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Pilot study of patient and phantom breast dose measurements in Bulgaria

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A pilot study of breast dose measurements on two mammography units in Bulgaria was conducted. The mean glandular doses (MGDs) to samples of approximately 60 women per unit were measured. MGD with a standard PMMA phantom was measured as well. The MGDs were calculated according to the European protocol on dosimetry in mammography as well as to the European protocol for the quality control of the physical and technical aspects of mammography screening. The measured women's MGDs were divided into three groups depending on the compressed breast thicknesses. The results for the group of thicknesses in the interval 40-60 mm were compared with the results from the measurements on the standard 45 mm PMMA phantom. Some differences were found which could be due to errors in breast thickness measurements, differences in breast and phantom densities and other factors. A standardized procedure was elaborated for patient dose measurement and calculation both from patient and phantom studies.

Key words: breast, mean glandular dose, phantom, mammography, conversion factor.

Introduction

Breast cancer represents about 24% of all newly diagnosed cases of cancer rate in Bulgaria and is the second reason for death from oncological diseases. Statistics from the last thirty years show that there is a trend toward increase of the morbidity from this disease in the country [8]. X-ray mammography is the method of choice for early detection of breast cancer. Although the mammography examination is associated with a very low dose to the breast tissue there exist some risk of cancer induction. Several

documents for breast dosimetry are published using different measurement set up and conversion factors [2, 3, 6, 7, 9, 11, 12, 14-16, 19, 20].

A new regulation for protection of individuals at medical exposure was enforced in Bulgaria in 2005 harmonizing the Bulgarian legislation with the requirements of the European Union, in particular Directive 97/43/EURATOM [10, 17]. According to this regulation, quality control programme is implemented in the country and a national dose survey should be performed in order to elaborate national diagnostic reference levels.

The purpose of the present work is to establish the feasibility of the European protocol on dosimetry in mammography [9], the European protocol for the quality control of the physical and technical aspects of mammography screening [11, 12] and the Code of practice: TRS 457 of the IAEA [15] in the conditions found in the country and to define more accurately some ambiguity in the measurement procedures. The final aim is to elaborate a standardized procedure to be included in the national protocol for breast dosimetry in Bulgaria.

Material and Methods

Mammography systems

Two mammography units were included in this study: Melody (Villa, Italy) named in this text Unit 1 and Affinity (Lorad, USA) named Unit 2. Both units use molybdenum (Mo) anode plus 0.03 mm Mo filter. Both units used the same film processor — Protec Compact 2 (Germany) with 31°C developer temperature used for conventional films as well. The screen-film combinations were Kodak MIN-R screens with Kodak MIN-R S films for Unit 1 and Kodak MIN-R 2190 screens with the same films for Unit 2.

Full quality control measurements were made on both units according the requirements of the Bulgarian regulation for protection of individuals at medical exposure [17]. The instruments used for these measurements were an ionization chamber 77337 and a dosimeter UNIDOS E (PTW Freiburg, Germany) for tube output and half value layer (HVL) measurements and an X-ray multimetre Barracuda (RTI Electronics, Sweden) for tube voltage measurements.

Patient measurements

Estimation of mean glandular doses (MGDs) for approximately 60 women per unit on two mammography units was made. All patient exposures were made in fully automatic mode of the automatic exposure control (AEC) systems of the units — for these units this means automatic choice of tube potential [kV] and tube loading [mAs].

For each patient the exposure data were recorded, including patient age, projection (mediolateral oblique (MLO) or craniocaudal (CC)), left or right breast exposed, tube potential [kV] and tube loading [mAs] and compressed breast thickness (CBT). The last parameter was measured on Unit 1 with a ruler and on Unit 2 with a built in device whose accuracy was verified. Patients with exposures of only one breast were excluded from the study. All patients included in the study had MLO exposures of both breasts and some of them had a supplementary CC exposure of one or both breasts.

Patient doses were calculated from patient exposure data and from the measurements of tube output and HVL for each unit. Method described in the European protocol on dosimetry in mammography [9], the European protocol for the quality control of the physical and technical aspects of mammography screening [11, 12] and the TRS 457 of the IAEA [15] was used. All measurements and calculations were made for the reference point (6 cm from the chest wall edge and centred laterally) [9, 11, 12]. In TRS 457 the reference point is defined 4 cm from the chest wall edge.

