Evaluation of an intelligent AEC performance for local dense area in digital mammography unit—a phantom assessment under clinical condition

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Aims and objectives

In order to maintain a stable Signal to Noise Ratio (SNR) of mammary gland area, the performance for controlling proper X-ray dose is required in Automatic Exposure Control (AEC) of a Digital mammography unit (DM unit).

The European guidelines [1] regulate a 'Local dense area' test (LDA test) as an annual quality control to evaluate whether AEC selects a high density area within the mammary gland area and exposes with adequate SNR for X-ray dose control. In the LDA test, a 30mm-thick Polymethyl methacrylate (PMMA) block (180 mm x 120 mm) is placed on a bucky table, and a compression paddle is fixed 40mm above the bucky table. Subsequently, a small PMMA plate (20 mm x 40 mm, thickness 2mm) simulating a local dense area is placed on top of a compression paddle and then additional small plates are repeatedly stacked aiming to evaluate the SNR of small PMMA plates and the exposure condition.

Recent DM units are equipped with AEC that determines the X-ray exposure condition based on the image information obtained from pre-exposure. AMULEL Innovality DM unit (Fujifilm, Japan) is one of these. According to the manufacturer [2], regardless of subject conditions including adipose, scattered mammary gland or implant, AEC (i-AEC mode) detects the mammary gland area according to the structural feature achieved from the pre-exposure image, and controls the dose for optimum image quality of mammary gland area.

In this study, to verify the characteristic of i-AEC mode that is a useful feature for clinical mammography exposure, the PMMA block was replaced with a breast shaped phantom in a form of semi-cylindrical PMMA that is 30mm thick with a diameter of 240mm (Leeds Test Object, UK) (Fig.1). How the position of small PMMA plates, or the depicted area size of the implant and pectoral muscle, would influence SNR was evaluated by modifying the LDA test of the European guidelines.
**Fig. 1:** Set-up for the "Local dense area test" with Breast shaped phantom and added small PMMA plates, top view.

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Methods and materials

1. First, the LDA test was performed according to the European protocol to verify the basic performance of i-AEC mode and to calculate the reference SNR of this test. A small PMMA plate (AcroBio, Japan) was set at a position 5cm from the chest wall side and thickness was added by 2 mm up to 14 mm. The European guidelines suggest to add a 2mm-thick small PMMA plate until 10 small plates have been stacked, however we chose to add until 7 such plates are stacked by reference to literature [3]. Exposures were performed 10 times per thickness (Fig.2-a). The mean value calculated from all SNRs was used as the reference for this test.

2. The position of the small PMMA plate was changed by 1cm starting from 0cm up to 7cm from the chest wall side, and the LDA test was performed per position to verify whether the mammary gland area that is unevenly distributed within the breast is properly identified (Fig.3-a).

3. A silicone implant Style 110 (Allergan, USA) that is compressed to 10mm thickness with a diameter of 12.3cm was inserted between the breast shaped phantom and compression paddle, and the LDA test was performed at 5cm from the chest wall side to verify the stability of SNR with an implanted breast (Fig.4-a).

4. While a clear depiction of pectoral muscle is mandatory for mammography, we verified whether the size of such pectoral muscle depicted area would influence SNR or not. A muscle phantom SZ-220(Kyoto Kagaku, Japan) simulating a 5mm-thick pectoral muscle was placed between the breast shaped PMMA phantom and compression paddle. Then, the LDA test was performed at 5cm from the chest wall side (Fig.5-a). The X-ray permeability of the 5mm-thick muscle phantom upon tube voltage 28kV (W/Rh) was equivalent to that of a 6mm-thick PMMA.

SNR per thickness obtained by each test was evaluated based on the deviation (%) to the reference SNR.
Fig. 2: a: Image of breast shaped phantom with added small PMMA plates. Region of interest (ROI) of 5×5# was centered on the PMMA plate, to calculate the SNR. b-1: Result of SNR measurement and mean SNR (reference SNR). Error bars indicate 95% confidence limits. b-2: Image acquisition tube load (mAs).

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Fig. 3: a: Image of breast shaped phantom with added small PMMA plates from 0cm up to 7cm. b-1: SNR deviation (%) to the reference SNR. b-2: Image acquisition tube load (mAs).

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**Fig. 4:** a: Image of breast shaped phantom and Implant with added small PMMA plates. b-1: SNR deviation (%) to the reference SNR. b-2: Image acquisition tube load (mAs).

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**Fig. 5:** Image of breast shaped phantom and pectoral muscle phantom with added small PMMA plates. b-1: SNR deviation (%) to the reference SNR. b-2: Image acquisition tube load (mAs).

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Results

1. The SNR deviation at 5cm from the chest wall side was less than ±3% (Fig.2-b). This deviation is the same result described in the NHS Breast Screening Programme Equipment Report 1601 [4] that used a PMMA block.

2. SNR deviation at 1cm to 7 cm from the chest wall side was ±5% (Fig.3.b-1). In the case of 0 cm from the chest wall side, the mAs value did not change when small PMMA plates were added (Fig.3.b-2), and the SNR maximum deviation was -40% (Fig.3.b-1). This indicates that i-AEC mode is not effective for small breasts that is within 2cm from the chest wall side of the bucky table, and furthermore, exposure by manual mode will be required.

3. SNR was stable even after inserting implant and widening the implanted area size (Fig.4. b-1).

4. When the area size of the pectoral muscle phantom becomes wider in the breast shaped phantom, the added small PMMA plates stacked to less than 6 mm showed a tendency of a larger SNR deviation (Fig.5. b-1).
Fig. 2: a: Image of breast shaped phantom with added small PMMA plates. Region of interest (ROI) of 5×5# was centered on the PMMA plate, to calculate the SNR. b-1: Result of SNR measurement and mean SNR (reference SNR). Error bars indicate 95% confidence limits. b-2: Image acquisition tube load (mAs).

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Fig. 3: a: Image of breast shaped phantom with added small PMMA plates from 0cm up to 7cm. b-1: SNR deviation (%) to the reference SNR. b-2: Image acquisition tube load (mAs).

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Fig. 4: a: Image of breast shaped phantom and Implant with added small PMMA plates. b-1: SNR deviation (%) to the reference SNR. b-2: Image acquisition tube load (mAs).

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Fig. 5: Image of breast shaped phantom and pectoral muscle phantom with added small PMMA plates. b-1: SNR deviation (%) to the reference SNR. b-2: Image acquisition tube load (mAs).

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Conclusion

Evaluation of the basic performance of i-AEC mode was enabled by carrying out the LDA test in compliance to The European guidelines using a breast shaped PMMA phantom. Additionally, properties useful for clinical mammography exposure was obtained by using implants and muscles during the LDA test. Further evaluations using breast shaped PMMA phantom with different size and thickness are needed.
References


