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Use of prior mammograms in the transition to digital mammography: A performance and cost analysis

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ABSTRACT

Breast screening in Europe is gradually changing from film to digital imaging and reporting of cases. In the transition period prior mammograms (from the preceding screening round) are films thereby potentially causing difficulties in comparison to current digital mammograms. To examine this breast screening performance was measured at a digital mammography workstation with prior mammograms displayed in different formats, and the associated costs calculated. 160 selected difficult cases (41% malignant) were read by eight UK qualified mammography readers in three conditions: with film prior mammograms; with digitised prior mammograms; or without prior mammograms. Lesion location and probability of malignancy were recorded, alongside a decision of whether to recall each case for further tests. JAFROC analysis showed a difference between conditions ($p = .006$); performance with prior mammograms in either film or digitised formats was superior to that without prior mammograms ($p < .05$). There was no difference in the performance when the prior mammograms were presented in film or digitised form. The number of benign or normal cases recalled was 26% higher without prior mammograms than with digitised or film prior mammograms ($p < .05$). This would correspond to an increase in recall rate at the study hospital from 4.3% to 5.5% with no associated increase in cancer detection rate. The cost of this increase was estimated to be £11,581 (€13,666) per 10,000 women screened, which is higher than the cost of digitised (£11,114/€13,115), or film display (£6451/€7612) of the prior mammograms. It is recommended that, where available, prior mammograms are used in the transition to digital breast screening.

1. Introduction

The transition to digital mammography is underway in Europe. A variety of solutions are available to display the film prior mammograms from the previous screening round. These solutions can be broadly classified as digitisation solutions and film display solutions. In the United States of America's transition to digital mammography some screening centres did not use prior mammograms during the transition period, and this approach may be reproduced in some parts of Europe. In this study cancer detection performance was examined using film prior mammograms, digitised prior mammograms, or without prior mammograms, and these data were used to project possible human and financial implications of this choice.

Prior mammograms are known to improve cancer detection performance through an increase in specificity [1–4]. Several prospective studies using ROC based methods have shown an increase in cancer detection performance when prior mammograms are used [1–3], however the ROC figures of merit cannot be directly translated into changes in the number of women recalled. This may make these studies less influential in decisions about how to display the prior mammograms. A retrospective study in America [4] reviewed 38,456 screening cases. All cases had prior mammograms available but they were not used for 6743 cases. The recall rate was higher when the prior mammograms were not used (4.9% versus 3.8%, $p = .0001$), with no significant increase in cancer detection rate. Whether the mammograms were digital or film was not reported, but the data were collected from 1997 to 2001 so either is possible.

The effect of the presentation medium of the prior mammograms on cancer detection performance using digital mammography has not been studied, or indeed whether analogue prior mammograms are of benefit when the current mammograms are digital.

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Equivalent performance using digital mammograms in wholly soft copy display in comparison to wholly printed film display has been demonstrated [5], but no such study reports performance using digitally displayed current mammograms with film versus digitised prior mammograms. Using soft copy images only the effect of presenting prior mammograms for every case has been investigated. Using a Localised Receiver Operating Characteristic study, Roelofs et al. [1] demonstrated that performance was superior when radiologists were presented with the prior mammograms for every case, rather than just the cases for which they deemed the prior mammograms necessary. For digital mammography screening in the UK, prior mammograms were likely to be used for a greater proportion of cases when displayed in digitised (82%) rather than film (63%, $p = .04$) format [6]. This implies that digitising prior mammograms may improve specificity in cancer detection.

In the present study cancer detection performance using digital mammography was examined using film prior mammograms, digitised prior mammograms, or without prior mammograms. These data were used to project possible health and financial implications of this choice.

2. Method

2.1. Equipment

Digital mammograms were obtained from the MicroDose Mammography system (Sectra, Sweden) displayed using Sectra mammography PACS on twin five megapixel LCD screens (EIZO, Japan). Previous mammograms were acquired using a Mammomat 3000 Nova (Siemens, Germany), with Kodak MIN-R2000 mammography film, developed using a Kodak X-OMAT Multiloader 7000 (Carestream Health, Toronto, Canada). The films were digitised using an Array 2905 Laser Film Digitiser (Array Corporation, New Hampshire, USA), set to 75 μm, standard resolution, and 12 bit depth. Mammographic film display was on a Mammolux XL multiviewer (Planilux, Germany), which was positioned adjacent and perpendicular to the digital workstation. Reading conditions were identical for all conditions with the room darkened. Participants had access to the multi-viewer, which they could dim or turn off as necessary for all conditions.

