PRELIMINARY EXPERIENCE WITH A NEW TEST METHOD FOR THE AUTOMATIC EXPOSURE CONTROLLER IN DIGITAL MAMMOGRAPHY, AND ITS LINK TO PATIENT DOSIMETRY

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Abstract

The automatic exposure controller (AEC) is an integrated part of a digital mammography system of which the working principle directly relates with patient dose. In the supplement to the European Guidelines on breast cancer screening and diagnosis, a 'local density test' is proposed to verify parts of the working principle of the AEC. We have assessed the results on different systems as well as the robustness of this test with regard to the position of the local density simulations (small PMMA plates). We compared the range of caluclated average glandular doses (AGD) from the test object exposures to the AGD from patient dose surveys. The test reveals indeed important aspects of the AEC. In addition, the position of the small PMMA plates are determining for the AEC and an optimal position might have to be searched and fixed for every different type of digital system. The dose range as estimated from the local density test is broader than what is observed in patient dose surveys. The local density test could be further worked out towards a test for patient dose range assessment.

1. INTRODUCTION

In the supplement of the "European guidelines for quality assurance in breast cancer screening and diagnosis" [1, 2], a new test of the automatic exposure controller (AEC) has been included to verify whether the AEC is able to detect local dense areas in the breast. To do so, small and thin PMMA plates are put on top of a stack that consists of 3cm of large homogenous PMMA plates and 1cm spacers to fix the height of the compression plate to 4cm. The system is then used in its full automatic clinical working mode. The signal to noise ratio (SNR) as measured at the position of the small PMMA plates should not deviate by more than 20% from the SNR in the absence of a small plate.

Prior to the implementation of the test in our routine QA protocol, we have looked for answers to the following questions:

(1) Does the position of the small plates affect the results of the test?

(2) Will digital mammography systems pass the preliminary limits of the protocol?

(3) How do the range of average glandular doses (AGD) as estimated for the exposures occurring with the small PMMA plates compare to the range in AGD of patients?

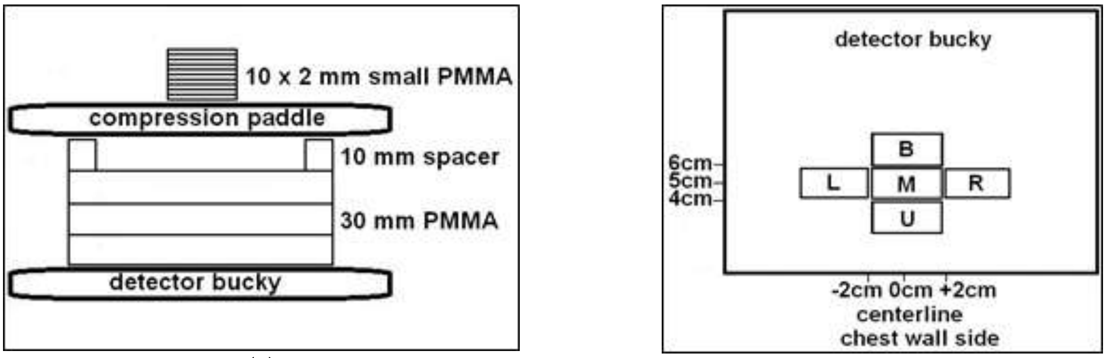
2. MATERIALS AND METHODS

The tests were performed on 4 digital mammography systems: the Amulet (Fuji, Japan), the Senographe DS (GE, France), the Selenia Dimensions (Hologic, USA), the Inspiration (Siemens, Germany).

AEC controlled acquisitions were performed with 3cm of PMMA on the bucky, a 1cm spacer to make the stack mimick a 4cm (fatty) breast and small PMMA plates (Fig. 1a). All 10 plates are 20mm × 40mm and 2mm thick (Artinis, The Netherlands). The protocol prescribes to put the small PMMA plates centrally at 5cm from the chest wall side. Eleven (1+10) succcessive measurements were performed with an increasing number of PMMA plates. We calculated the average glandular doses (AGD) that would be obtained in patients for the resulting exposure settings using the method of Dance [3] (and its more recent extensions towards other beam qualities) and assuming a constant glandularity. For all these conditions, we measured the SNR at the location of the small PMMA plates.

To answer question 1, we have tested also other positions, as indicated in Fig. 1b: above (B), under (U), left (L) and right (R) from the position as described in the protocol. Test 2 verifies whether the SNR values for the 11 test conditions are within the provisional limits of the protocol.

The AGD range obtained from the 10 exposures was then compared to the AGD range of patients with compressed breast thickness from 35mm to 45mm.



(a) (b)

FIG. 1. (a) Configuration of 'local density test' as prescribed in the European Guidelines, (b) Reference position as described in the protocol (M, middle) and 4 other choices around the middle.

