchester, UK

Received: 1 June 2000
Revisions requested: 11 July 2000
Revisions received: 20 July 2000
Accepted: 28 July 2000
Published: 25 August 2000

Breast Cancer Res 2000, **2**:392–395

Abstract

Computer-assisted mammography imaging comprises computer-based analysis of digitized images resulting in prompts aiding mammographic interpretation and computerized stereotactic localization devices which improve location accuracy. The commercial prompting systems available are designed to draw attention to mammographic abnormalities detected by algorithms based on symptomatic practise in North America. High sensitivity rates are important commercially but result in increased false prompt rates, which are known to distract radiologists. A national shortage of breast radiologists in the UK necessitates evaluation of such systems in a population breast screening programme to determine effectiveness in increasing cancer detection and feasibility of implementation.

Keywords: algorithm, computer-assisted mammography, digital, digitally acquired, digitised, effectiveness, prompt

Mammographic screening programmes require radiologists to search through large numbers of films for signs of abnormality that occur only infrequently, and that may be small, subtle, or embedded in a complex background. This is a time-consuming and error-prone process. Improved accuracy can be achieved by having two radiologists read each mammogram, and potentially by using computers to aid the film reader.

A typical large breast screening unit in the UK National Health Service Breast Screening Programme may be responsible for screening as many as 38 000 women each year, in addition to its symptomatic breast practice. Such a service, which corresponds to 3.5 Forrest Units [1], may generate approximately 1000 mammograms per week, and may diagnose up to 250 breast cancers per annum. The radiological input to support such breast units comprises daily single-screen reading (2–2.5 h), resulting in five assessment clinics weekly.

Even greater radiological input is required to support double reading of mammograms, which has been shown to improve detection of breast cancer by 9–15% [2,3]. Additional resources will also be needed to cope with an estimated demographic increase of 50% in the screening population by the year 2015; this includes an expected demand to raise the upper screening limit to 70 years. The population increase will also have an effect on the symptomatic services because of the increasing incidence of breast cancer with age. To reduce the screening interval to the clearly beneficial 2 years would necessitate a massive financial investment to ensure sufficient equipment, facilities and staff [4].

CAD = computer-assisted diagnosis.

There is, however, a nationally recognized shortfall in radiologists, specifically in those who are interested and trained in mammographic interpretation. Breast imaging services are already efficient and are developing innovative methods to ensure delivery of service needs. Computer-assisted mammographic screening, including both digital acquisition of mammograms and computer-assisted diagnosis (CAD), could potentially ease the problem either by enabling new groups of readers to interpret mammograms, or by improving individual performance and obviating the need for double reading.

Computer-based systems have been developed to digitize mammograms and process them to detect putative abnormalities. These are then displayed as prompts, either on miniature monitors incorporated into the film viewer, or as paper reproductions of the mammogram. The prompts are reviewed at the time of reporting by the radiologist. The aim is to improve the effectiveness of radiologists in detecting breast cancers on both screening and symptomatic mammograms. Ultimately, such a system could be used instead of a second reader for screening mammograms.

Prompting systems incorporate algorithms to detect potential abnormalities such as masses and microcalcification clusters in digitized images. This is challenging for both human and machine, and successful algorithms have not yet been developed for all types of abnormality. As a result, computer-based systems cannot be used to identify films that are unequivocally normal, and a skilled human interpreter must make the final decision on every film. Prompting, in which the areas detected by the computer are used to draw the radiologist's attention to the corresponding regions in the original films, has the potential to improve an individual's detection performance, provided that the prompts are sufficiently accurate [5]. It allows radiologists to exploit some of the benefits of computer-based analysis such as reproducibility and objectivity, without making unrealistic demands on algorithm performance, because it neither requires a complete suite of algorithms nor perfectly sensitive prompts. Prompting systems do, however, require digital input data. At present, most mammograms are produced using film-screen systems, so the films must be digitized, but it is a relatively short step to use digitally acquired mammograms as input.

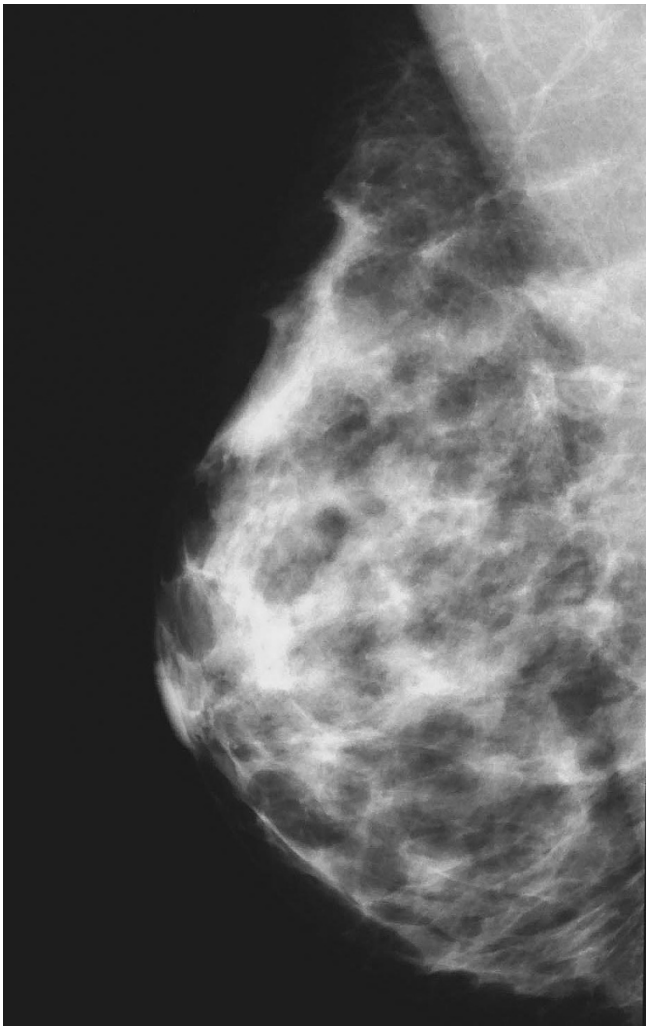
Although there is some evidence to support the view that prompting can significantly improve an individual radiologist's detection performance [6,7], there are still many unanswered questions about the way in which prompting will affect radiologists in the National Health Service Breast Screening Programme. In particular, studies have shown that the number and distribution of false prompts are critical to the success of the process [5,7]. In most commercial systems, in which sensitivity to abnormalities is seen as an important selling point, false prompts are the price one has to pay. Some systems produce, on average, nearly one false prompt per mammogram. Published research studies on commercial prompting systems [8,9] have not to date demonstrated any statistically significant improvement in radiologists' detection performance within a screening programme in which the vast majority of films are normal. However, such studies have shown that systems can detect a large proportion of subtle lesions using a retrospective review of prior screening films of patients with cancer. Because it is not yet known whether prompting has any detrimental effects on radiologists' performance in population screening mammography, these systems cannot yet be used in a population screening programme.

