Digital mammography - objective vs. subjective methods of image evaluation

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Introduction

The constant challenge in mammography is to ensure high image quality while keeping the radiation dose to patients as low as possible. The introduction and subsequent development of flat-panel detectors has brought significant improvement in the field. However, most mammography evaluation methods remain subjective (e.g. visual) , and do not take advantage the possibility of more precise digital image processing. In our work, we compared the results of simple visual analysis of phantom structures with two computable parameters: figure-of-merit (FOM) and detective quantum efficiency (DQE).

Materials and Methods

All measurements were performed on a Siemens Mammomat Inspiration digital mammography system at MSCNRIO in Warsaw.

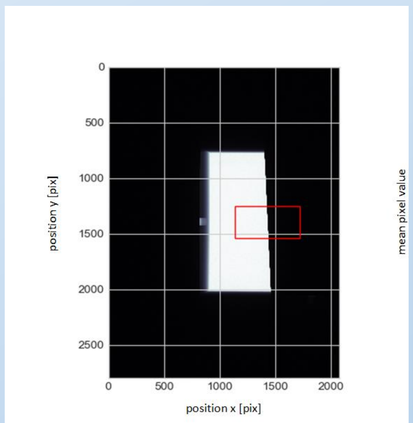
DQE was calculated according to Standard IEC 62220-1-2:2007 of the International Electrotechnical Commission. For MTF evaluation, we used an edge test device (Fig.1 left) designed and manufactured at the NCNR, as well as Python-based software used for all calculations.

FOMs are a wide range of parameters that describe contrast information in radiographic images. In this work, we used a version of FOM based on squared contrast-to-noise ratio (CNR) divided by air kerma at detector (KAD) (Eq.1). CNR was determined as specified in the 4th edition of the European Guidelines. For a contrast object, we used 0.2 mm Al foil placed on PMMA blocks.

Visual assessment was performed by examining a tissue-equivalent, anthropomorphic breast phantom (Fig.2, left) mimicked an average firm breast with 50% glandular and 50% adipose tissue. Images were viewed on mammography dedicated displays. We paid particular attention to the visibility of microcalcifications (0.13 - 0.4 mm grains) and fibrous (0.3 - 1.25 mm diameter) elements (Fig.2 right).

$$FOM = \frac{CNR^2}{KAD}$$

Eq. 1 FOM equation used in this work



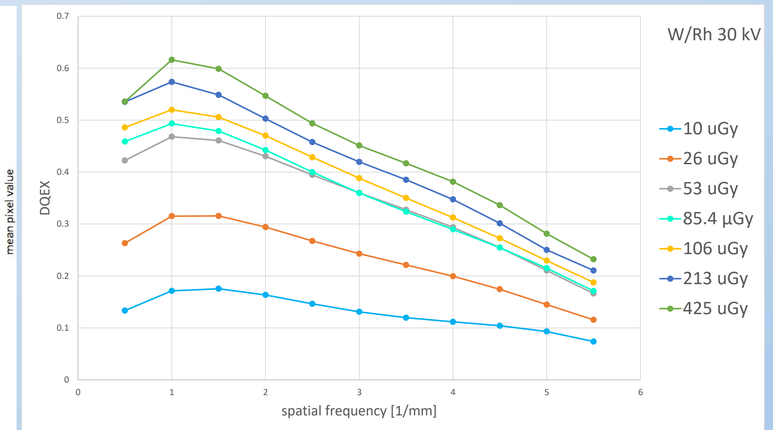
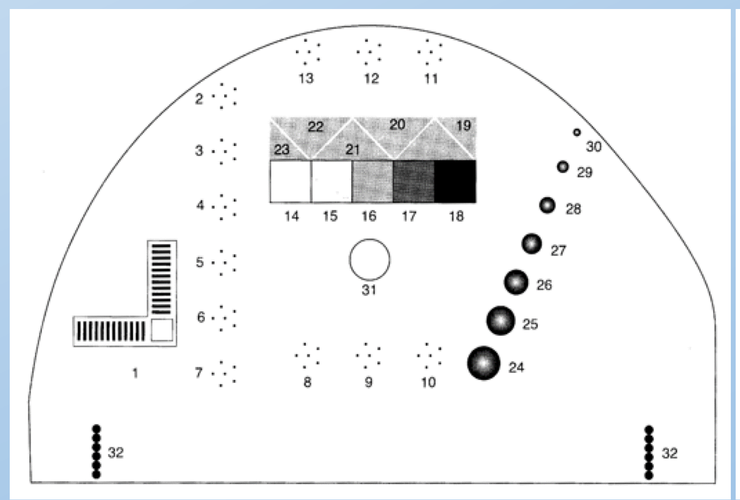


