

ASSESSING IMAGE QUALITY AND ESTIMATING THE GLANDULAR AVERAGE DOSE IN SOME MAMMOGRAPHY LABS*

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Abstract. Mammography is the safest method of detecting breast cancer but, at the same time, the most exacting radiological examination which implies getting high quality images and a minimum dose per breast. The present study was carried out in six mammography laboratories, from which only one has partially implemented a programme of quality control. There were evaluated the phantom image, film contrast, background optical density (OD), density difference (DD), radiation beam quality, and the entrance surface air kerma was measured. The glandular average dose was also estimated. Compared to the reference lab, all the other five labs failed all the tests, obtaining unacceptable results both for the phantom image and for the contrast, for the OD and DD. The average glandular doses estimated for the standard breast varied between 1.4 and 7.7 mSv, being in four out of the six hospitals, statistically significant ($p < 0.001$), lower or higher than those currently accepted by international authorities (3mSv). Such simple quality control procedures will improve the chances of accurate diagnosis and reduce the probability of false negatives. This is particularly important for early detection and treatment of breast cancer which is the highest type of cancer among females.

Key words: breast cancer, mammography, quality control, average glandular dose.

1. INTRODUCTION

Breast cancer is considered the most frequent and the main decease cause of middle aged women [1].

The European Parliament Resolution of June 2003 and October 2006 [2, 3] called all the member states of the European Union (EU) to make the fight against breast cancer a priority policy of public health, to develop and implement efficient strategies which should include screening, diagnosis and treatment all over Europe [4].

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Mammography is the most efficient method of detecting breast cancer with a precision going up to 83–97% depending on the patient's age [5] and the only method of finding micro-calcifications.

The procedure is used both for diagnosis purposes with patients showing diverse symptoms and in breast screening as a method of mass detection with patients showing no symptoms. Specialists consider that breast cancer can be detected even 3 to 4 years before the woman discovers it herself [6].

A correct mammography increases a lot the chances of treating and curing cancer. However, special attention must be paid to dose management as, on the one hand, the breast is very radio-sensitive and, on the other hand, getting a high resolution image implies a greater exposure to radiation than other radio-graphical procedures.

The breast is made up of soft tissue which has a low contrast. The X-ray attenuation coefficients in the two breast structures (glandular and adipose) are similar and, between the normal breast soft tissue and the sick one there are small density differences [7]. Detection of minute details on mammography, such as micro-calcifications and marginal structural characteristics of the soft tissues is of utmost importance as this subtle information, which implies a high contrast of the soft tissue, can determine the diagnosis of a malignant lesion. In order to visualise both the normal tissue and the sick one, these differences must be amplified by using low X-ray beams.

For maximising the contribution of the photoelectric effect and determining the differentiated absorption in the two tissues, the procedure uses as an exposing factor, low kilo-voltages of 25–32 kV (increasing the contrast and decreasing spreading) and high values of the mAs product. Interaction through photoelectric effect is predominant at these energies which produces a high contrast. The probability of absorbing the incident photon through photoelectric effect increases greatly, being proportional with Z^3 (e.g. the bone has $Z \sim 20$, the tissue has $Z \sim 7$). The breast internal structure is visualised in two exposures, on each breast, using two standard projections – craniocaudal and mediolateral. In order to minimise the potential risk of the procedure, it is not recommended to have any additional projections if the suspected anomalies do not require supplementary investigations.

An ideal X-ray spectrum for a mammography would be a compromise between getting a high contrast (low energy photons) and maintaining a small dose per breast (high energy photons).

According to the basic principles of radioprotection, any exposure to ionizing radiation must be justified.

Thus, the benefits of this method must be greater than the risk of inducing a hypothetical number of cancers through repeated irradiation of the population, and it is reflected in the number of saved lives or detected cancers [8].