3. RESULTS

The local density test was performed first for the reference position of the protocol (Fig 2a). It can be seen that all AECs react on the small PMMA plates, but all in a different way. The Amulet f and the Selenia Dimensions achieve the highest deviation from the AGD value in absence of any small PMMA plate. The Inspiration system shows a strange behaviour at first sight, with increasing AGD up to 5 PMMA plates and stabilization of the AGD, back to the starting condition in the absence of small plates, in case of more than 5 plates. The Senographe DS shows a lower increase in AGD for the largest number of PMMA plates. The SNR values remain within the limits for all systems, except for the Inspiration system (Fig 2b). One out of 4 repeated series of measurements on the Amulet f system failed for this criterion too (results not shown).

The reason for what has been observed with the Siemens system was explained to us [4]: small regions with a sudden increase in density above a set threshold are interpreted as implant or any other non-breast tissue. Under this condition, the AEC is programmed not to take this region into account, and it switches back to the exposure needed for a region at 2cm from the chest wall where we did not have any small PMMA plate. This working condition may guarantee a safer condition for the patient than what would happen in absence of this extra criterium, and we would therefore approve Siemens' approach. The specific behaviour of the AGD increase for the GE system is due to the fact that the system automatically switches to higher tube voltages in case of very dense (local) regions, with a dose reduction as logical consequence. Figs 2c and 2d recruit, from all the tests performed in the positions shown in Fig 1b, the highest response curve. The systems of Fuji, Siemens and Hologic react in a very similar way. The response of the GE system is more moderate, but all systems pass the criterion on SNR.

Figure 3 illustrates the exposure range as obtained with the successive acquisitions with the 10 PMMA plates to the distributioon of patient doses as calculated with the Dance model assuming a breast density as in UK women of 50-64 years for the Hologic system. Patient doses had been calculated from exposure data that were found in the DICOM header using automated software (Gladys, Qaelum NV, Belgium). Table 1 shows the ranges as observed for 3 of the 4 digital mammography systems. We had not yet any patient dose data available for the (new) Amulet f system.