Fig. 1 Edge test device (left) and example of calculated DQE (right) for W/Rh anode filter combination, 30 kV and different KAD



- **Line Pair Target** 20 lp/mm
- **Ca Co$_3$ Specs** Grain Size (mm)
  2. .130
  3. .165
  4. .196
  5. .230
  6. .275
  7. .400
  8. .230
  9. .196
  10. .165
  11. .230
  12. .196
  13. .165
- **Step Wedge** 1 cm thick
  14. 100% Gland
  15. 70% Gland
  16. 50% Gland
  17. 30% Gland
  18. 100% Adipose
- **Nylon Fibers** Diameter size (mm)
  19. 1.25
  20. 0.83
  21. 0.71
  22. 0.53
  23. 0.30
- **Hemispheric Masses** 75% Glandular/ 25% adipose, thickness (mm)
  24. 4.76
  25. 3.16
  26. 2.38
  27. 1.98
  28. 1.59
  29. 1.19
  30. 0.90
- **Optical Density** 31. Reference zone
- **Edge of Beam** 32. Localization target

Fig. 2 Scheme (left) and description of elements (right) of phantom used in this work [VICTOREEN, INC.]

Results

We performed preliminary measurements and calculation of DQE, FOM (see Fig.3) and visual assessment of microcalcifications and fibers (see Tab.1) using W/Rh (a tungsten anode with rhodium filter) under clinical exposure conditions. In Figures 3 and 4 we present results for a 30 kV tube load, which the OPDOSE system in our mammography unit selected on the basis of phantom thickness (4 cm).