Tube output on both units was measured for all clinically used tube potentials with the compression plate present in the beam. The first two protocols don't specify the precise place of the compression plate [9, 11, 12]. Since the conversion factors g, for the calculation of MGD, are determined with Monte Carlo calculations simulating measurement of entrance surface air kerma (ESAK) at a position under the compression plate on the breast surface, excluding only backscatter from the phantom, not forward scatter from the plate [6, 7], it was decided to determine the tube output with the compression plate on top of the ionization chamber. It was found in our previous work that if the compression plate is away from the chamber it would lead to an underestimation of the dose of about 6.5% [1]. This set up with the compression plate in contact with the detector is suggested in TRS 457 of the IAEA as well, but it is emphasized only for phantom measurements [15]. HVL was measured at 28 kV with compression plate away from the detector. Values of HVL at other tube voltages were determined using the IPEM Report 78 [5] spectrum processing software with the specific

tube data: target angle and material, filter material and thickness including compression plate thickness.

ESAK without backscatter on patient's skin was calculated for each exposure by multiplying the tube loading and the measured tube output for the relevant tube voltage with correction for the distance to the patient's skin surface. Patient's MGD per film (i.e. per exposure) was calculated by multiplying the ESAK by the conversion factor g corresponding to the relevant HVL and CBT from the three protocols mentioned above [9, 11, 12, 15]. New conversion factors, taking into account the age of the patients, are published in the last edition of the European protocol for the quality control of the physical and technical aspects of mammography screening [12]. These conversion factors are established for the UK population and may vary for other populations. For that reason, it was decided not to include them in our study. MGD per woman was calculated by summing MGDs for all exposures for a woman and averaging over both breasts.

Mean CBT ± standard deviation and mean MGD ± standard deviation were calculated for the samples of both units separately.

The mean ESAK and MGD for the patient's group of compressed breast thicknesses in the interval 40-60 mm were compared with the results from the measurements on the standard 45 mm polymethylmethacrylate (PMMA) phantom.

Phantom measurements

Measurements with the 45 mm PMMA phantom started with exposing the phantom in clinical conditions. The phantom was positioned on the breast support, the compression plate on it, a film in a cassette was positioned in the cassette holder and an exposure was made in fully automatic AEC mode. Exposure parameters were recorded. The MGD to the phantom was calculated the same way as the MGDs to the patients, only the conversion factor g_{pb} was taken for phantom measurements [9, 11, 12, 15]. The target optical density in the reference point of the exposed films was measured.

Results and discussion

Patient measurements

Histogram of age distribution of the patient's sample for both units is presented on Figure 1. About 27% of the patients on both units were within the age interval 40-49 which was one of the intervals for the age dependent conversion factors [12]. The other interval was of ages 50-64 with approximately 43% of all patients felling in it, and about 25% for Unit 1 and 14% for Unit 2 were above ages 64 (see Figure 1). The bigger part of