The main challenges in acquiring digital images for mammography are obtaining images with sufficiently high spatial resolution, and providing a system for viewing such images. The smallest microcalcifications are approximately 0.1 mm in size; in order to visualize these in a digital mammogram of standard dimensions, one needs images over 3000 pixels across. In many applications, images acquired digitally are printed out and viewed on film for ease of viewing locally within the unit, for comparison with subsequent mammographic examinations, and for archiving purposes. The implication of using film images in conjunction with digital images is that there is no reduction in cost resulting from installation of a digital mammographic machine. The alternative is to display the digital images on screen, but this also causes problems, as a radiologist will typically wish to view four current films and two previous films per case.

However, direct acquisition of mammograms, as opposed to digitizing film images, can produce very high-quality images (Fig. 1). Digital images provide flexibility, particularly in enabling postprocessing and enhancement. Digital acquisition of mammograms has been available for over 10 years and has been shown to be satisfactory for radiological interpretation [10].

At present the increased cost of these machines and the necessity that they be incorporated into a digital radiography department is precluding their general purchase for breast screening in the UK. However, digital attachments to mammography machines for the localization procedures of core biopsy and preoperative wire placement are popular. These systems increase the efficiency and accuracy of localization procedures by decreasing the time taken for completion; they increase the ease of performance, enable production of rapid check films, and therefore increase patients' acceptability of the technique. Computerized localization systems have also been demonstrated to increase the accuracy of core biopsies [11]. The use of vacuum extraction biopsy devices in conjunction with digital imaging systems are available commercially that can enable biopsy and removal of tissues up to

Figure 1



Example of a normal digitally acquired mediolateral oblique mammogram.

3 cm in diameter. It is proposed that this method improves the accuracy of core biopsy still further. At present, studies are being undertaken to investigate the efficacy of this method in UK practice [12] (Reaney S, Hurley E, personal communication). Future development of the use of vacuum extraction biopsy devices in association with sentinel node biopsy [13] could potentially allow day case surgery for small breast cancers.

Computer-based prescreening of mammograms to identify the vast majority that are unequivocally normal is, at present, technically infeasible, because it requires the development of highly sensitive (and specific) algorithms to detect all possible types of mammographic abnormality. Although such algorithms do exist for microcalcification detection, other signs such as asymmetry and distortion are proving more difficult for the scientists working in this area. A more promising approach to solving the problem of shortage of mammographic film readers is to extend the role of the radiographer to include screen reading. This is practicable, and individual radiographers are experienced, keen to practice, and are already doing so in some breast screening units. There are limitations on this route to increase expert film readers because of a general shortage of mammographic radiographers and also from the basic principle of single reading of screening films as promoted in the Forrest report [1].

Evaluation of CAD systems has been undertaken predominately in the US [8,9]. The findings of these studies cannot be directly transposed to UK breast imaging services because of the markedly different radiological practices. It is necessary to validate the commercial claims for sensitivity and specificity, in order to determine the accuracy and reliability for the products presently available with respect to our UK practices. No published information is available regarding the cost-effectiveness of CAD systems. Anecdotal evidence suggests that additional members of staff are required to digitize the mammograms, which would not be necessary with the advent of full-field digital mammography. For a screening programme this would be required to be done overnight, incurring the costs of night working. The increased costs of time spent by radiologists reviewing prompts, thereby increasing time taken reading mammograms and the potential increased recall rate, also need to be evaluated. Studies to determine these factors have not been undertaken, and so clear information about the impact of CAD systems on working practice and on financial budgets is unavailable. National funding to support the trials to answer these questions needs to be forthcoming, and could result in an evidence-based strategy for the incorporation of CAD systems into UK mammographic practice.

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Authors' affiliations: Caroline RM Boggis (Nightingale Centre, South Manchester University Hospitals NHS Trust, Manchester, UK) and Susan M Astley (Imaging Science and Biomedical Engineering, Manchester Medical School, Manchester, UK)

Correspondence: Dr Caroline RM Boggis, Nightingale Centre, South Manchester University Hospitals (NHS) Trust, Nell Lane, West Didsbury, Manchester M20 0PT, UK. Tel: +44 (0)161 291 4060; fax: +44 (0)161 448 1577; e-mail: caroline.boggis@lineone.net