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Mean glandular dose survey of 2D mammograms acquired with the Siemens Mammomat Inspiration system

MAMMOMAT Inspiration

White Paper

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Abstract

In the present study we evaluated the mean glandular doses from mammographic examinations performed with the Siemens MAMMOMAT Inspiration digital mammography system. This X-ray modality for digital mammography belongs to the so-called 'direct radiology' or 'DR' group of systems. It uses an a-Se detector with pixel spacing of 85 µm and the W/Rh anode/filter in the majority of all cases. Dose data were collected from 8 systems in our region and for at least 100 patient cases from each system. Dose data from the Siemens systems were compared to data from 9 other DR systems of other vendors and to the Diagnostic Reference Level (DRL) derived from our regional survey results. The latter were obtained 3 years ago from a larger number of centers, including the present mammographic units, at a time when film-screen mammography was still being used for the most part.
The Siemens systems are adjusted to operate at patient dose levels significantly below the achievable levels of the European Guidelines. For all thicknesses greater than 3 cm, they are operated below the desirable level. The mean glandular doses are among the lowest in DR mammography and significantly lower than film-screen data.

Introduction

Evaluation of the radiation dose to the patient is an important part of the justification process of an X-ray modality. This is especially the case if doses are given to organs in which there is a risk of radiation induced detriment. According to the new ICRP documents[1], the radiation weighting factor for breast tissue is among the highest. Especially in breast cancer screening programs and for younger women with dense breasts, it is therefore advantageous to use low dose techniques.
Breast tissue is composed of different components. In the context of dosimetry, it is the dose absorbed by the glandular part that is estimated or measured, as this dose is thought to correlate with risk. In many studies, the mean glandular dose (MGD) estimates as calculated with the equations of D. Dance are reported[2]. This value is calculated from the incident exposure to the breast, the half value layer of the X-ray beam and the thickness of the compressed breast. The glandularity of the breast can be input or an age and thickness related average glandularity can be assumed for the exposures under study.
Many studies have evaluated MGDs, from patient cases or surrogates from technical measurements on breast simulating slabs. Doses differ among systems and among studies. This is especially the case in 2D digital mammography, where very different technologies are involved. In this study we have focused on direct radiology technology (DR). We examined the MGDs from 2D mammograms acquired from a large series of patients on 8 different Siemens MAMMOMAT Inspiration systems. We used Dance's equation and glandularity estimates as determined for a screening population, i.e. women between 50 and 69 years. These dose values were then compared to the currently desirable and acceptable levels of the European Guidelines[2], doses estimated using the same methodology on 9 DR systems of other vendors[3] and the Diagnostic Reference Levels (DRLs) obtained from survey data acquired 3 years ago among a large group of centers, including the centers present in this study, at a time when most centers were still using film-screen technology.

Materials and Methods

Data collection was performed on 8 Siemens MAMMOMAT Inspiration systems between January 2009 and August 2010. All of these systems were incorporated in a quality assurance (QA) protocol based on the European Guidelines[3]. Daily quality control (QC) procedures were performed to continuously monitor the stability and homogeneity of the detector and the automatic exposure control of the system[4].

In each center, two images of a homogeneous test slab were made every day using the routine clinical exposure settings, our software tool analyzed these test images, and the results were immediately sent to our center for central supervision and feedback. All systems included in the present study performed very well in terms of daily constancy.

Dedicated tools had been developed by our team in order to allow the efficient dose data collection that is necessary to fulfill a national obligation to perform tri-annual patient dosimetry on all X-ray systems in our QA network. The software tool retrieves the dose related data from the DICOM headers of the images. For each image, the MGD is calculated from these data and from system related exposure factors obtained during semiannual QA tests. We make sure to measure the tube output and half value layer for all anode/filter combinations at a fixed tube voltage of 28 V (if available). Exposure data for other tube voltages are then calculated based on the method in Robson[5]. For each system in the study, at least 100 successive patient cases were collected directly from the modalities or from the PACS systems in the respective hospitals. This figure of 100 is related to the legal requirements in our country: at least data from 50 patients have to be used. At most of the centers, we collected a significantly larger number of cases to enrich the survey. Our software retrieves the view, the compressed breast thickness, the tube load and the anode/filter. The thickness as retrieved from the DICOM header was corrected if semiannual QA tests showed a difference of more than 0.5 cm between the indicated and the real thickness measured in a series of test slabs with known thickness.