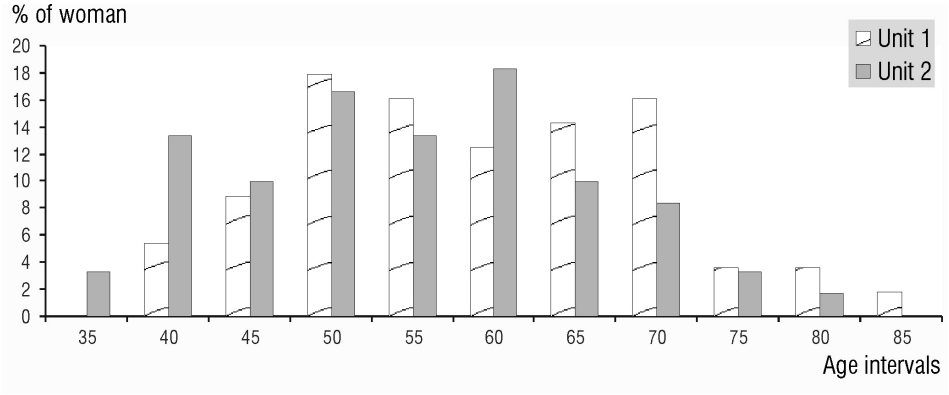

Figure 1. Histogram of age distribution of the patient's sample for both units

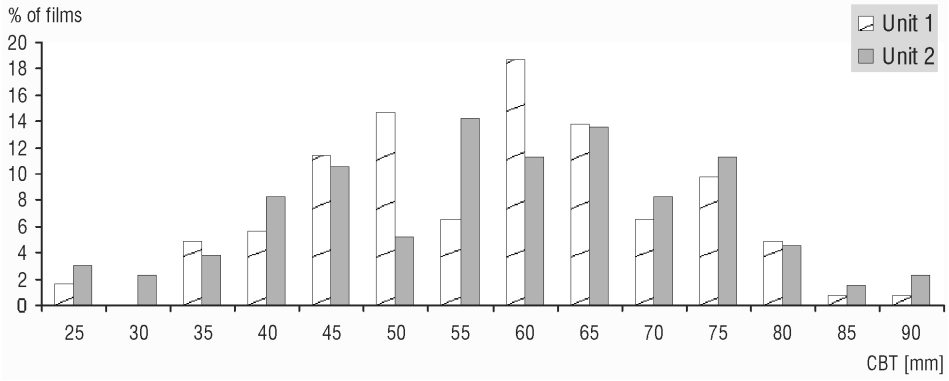

Figure 2. Histogram of CBT distribution of the patient's sample for both units

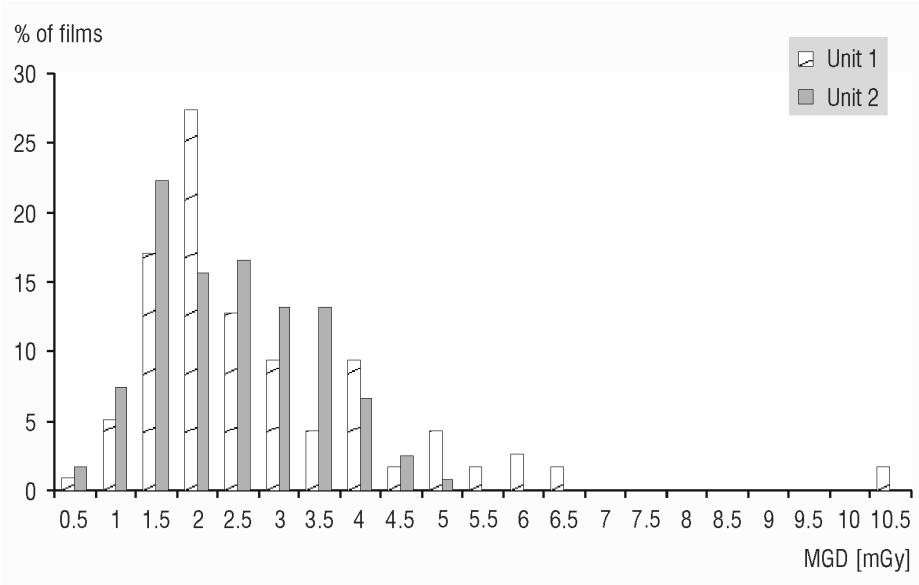

Figure 3. Histogram of mean glandular doses distribution per film of the patient's sample for both units

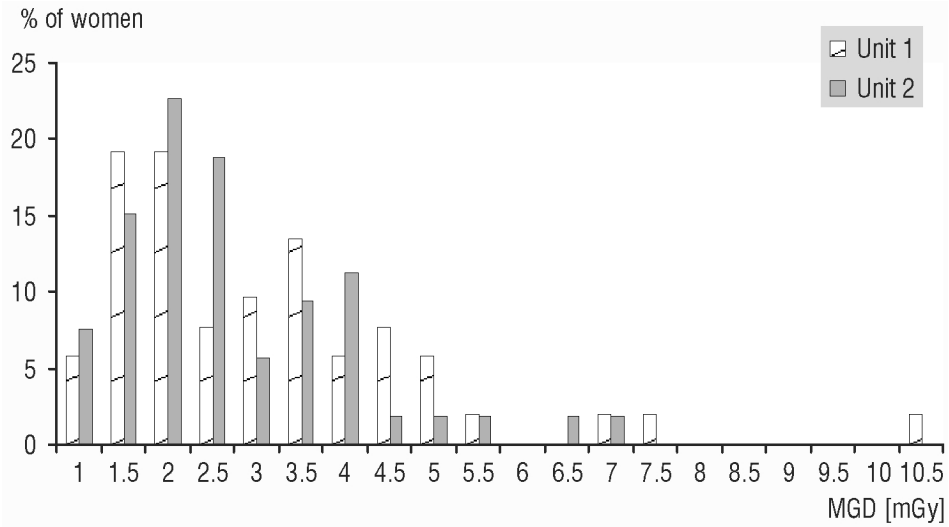

Figure 4. Histogram of mean glandular doses distribution per woman of the patient's sample for both units

Table 1. Mean glandular doses and compressed breast thicknesses for individual films

View	Number of films		MGD for hole samples [mGy]				Thickness [mm]			
			Mean ± SD		Median (Q_1, Q_3)		Mean ± SD		Median (Q_1, Q_3)	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Both projections	117	121	2.6 ± 1.7	2.2 ± 1.0	2.0 (1.5, 3.3)	2.0 (1.4, 2.9)	55.8 ± 13.0	54.2 ± 15.4	58 (49, 65)	58 (44, 67)
MLO	106	106	2.6 ± 1.8	2.2 ± 1.0	2.2 (1.6, 3.3)	2.1 (1.4, 2.9)	57.3 ± 13.2	56.8 ± 15.7	59 (48, 66)	59 (44, 69)
CC	11	15	2.0 ± 1.0	2.1 ± 1.0	1.8 (1.2, 2.4)	1.9 (1.5, 3.0)	54.2 ± 10.3	51.6 ± 12.9	55 (50, 60)	51 (42, 60)