The main objective of the programme of quality control in mammography is producing high quality images which can show the breast anatomy and the disease signs. Such a programme, even if it does not remove the problems, may help in

identifying them before patient's care is affected. The smallest change in equipment functioning or film processing system can affect the image quality and dose per breast.

Romanian legislation comprises some of the performance criteria in mammography since 2002 [9], but the system of quality control has not yet been implemented. However, there are 10 pilot centres which took part in a training programme in 2005, coordinated by the American International Health Alliance and the Romanian Society of Breast Imaging. Such programmes have also been implemented in other countries and they aim at promoting quality control and training the technologists in order to carry out the simplest procedures and data processing. [10, 11, 12, 13]. Each centre was equipped with a special kit at the end of the programme so that it could carry out some of the simplest tests. But even in these laboratories, the absence of medical physicists and adequate equipment makes it impossible to apply all the quality control tests and the valuation of the glandular average dose.

The present study tries to assess six mammography labs in order to find out whether they are efficient or not, and to what extent they correspond to the standards of quality control.

2. MATERIALS AND METHODS

There have been chosen the most important laboratories in Dolj, Olt, Gorj and Mehedinti counties, out of which only one has partially implemented the quality control system, and we have applied several work procedures according to the Mammography Quality Control Manual (American College of Radiology – ACR, 1999) [14] and to The European Protocol for the Quality Control of the Physical and Technical Aspects of Mammography Screening (1993) [15].

The infrastructure:

- Hospital A – Senograf DMR type installation – quality control partially implemented;
- Hospital B – Senograf DMR type – without quality control;
- Hospital C – Senograf DMR type – without quality control;
- Hospital D – Senograf DMR type – without quality control;
- Hospital E – Alpha RT type – without quality control;
- Hospital E – Mammomat 3000 – without quality control.

We assessed the image quality, the background optical density, the density difference, the beam quality assessment and we estimated the glandular average dose.

The image quality is the most important thing in the mammography quality control because it verifies the functioning of all the imagistic chain components except for those regarding breast positioning and patient movement [14, 15].

In order to check the image quality we used the standard phantom of RMI 156 type, accredited for mammography.

The phantom is a perspex cube of 10x10cm at the base and 4.2 cm in height, simulating a standard breast (50% glandular tissue and 50% adipose tissue). The phantom has a wax insertion which contains: 6 fibres (with diameters of 1.56, 1.12, 0.89, 0.75, 0.54, and 0.40 mm), 5 specks (with diameters 0.54, 0.42, 0.32, 0.24 and 0.16 mm) and 5 masses (with decreasing diameters and thicknesses of 2.00, 1.00, 0.75, 0.50 and 0.25 mm) ranging from visible to invisible on the mammography image. The phantom was exposed to the set parameters by the automatic exposure control (AEC) and the film was processed. The evaluation was made by pointing out the number of visible test objects on the mammography image.

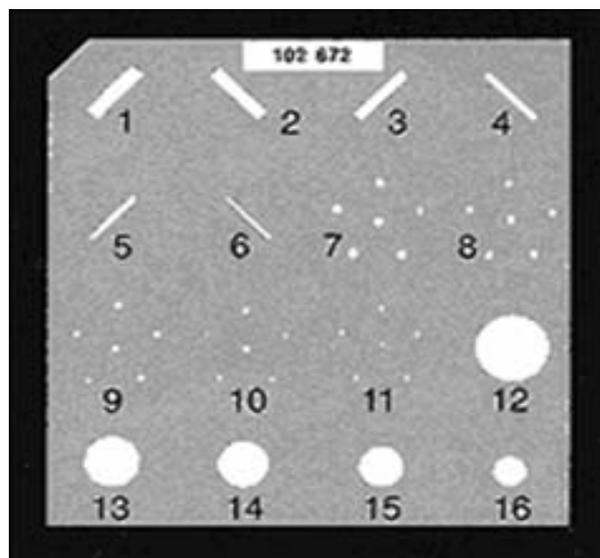


Fig. 1 – The structure in ACR accreditation phantom (RMI 156) used for Image Quality Evaluation [16].