2.2. Case selection

A set of 160 anonymised cases consisting of 66 malignant and 94 benign/normal cases was assembled from a UK breast screening centre (screening women aged 50–70 every 3 years with two view mammography and routine double reading with arbitration). Of the benign/normal cases 58 had been recalled for further tests at breast assessment (36 biopsy and 22 mammography/ultrasound) and 36 had not been recalled (30 of which had been discharged after arbitration by a third reader). All cases had digital current mammograms and film prior mammograms from three years previously. No attempt was made to identify cases with multiple prior examinations and these were not digitised or displayed. All incident round cancers detected at digital screening between March 2005 and June 2007 as part of the Warwickshire, Solihull and Coventry Breast Screening Programme were considered for inclusion in the study (79 in total). Benign/normal cases were selected at random from a database of difficult benign/normal cases from the same time period. This database included all cases which went to third reader arbitration, or were recalled and subsequently found to be normal or benign.

For the purposes of clarity malignant cases will be referred to here as 'abnormal' and difficult benign or normal cases referred to as 'normal' henceforth. Classification of cases as normal or abnormal was carried out by an expert radiologist with 20 years experience in breast screening. Normal cases were defined as such by screening results, the results of any follow-up tests (mammography, ultrasound, and biopsy) for those cases which were recalled after screening, and a minimum of two years after screening free from the development of interval cancers (80% of which had a subsequent negative screening round, the remainder had not yet re-attended screening). All abnormal cases were proven by biopsy. The same expert radiologist marked the outline of any lesions on a paper print out of the mammograms, and advised whether each case was appropriate for inclusion in the study. Some 19 cases were not appropriate for inclusion due to either: being mammographically occult; only having single view prior mammograms; technical problems; or being normal cases subsequently presenting with an interval cancer.

2.3. Participants and methods

Ethical approval was obtained from the UK National Health Service South East Research Ethics Committee, and informed consent given by each participant. Eight participants from one breast screening centre in the UK took part in the study, four radiologists and four radiography advanced practitioners (radiographers trained to read mammograms). All were qualified to interpret mammograms in the UK NHS Breast Screening Programme, with an average experience of reading mammograms of 7 years (range 3–14 years). The same 160 cases were each read three times on a digital workstation: with film prior mammograms; digitised prior mammograms; and without prior mammograms. At least one month elapsed between participants re-reading the same cases. Reading sessions were undertaken by each participant on the same day of the week and at the same time of day to reduce confounding due to location, situation or timing. Each session involved reading no more than 54 cases to reduce the effects of fatigue. Participants were asked to mark the location of any lesions with a cross on a paper print out of the mammograms, rate the probability of malignancy of lesions from 0 to 100% on a linear scale, and to report whether they would recall the case for further tests if it was encountered in the breast screening programme. Appendix 1 is an example data recording sheet. Each mammogram measured 6 cm × 5 cm on the print out. There were no restraints on how many lesions participants could mark per mammogram. Participants were instructed to mark the lesion if they considered that there was any indication of possible malignancy. All participants were familiar with the equipment, but unfamiliar with reporting on a percentage confidence scale. Before starting the study each participant was given three practice cases to report, and an opportunity to ask questions about the study.

To examine individuals' performance in the study JAFROC (Jackknife Free Response Receiver Operating Characteristic) analysis [7,8] was used. This approach was chosen because it measures performance both in distinguishing whether an abnormality is present, and in marking the location of the abnormality, and because more than one abnormality can be identified per case. This is the closest approximation to breast screening practice currently available using ROC methods. Lesion location was considered correct if the centre of the participants' marked cross on each paper image was within 2 mm of the lesion outline as defined by the expert radiologist. In addition to JAFROC analysis the rates of false positive and false negative cases were calculated for each participant in each modality using the participants' decisions of whether to recall each case or not. An a priori within-subjects comparison between using film prior mammograms and no prior mammograms was made for the number of false positive cases, the number of false positive lesions per case, and the number of false negative cases, because these are the two lowest cost solutions in terms of initial outlay.