During the same period, we also collected in the same way dose data from a subset of other DR systems in our network, namely 4 GE Essential systems, 1 IMS Giotto system, 1 Sectra Microdose system and 3 Hologic Selenia systems, using the same approach as for the Siemens systems.

At first, a descriptive analysis of acquisition view, anode/filter, tube voltage and breast thickness was performed for all systems. This allows a verification of the automatic choices of the automatic exposure controller. Images obtained with magnification view were disregarded from the analysis.

Then, for each mammography system, the MGDs of all the patient cases were calculated and ordered as a function of compressed breast thickness. For each thickness *t*, we then calculated a new function named 'thickness averaged MGD(t)', defined for every thickness *t* as the average MGD of all cases with a thickness ranging from 5 mm thinner than *t* to 5 mm thicker than *t*. For all systems, these thickness averaged doses were plotted as a function of thickness, next to the classical plots showing all individual patient dose data. The thickness averaged MGD function summarizes the patient dose data. During semiannual tests, we also estimated the MGDs via PMMA test slabs. These MGDs were plotted on top of the patient data for verification purposes.

All data of all Siemens systems were then pooled and average MGDs were retrieved for all thicknesses in the range of 2 cm – 9 cm. The same analyses were performed for the other DR systems. All individual patient dose data within the thickness class of 4.5 cm to 5.5 cm were then used for comparisons with unpaired t-tests, i.e. in order to compare to the achievable and acceptable levels of the European Guidelines, to the different types of DR systems, and to the Diagnostic Reference Levels (DRLs) of the investigation we conducted 3 years ago[6].

Results

Data from 10,502 mammograms were included in the present study.

In Figure 1, the mean glandular doses of all 8 Siemens systems are shown as a function of breast thickness. These dose data are compared to the achievable and acceptable levels of the European Guidelines and to our DRL. All Siemens systems remain well below these values, except for the smallest thickness (< 3 cm), where the data approach the desirable level. For the 5 cm breast, doses range between 35% and 50% of the desirable level.

In Figure 2, the dose data of the Siemens systems are shown next to dose data of 4 other types of DR systems that have been tested and processed with data pooling in the same way. The Siemens systems have the second lowest dose data curve. The mean glandular dose in the thickness class (4.5 cm – 5.5 cm) differed significantly from the corresponding doses for 3 of the other modalities.

Discussion

On all Siemens systems, breasts with compressed thickness larger than 2 cm were imaged with the W/Rh anode. This choice of exposure settings is supported by technical studies which showed that W/Rh has the best figure of merit per unit of absorbed dose by the glandular tissue and the best signal-difference-to-noise was obtained with an insert of 0.2 mm Al[7, 8, 9, 10]. The mean glandular dose versus compressed breast thickness curve is very similar among the 8 Siemens systems. The MGD values for the 5 cm breast vary from 0.85 mGy to 1.20 mGy. Doses increase monotonically in response to increasing thickness.

The present study used data from more than ten thousand images. This was possible due to our automatic software tool, which automatically retrieves all dose related data from the DICOM header of any sample of images as performed by Chevalier (10). Verification of the DICOM header information is therefore also part of our semiannual protocol. DICOM headers were correctly completed for all DR systems included in the study. Compared to manual registration of dose data, the automatic method offers the following advantages: it is fast; the total time required to run the analysis is no longer proportional to the number of images; dose data cannot be manipulated. Automatic methods sometimes leave the physicist with a huge data cleaning task. In this case the manual data cleaning efforts were minimal. Supervision of the whole process by a physicist remains important.