The score was determined in the following way [14]:

- we registered the fibres gross score granting 1 point if the fibre was wholly visible while the fibre location and orientation was correct, and 0.5 points if more than half was visible with a correct location and orientation. Then we subtracted from the gross score all the defects in the form of fibres on the film, in the wax insertion area, if the wrong fibre was the same or more visible.

- we registered then the group of specks gross score, starting with the greatest, granting one point if at least 4 specks in the group were visible in correct locations, and 0.5 if only 2 or 3 specks were visible in correct location. There were subtracted one by one all the defects in the form of specks on the film in the wax insertion area if they were as obvious as real specks;

- lastly, we registered the formations gross score, granting one point if the formation was visible at least three quarters in the correct location and was circular

in shape, but 0.5 if it wasn't circular in shape. There were subtracted all the formations noticed on the film in other parts of the wax insertion if these faulty formations were as evident.

Performance criteria. There should be wholly visible, in the correct location and orientation at least the largest 4 fibres, the greatest 3 groups of specks and the biggest 3 masses, and their number must not decrease more than half compared to the operation level.

In order to check the image contrast [14], the phantom was attached an acrylic disc (1 cm in diameter and 4 mm thick), placed a bit under the first two largest fibres, not to hide details in the phantom or cast any shade over any part of the AEC.

After having exposed the phantom to the used parameters for the standard breast, we measured the background optical density (OD) with a densitometer in the geometric centre of the phantom and we calculated the density difference (DD) between the values obtained inside the acrylic disc and near it, left or right, perpendicular on the anode-cathode axis.

The AEC setting must reach a background optical density for the phantom between 1.4 and 2.0 OD [9, 14, 15] in order to guarantee the exposure of glandular tissues to optical densities high enough to be able to see them.

Measuring the beam quality and air kerma at the entrance of the standard phantom was performed using the multi functional device for testing the quality of the RMI-242 type radiological systems, with a flat ionizing camera, set for mammography and the accredited phantom.

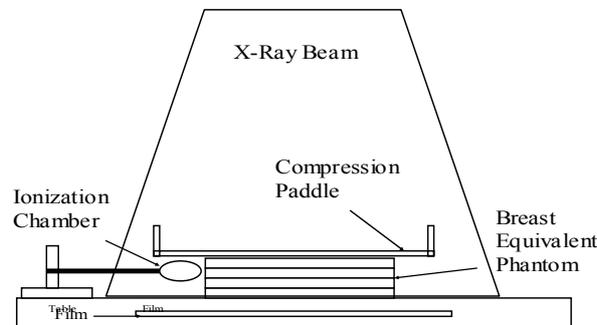


Fig. 2 – Measuring air kerma at the entrance of the standard phantom [16].

The radiation beam quality was checked by measuring the half-value layer (HVL, which represents the material thickness in mm Al that reduces the exposure rate to half from its initial value) [14, 15, 17, 18]. For this reason we used 0.1 mm thick Al sheets of 99.9% purity (type 1145 aluminium alloy).

The phantom was set on the special table on which the breast is positioned, at 4 cm in, from the chest-wall edge of the image receptor, and on the compression plate, half way tube-table, more aluminium filters.

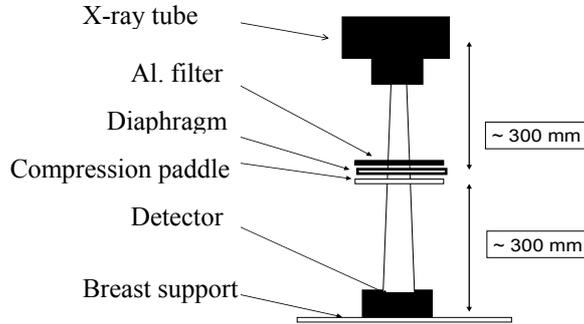


Fig. 3 – Checking the HVL [17].

