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Research article

Comparison of screening performance metrics and patient dose of two mammographic image acquisition modes in the Danish National Breast Cancer Screening Programme

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ABSTRACT

Introduction: In this study, screening performance metrics and radiation dose were compared for two image acquisition modes for breast cancer screening with MAMMOMAT Inspiration (Siemens Healthcare GmbH, Forchheim, Germany). This mammography system can operate without an anti-scatter grid in place but using software scatter correction instead. This grid-less acquisition mode (PRIME) requires less patient dose due to the increase in primary radiation reaching the detector. This study retrospectively analyses data from the Region of Southern Denmark where the grid-less mode has been installed in November 2013 and replaced grid-based screening.

Methods and materials: A total of 72,188 screening cases from the same geographical region in Denmark were included in the study. They were subdivided into two study populations: cases acquired before and after installation of the grid-less acquisition mode. Sensitivity and specificity of breast cancer screening were calculated for the two populations; thus representing the performance of grid-less and grid-based screening. To measure the entrance surface air kerma (ESAK) additional phantom tests were carried out. Polymethylmethacrylate (PMMA) attenuation plates with different thicknesses (20–70 mm in steps of 10 mm) simulated the compressed breast (21 mm–90 mm) and a solid-state dosimeter was used.

Results: Statistical testing of the results showed that screening with grid-less acquisition provides equivalent performance with respect to sensitivity and specificity compared to grid-based screening. The specificity was 98.11% (95% confidence interval (CI) from 97.93% to 98.29%) and 97.96% (95% CI from 97.84% to 98.09%) for screening with grid-less acquisition and grid-based acquisition, respectively. The cancer detection rate as a measure for sensitivity was equal (0.55%) for grid-less screening and grid-based screening. An average glandular dose saving between 13.5% and 36.4% depending on breast thickness in grid-less acquisition was obtained compared to grid-based acquisition.

Conclusion: Statistically significant equivalence was shown with an equivalence margin of 0.12% points for cancer detection rate and with an equivalence margin of 0.40% points for specificity. A marked patient dose savings in grid-less acquisition of up to 36% compared to grid-based acquisition was achieved. It can be concluded that grid-less acquisition with software scatter correction is an alternative to grid-based acquisition in mammography.

1. Introduction

To acquire images with low patient dose is of high importance in screening mammography where asymptomatic women are examined. At the same time mammographic image quality must be high to have high sensitivity and specificity during breast cancer screening. The ALARA (as low as reasonable achievable) principle states that patient dose should be low however image quality and diagnostic performance must not be compromised. Over the last years, several technical approaches have been developed that allow reducing patient dose while

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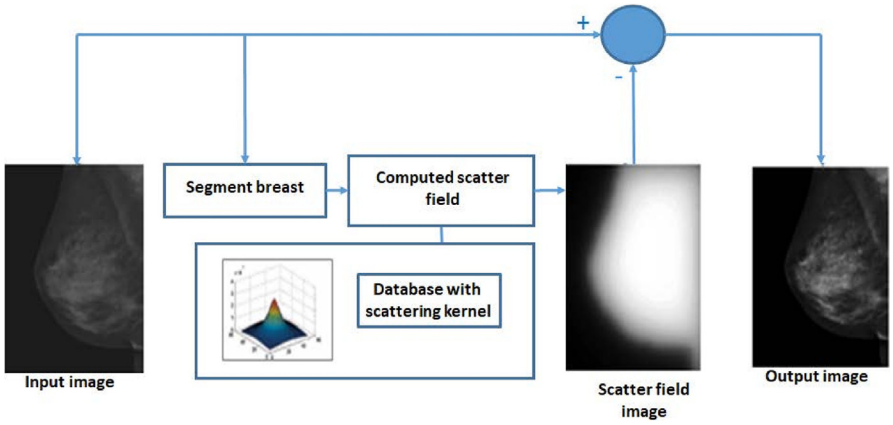

Fig. 1. Illustration of the functionality of PRIME algorithm [7].

keeping image quality at a high level.