The doses from the Siemens system compare favorable to those of other systems. The present study does not allow a comparative evaluation of the intrinsic performance of the system though, as image quality factors or detector characteristics are not compared. Rather, it shows how the dose levels of these different DR modalities are preprogrammed on the modalities.

The doses seen in the present study are similar to or below all European reference levels. The desirable and achievable levels of the European Guidelines are prescribed for acquisitions on homogeneous slabs of PMMA, and should therefore be used with caution. In the present study, they were applied to the patient dose data survey. A better approach would be to compare the patient dose data with DRLs, however, a value for digital mammography has not yet been proposed. In a patient dose survey which we performed 3 years ago at the same centers, most of which were using film screens at that time, the DRL was found to be 1.3 mGy (2.1 cm), 1.6 mGy (3.2 cm), 2.1 mGy (4.5 cm), 2.5 mGy (5.3 cm), 2.9 mGy (6 cm), 3.8 mGy (7.5 cm) and 5.0 mGy (9 cm). The present dose data are lower.

The image quality associated with the Siemens systems is not shown in these graphs, but all systems passed CDMAM criteria and the SDNR test of the European Guidelines. As literature confirmed the performance of screening programs using the Siemens Inspiration system[11], we presume that this also applies to the systems included in the present study.

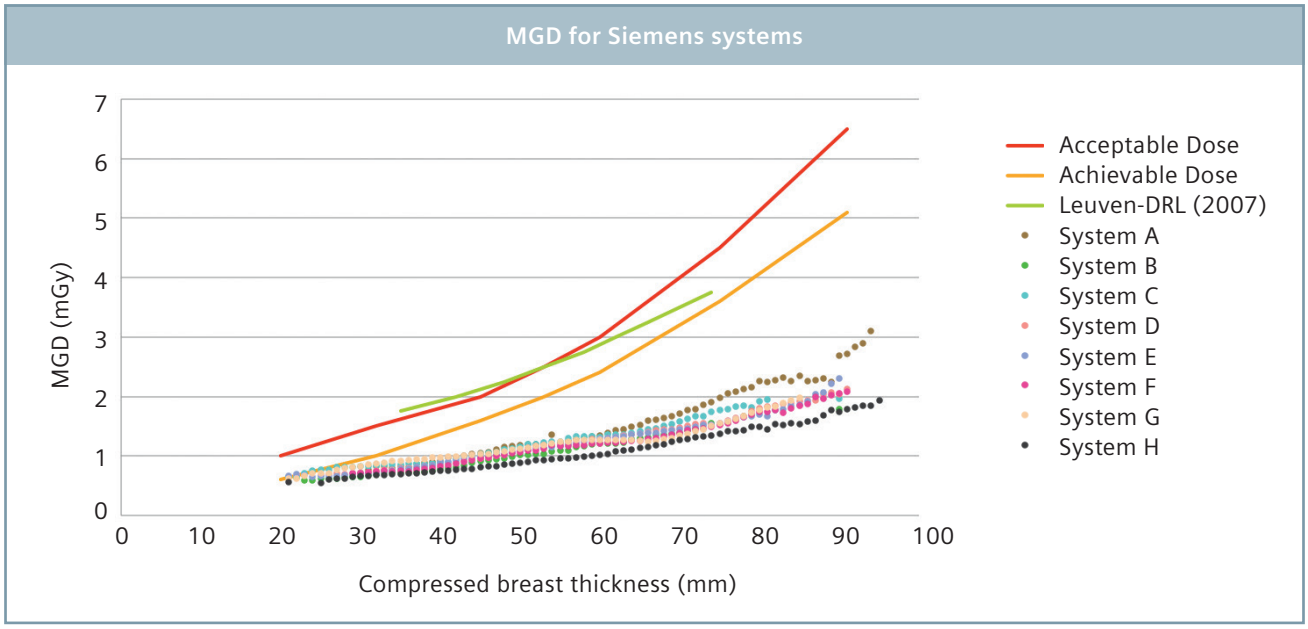

Figure 1: Thickness averaged mean glandular doses as a function of compressed breast thickness for 8 Siemens MAMMOMAT Inspiration systems. Comparison to the achievable and acceptable levels of the European Guidelines and our local Diagnostic Reference Level (DRL) derived from dose data with film-screen systems.