Depending on the exposure reading, there were added or taken filters until the measured exposure was smaller than half of the initial value.

The HVL was computed using the formula (1):

$$\text{HVL} = \frac{t_b \cdot \ln \left[\frac{2E_a}{E_0} \right] - t_a \cdot \ln \left[\frac{2E_b}{E_0} \right]}{\ln \left[\frac{E_a}{E_b} \right]}, \quad (1)$$

where: E_0 exposure reading without any added aluminum; E_a the first exposure reading that is just greater than $E_0/2$; t_a the corresponding aluminum thickness; E_b the first exposure reading that is just less than $E_0/2$; t_b the corresponding aluminum thickness; $E_a > E_b$ și $t_a > t_b$.

Performance criteria: $\text{HVL} \geq \frac{kVp}{100}$ mmAl ($\text{HVL} \geq \frac{kVp}{100} + 0.03$ mmAl with the

compression paddle in place) and smaller than $\text{HVL} \leq \frac{kVp}{100} + 0.1$ mmAl.

For units using combinations target/filtration Mo/Mo, Mo/Rh or Rh/Rh, it is recommended that the minimum acceptable HVL is smaller than:

$$\text{HVL} < \frac{kVp}{100} + C \quad [\text{mmAl}], \quad (2)$$

where: $C = 0.12$ mmAl for Mo/Mo; $C=0.19$ mmAl for Mo/Rh; $C = 0.22$ mmAl for Ro/Rh $C = 0.3$ mmAl for W/Rh.

In order to estimate the average glandular dose for the standard breast out of the measured dose at the phantom entrance surface (ESAK), we applied the conversion factors used by Faulkner K in RC-4 entitled Mammography Screening, at the 11th Radioprotection Congress, Spain, 2004 [17]:

$$D = K_{\text{air}} \cdot p \cdot g \cdot s = 0.00873 \cdot E \cdot p \cdot g \cdot s, \quad (3)$$

where: p converts incident air kerma for perspex phantom to that of the standard breast (Table 1); g converts incident air kerma for standard breast to mean glandular dose; s spectral conversion factor (Table 2).

Table 1

The conversion factors p and g [17]

HVL (mmAl)	p	g (mGy/mGy)
0.25	1.12	0.155
0.30	1.10	0.183
0.35	1.10	0.208
0.40	1.09	0.232
0.45	1.09	0.258
0.50	1.09	0.285
0.55	1.07	0.311
0.60	1.06	0.339

Table 2

The spectral conversion factors [17]

Spectre	s
Mo/Mo	1.000
Mo/Rh	1.017
Rh/Rh	1.061
Rh/Al	1.044
W/Rh	1.042

In order to compare the average values, we used the Student test, t , for unequal dispersion:

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\frac{\sigma_1}{\sqrt{n_1}}}, \quad (4)$$

where: \bar{x}_1 is the average value; \bar{x}_2 is the recommended level; σ_1 is the standard error of the means; n_1 the degree of freedom.

The theoretical values for t are:

- 1.96 for a probability of 95% (significance level 5%, thus $p = 0.05$);
- 2.57 for a probability of 99% (significance level 1%, thus $p = 0.01$);
- 3.29 for a probability of 99.9% (significance level 0.1%, thus $p = 0.001$).

3. RESULTS

First, we found out that the film of the phantom was of a low quality (especially the mediphot type). All the laboratories were penalized because the films presented artefacts under the shape of lines and specks so, C and D got the score of zero for the speck groups, after artefact deduction.