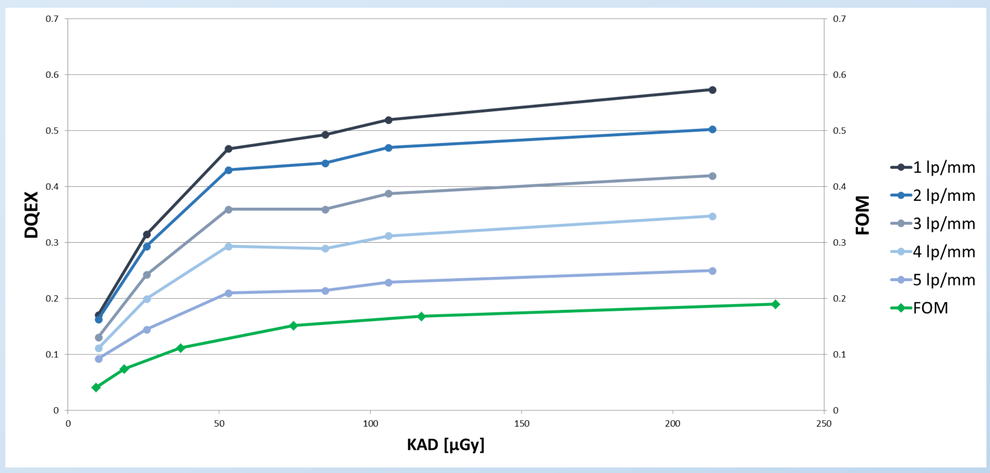


Fig. 3 DQE and FOM in function of KAD for W/Rh and 30 kV

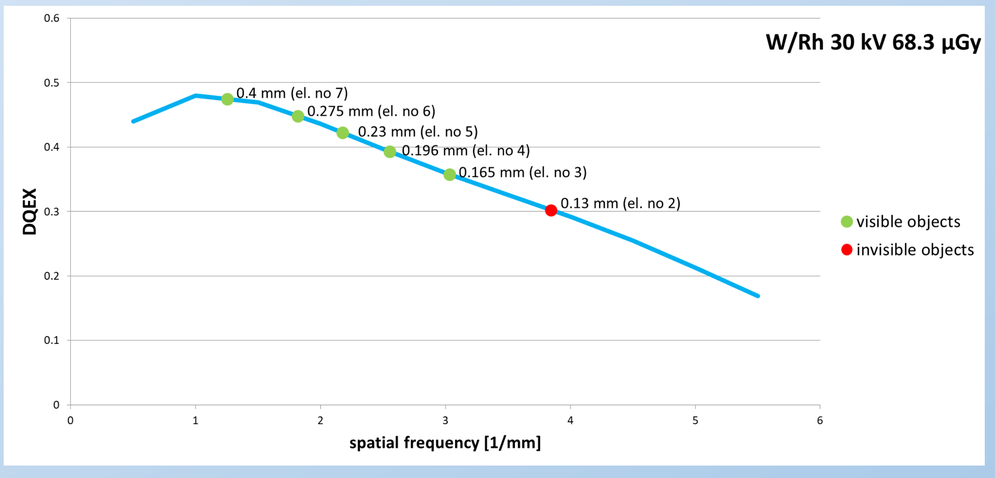


Fig. 4 DQE in function of spatial frequency for 30 kV and 68.3 µGy with visibility of microcalcification specs

kV	Device mode	KAD	Microcalcifications group			fibers	masses
			2-7 (max. 6)	8-10 (max. 3)	11-13 (max. 3)	19-23 (max. 5)	24-30 (max 7)
26	Manual	39.5	4	2	2	3	5
	Manual	56.0	5	3	3	4	6
	AEC	74.7	5	3	3	4	6
	Manual	90.2	5	3	3	4	6
	Manual	118.6	5	3	3	4	6
28	Manual	47.4	4	2	3	4	4
	Manual	53.5	4	2	3	4	5
	AEC	71.4	5	3	3	4	6
	Manual	75.7	5	3	3	4	6
	Manual	94.8	5	3	3	5	5
30	Manual	60.2	5	3	3	4	5
	AEC	68.3	5	3	3	4	6
	Manual	76.8	5	3	3	4	5
	Manual	86.6	5	3	3	4	5
	Manual	96.4	5	3	3	4	6
32	Manual	37.1	4	2	2	4	4
	Manual	46.7	4	2	2	3	5
	AEC	64.5	4	2	2	3	5
	Manual	83.7	5	3	3	4	6
	Manual	118.3	5	3	3	4	6
34	Manual	27.7	4	2	1	3	4
	Manual	45.1	4	2	2	3	5
	AEC	59.8	5	3	3	4	5
	Manual	101.4	5	3	3	4	5
	Manual	143.0	5	3	3	4	6

Tab. 1 Visibility of elements in phantom for different tube load and KAD

Summary

Based on subjective image evaluation (Tab.1) we observe that applying a higher dose on detector (KAD) improve image quality and number of correct observer-detected detail growths. We studied the dependence between the detector's DQE and FOM and KAD value, and we observed that DQE and FOM increased with KAD (Fig.3). Fig.4 shows the correlation between DQE and the number of observer-detected details in the first microcalcification group. DQE values show that the detector is able to transfer spatial frequencies of the smallest details, however the correlation between DQE and the number of visible details requires further studies.