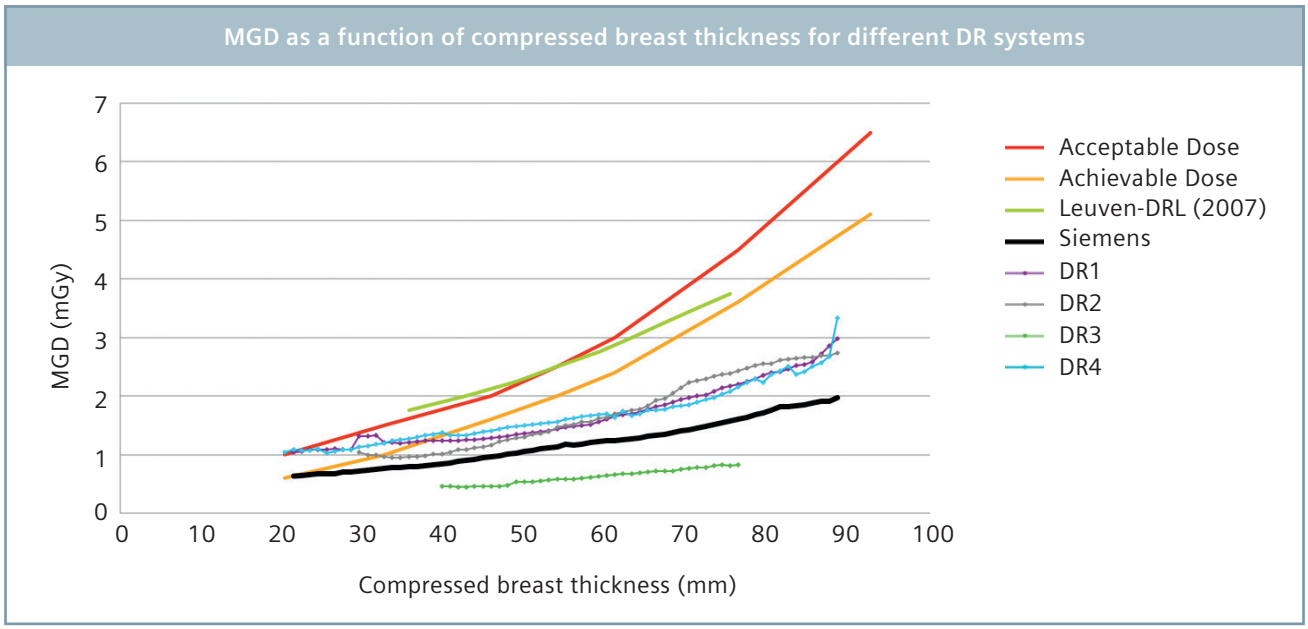

Figure 2: Thickness averaged mean glandular doses as a function of compressed breast thickness for pooled data of the Siemens MAMMOMAT Inspiration systems and 4 other DR system types. Comparison to the achievable and acceptable levels of the European Guidelines and our local Diagnostic Reference Level (DRL) derived from dose data with film-screen systems.
Note: The above results do not allow a comparative evaluation of the intrinsic performance of the systems, as image quality factors or detector characteristics are not compared. Rather, it shows how the dose levels of these different DR modalities are preprogrammed on the modalities.

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Conclusion

The patient dose data of the Siemens MAMMOMAT Inspiration systems comply with the European Guidelines. Curves of the mean glandular dose as a function of compressed breast thickness compare favorably to curves of other DR systems.

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