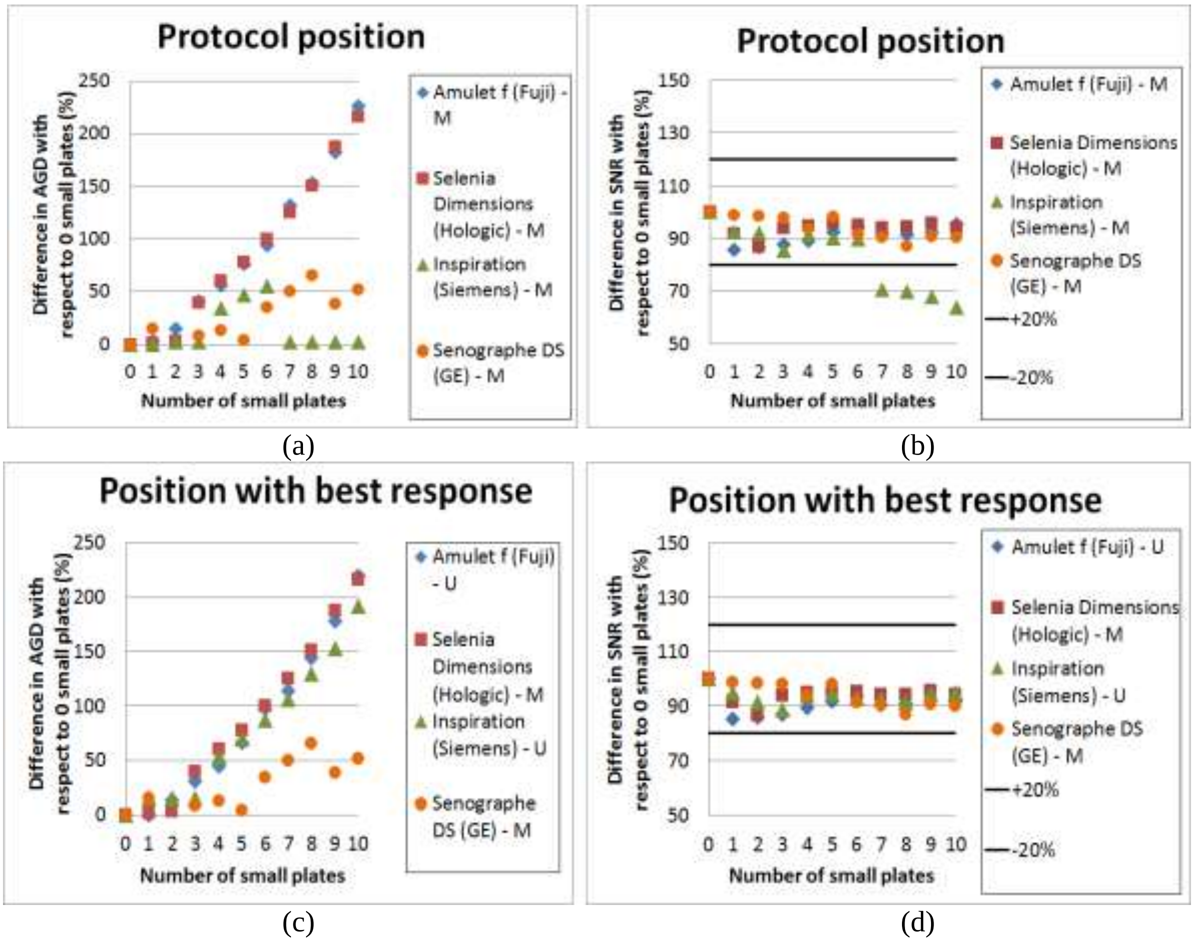


FIG. 2. Response of the AEC of 4 digital mammography systems on the successive adding of small PMMA plates on top of a 3cm PMMA slab+1cm spacer. (a) and (b) Plates in the position as specified by the protocol (M); (c) and (d) position with the best response from positions U, B, L, R and M (see Fig. 1).

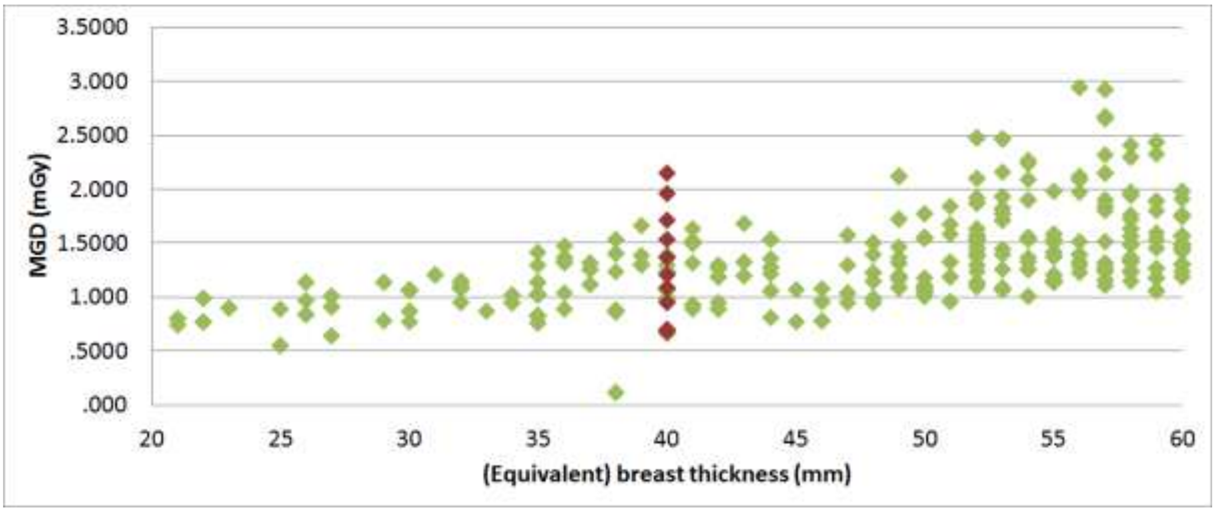


FIG. 3. Distribution of AGD of patients (green diamonds) and AGD as calculated from the exposures with the PMMA plates assuming a compressed breast of 4cm.

TABLE I. DOSE RANGE AS OBTAINED WITH THE LOCAL DENSITY TEST AND DOSE DISTRIBUTION FROM A PATIENT DOSIMETRY SURVEY CHARACTERIZED BY MINIMAL AND MAXIMAL VALUES AND PERCENTILES (in mGy).

Equipment	AGD associated with local density test		AGD of patients with breast thickness range 35-45 mm						
	Min.	Max.	0%	10%	25%	50%	75%	90%	100%
Selenia Dimensions (Hologic)	0.68	2.15	0.12	0.84	0.97	1.19	1.32	1.41	1.69
Inspiration (Siemens)	0.53	1.53	0.24	0.65	0.74	0.86	0.99	1.20	2.52
Senographe DS (GE)	0.75	1.25	0.68	0.79	0.88	0.98	1.08	1.20	1.31

4. DISCUSSION AND CONCLUSION

The local density test has revealed a few very interesting aspects of digital mammography systems. The best AECs may not necessarily behave as presumed in [2]. Vendors are asked to describe the basic principles in the manual of the system such that the local density test can be optimally performed. It is very important that the AEC reacts indeed on local densities in breast tissue. The test also allows us to predict the range of patient doses and could therefore be expanded to other thicknesses. The added value of the test at half yearly intervals, as opposed to at acceptance only, remains to be studied.

REFERENCES

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