Table 3
The image quality evaluation

Hospital	Film	DD	OD	Number of visible objects		
				Fibres	Speck groups	Masses
A	kodak	0.42±0.02	1.66±0.09	5	4	5
B	foma	0.35±0.05	1.4±0.1	5	3.5	4
C	mediphot	0.30±0.04	1.23±0.05	4	0	4
D	mediphot	0.51±0.03	2.3±0.1	5	0	4.5
E	agfa	0.32±0.04	1.1±0.08	4	2	4
F	foma	0.29±0.02	1.06±0.08	4	2	1
Action limit		0.4±0.05	1.4±0.2	4	3	3

In Table 3 it is shown that the background optical density was lower than the recommended values in C, E and F and higher in D (1.4 and 2.0 OD) [9, 14, 15].

In comparison with the recommended values, the density difference was considered unacceptable in C, D, E and F, being either too small or too big.

The number of visible test objects on the phantom image was unacceptable in B, C, D, E and F.

Figure 1 presents the film image of the phantom performed in hospital E. There are visible 4 fibres, 2 groups of specks and 4 masses.

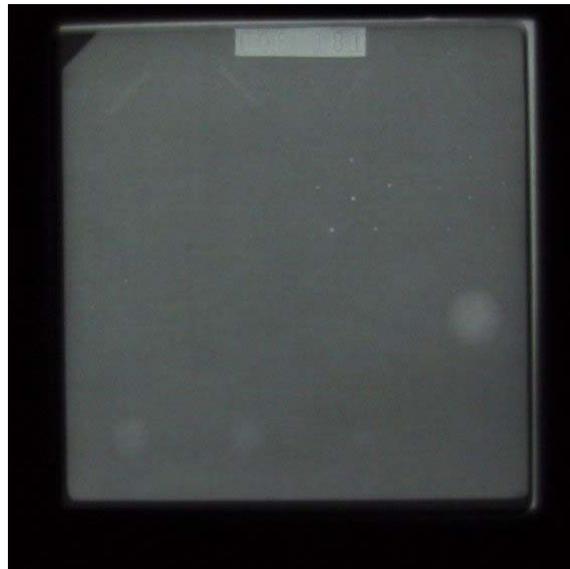


Fig. 4 – Phantom image on a mammogram.

Figure 5 presents two mammograms of the same breast. Due to the poor quality of the left image, we cannot observe the tumour.

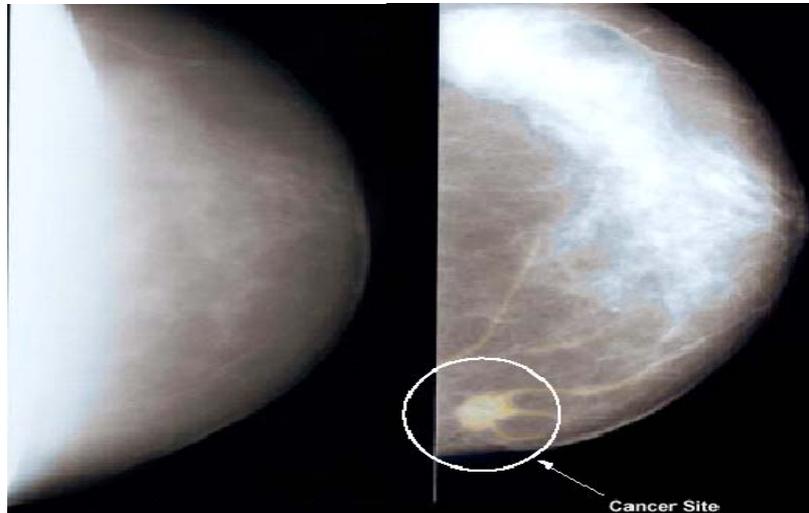


Fig. 5 – Importance of Image Quality [16].

For the HVL values (Table 4) measured by us, we could not use the conversion factors recommended by ACR in order to estimate the average glandular dose for the standard breast, for the Mo/Mo combination, because the values are too high. That's why we used the conversion factors recommended by Faulkner K (Table 1).