One example is the optimisation of beam spectra for digital mammography [1]. Another method for dose reduction is lowering patient dose and employing noise reduction to mitigate effects of quantum noise in the image. Noise reduction in clinical breast images is an important issue in order to distinguish the small cancer tumours and micro-calcifications. Computational denoising techniques may reduce both noise on the clinical image and radiation exposure to the patient in both full field digital mammography (FFDMG) and digital breast tomosynthesis (DBT) [2–4].

A further example is acquiring digital mammography images without hardware anti-scatter grid but using a software solution to mitigate the scattered X-ray radiation [5]. The anti-scatter grid also attenuates a certain amount of the primary (non-scattered) radiation. When the anti-scatter grid is removed more primary radiation can reach the detector. It has been shown that patient dose can be reduced depending on the compressed breast thickness when the anti-scatter grid is removed and a software scatter correction is employed [6,7].

Besides investigating dose reduction aspects when using grid-less mammography with software scatter correction it is also very important to investigate the performance of this new mammographic acquisition technique in a screening environment. I.e. it is to investigate that the screening performance is not affected negatively when using the new method. Two important metrics of screening performance are the cancer detection rate and the non-cancer recall rate.

In our study, we retrospectively analyse data from the Danish National Breast Cancer Screening Programme in which images have been acquired in the same geographical region with the conventional imaging method (with grid) and the new acquisition method (without grid and software scatter correction). We compare cancer detection rate and the non-cancer recall rate between the two acquisition modes. To assess patient dose phantom dose measurements were conducted.

2. Methods and materials

2.1. Danish national screening programme

A national breast cancer screening programme was implemented in Denmark in 2007 [8,9]. Women aged 50–69 years are offered a screening mammogram free of charge every two years. Denmark consists of the following five Regions which have their own booking systems and send personal invitations to the women.

- Capital Region Denmark (Hovedstaden)
- Region Zealand (Sjælland)
- North Denmark Region (Nordjylland)
- Central Denmark Region (Midtjylland)
- Region of Southern Denmark (Syddanmark)

Participation rate in the screening programme is 65%–82% depending on the Region and the mean age of women who participate in screening is 59 years [8]. Two images of each breast are acquired at each screening session. All images are read independently by two radiologists and at least one of them is an experienced breast screening radiologist [8]. For quality control, the radiation dose should be measured once a week on all technical equipment used for mammography screening [8].

Quality indicators from the screening programme are collected and stored in the Danish Quality Database of Mammography Screening (Dansk Kvalitetsdatabase for Brystkræftscreening, DKMS). There are three organisational (participation, screening interval, time to result) and eight clinical (recall rate, relative number of interval cancers, relative number of invasive tumors, relative number of node negative cancers, relative number of small cancers, number of women with breast conserving therapy, ratio of surgery for benign versus malignant lesions) quality indicators.

2.2. Grid-less imaging with software scatter correction (PRIME)

All mammography systems in the Region of Southern Denmark (MAMMOMAT Inspiration, Siemens Healthcare GmbH, Forchheim, Germany) were upgraded between November 11, 2013 and November 21, 2013 to allow acquiring images without anti-scatter grid and with software scatter correction for breasts with a compressed thickness of up to 69 mm.

This acquisition mode is denoted as PRIME (Progressive Reconstruction Intelligently Minimising Exposure) acquisition mode. The scatter correction algorithm receives an input image which contains both primary and scattered radiation. The algorithm identifies the scatter field image in the input image. The scatter field image is then subtracted from the input image and thus the output image contains only breast tissue structures [7]. The functionality of this algorithm is illustrated in Fig. 1.

A current limitation of the scatter correction algorithm is that it cannot be used when a breast implant is visible in the acquired image. Another limitation is that the detector dose increases when not using an anti-scatter grid. To avoid saturation of the pixel values in the image the PRIME acquisition mode is currently limited to breasts with a compressed thickness of up to 69 mm.

2.3. Comparison of screening performance metrics

2.3.1. Study populations

To compare screening performance of the two mammographic image acquisition modes (conventional acquisition and grid-less acquisition (PRIME mode)) we compare data collected from December 01, 2013 to April 30, 2014 (5 months after PRIME has been installed) with