Table 4
The HVL-value

Hospital	Parameters			HVL (mmAl)	Recommended values (mmAl) [14]
	kVp (nominal setting)	mAs	Target/ Filter		
A	25	120	Mo/Mo	0.31±0.02	0.28<HVL<0.35
B	27	63	Mo/Mo	0.42±0.02	0.3<HVL<0.37
C	28	63	Mo/Mo	0.43±0.02	0.31<HVL<0.38
D	27	117	Mo/Mo	0.41±0.02	0.3<HVL<0.37
E	26	79	Mo/Mo	0.4±0.02	0.29<HVL<0.36
F	28	28	Mo/Mo	0.58±0.03	0.31<HVL<0.38

Table 5
The average glandular dose for standard breast

Hospital	HVL (mmAl)	ESAK (mGy)	Conversion factors			Average glandular dose (mGy)
			p	g (mGy/mGy)	s	
A	0.31±0.02	14.2±0.29	1.1	0.183	1	2.9±0.06
B	0.42±0.02	5.5±0.12	1.09	0.232	1	1.4±0.02
C	0.43±0.02	6.1±0.15	1.09	0.258	1	1.5±0.04
D	0.41±0.02	9.55±0.29	1.09	0.232	1	2.6±0.05
E	0.4±0.02	5.9±0.14	1.09	0.232	1	1.5±0.02
F	0.58±0.03	21.4±1.9	1.06	0.339	1	7.7±0.7
Recommended level						3 [14]

Table 5 shows that the average glandular dose for the standard breast was statistically significant ($p < 0.001$) under the reference levels in hospitals B, C, and E and over in F ($p < 0.001$).

4. DISCUSSIONS

Except for hospital A, the physician and the technologists have no knowledge about quality control. The activity comes to performing the mammography and its interpretation by the specialised physician.

The hospital staff and management do not understand that technical checking of equipments are absolutely necessary (in hospital E, the mammograph hasn't been checked for 3 years, and in hospitals C and D, the technical checking files have been copied after some older ones), being at this moment, through the performed tests, the only clues that can bring information about the way the equipments work.

There are also problems with the firms which should ensure the service, as, on the one hand, they do not have specialists, and, on the other hand, they are not interested in concluding contracts with hospitals, because these have only one mammograph, which renders displacement unprofitable (there were necessary more auctions in hospitals A and B before concluding a service contract)

Hospitals B, C, and E do not use the automatic exposure control, the parameters being established by sight according to the size of the breast and whatever is noticed while touching the breast.

We measured the background optical density which was lower or higher than the recommended values, affecting thus the image quality, because films used in film-screen mammography diminish their contrast at optical densities that are too high or too low. The glandular tissue, where cancer starts from, generates the lowest optical densities on the film. If optical density is too low or too high, detection of low contrast lesions in the glandular tissues is compromised. In order to guarantee the exposure of glandular tissues to optical densities that are high enough, the setting of the automatic exposure control (AEC) should have obtained optical densities for the phantom between 1.4 and 2.0, and this happened only in hospital A.

The artefacts were attributed to the poor film quality, to the dust, and/or to the processing procedure.

Because the number of visible test objects on the phantom image was unacceptably small in the hospitals B, C, D, E and F we consider that the benefit of the patient exposed to radiations in these labs was minimum, while the risk of not detecting the illness maximum.

Though the measured HVL were higher than the recommended superior limits, this fact does not infringe any standard, but a high HVL leads to a contrast decrease [14, 15].

The estimated glandular average doses for the standard breast were either too low or too high, and it's a known fact that both high and low doses lead to missing minute details, diminish the early diagnose possibilities of cancer and increase the risk of inducing breast cancer through repeated irradiation.

If Romania applied the quality control standards, the five units would be closed and checked by their service units.

5. CONCLUSIONS

Hospitals should implement Quality Control to reduce the chances of misdiagnosis while maintaining safe levels of radiation exposure to mammography patients. In the absence of a medical physicist, the technologist should be trained to implement simple dosimetry and image quality measurements.

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