SD — standard deviation, Q_1 nad Q_3 — first and third quartiles

Table 2. Comparison of the results from measurements of ESAK and MGD with phantom and with patients with CBT in the interval 40-60 mm

Mammography system	Preferred net OD	Limiting value		Phantom data		Patients data for 40-60 mm CBT		% difference between patient's and phantom results	
		ESAK [mGy]	MGD [mGy]	ESAK [mGy]	MGD [mGy]	ESAK [mGy]	MGD [mGy]	ESAK	MGD
Unit 1	0.8	9	1.8	10.75	2.12	9.6 ± 4.9	1.7 ± 0.7	10.9	20.8
Unit 2	1	11	2.3	10.38	1.89	11.2 ± 5.8	1.9 ± 0.9	7.2	1.6

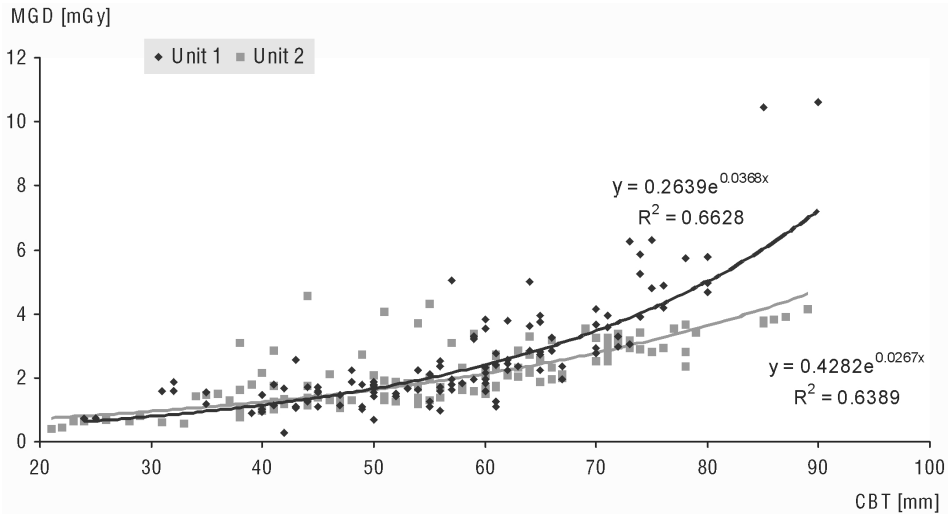

Figure 5. Mean glandular doses presented as a function of compressed breast thickness of the patient's sample for both units

the patients was in the age interval in which it was considered that the breast is less dense and contains less glandular tissue. The meaning of this fact will be discussed in the section of phantom measurements.

The distribution of the CBT in 5 mm bands is shown in Figure 2. The histograms of MGDs per film and per woman are presented in 0.5 mGy bands in Figure 3 and Figure 4 respectively. All projections are included in the plot of MGD per film because the total number of CC views was small compared to the number of MLO views. All examinations (1-view or 2-view for one or both breasts) were included in one plot for the distribution of MGD per woman.

The distributions of MGDs per film and per woman (Figures 3 and 4) were found to be skewed. Similar results are obtained by other authors [4, 21]. For that reason median ± quartile were calculated as more appropriate descriptors.

The mean of the MGDs for all projections and for MLO and CC projections separately, the median, first and third quartiles and the same statistics for the CBT are shown in Table 1. The mean of the MGDs for Unit 2 is less than that for Unit 1, but the values of the medians are very close, while the corresponding values of CBT are nearly the same.

The dependence of MGDs per film on CBT is graphically presented on Figure 5. This graph shows that the automatic exposure control system of Unit 2 compensates better for thicker, but not for medium sized breasts. Both trend lines are exponential with equations and R-squared values shown on the figure. This result is again in compliance with other publications [4].

Phantom measurements

The results from the calculation of ESAK and MGD for the patient's group of compressed breast thicknesses in the interval 40-60 mm (mean 50 ± 6 mm), as well as the results from the phantom measurements of these parameters are shown in Table 2. The measured optical densities of the exposed films and the limiting values of ESAK and MGD for the corresponding target optical densities, proposed in the European protocol on dosimetry in mammography [9], are also included in this table. The percent difference between the results from phantom and patient measurements are presented. ESAK and MGD values from the phantom study on Unit 1 exceed the mean value from the patient survey, whereas the values for Unit 2 are comparable. Smans et al. [18] and Young et al. [21] reported even higher differences between the MGD from patient and phantom measurements. The former author found phantom doses lower than patient doses and the latter author found higher phantom doses exceeding by about 50% the patient doses. The percent differences between phantom and patient results for the whole patient samples (all CBT) are 19% and 13% for Unit 1 and Unit 2 respectively (not included in the table). The bigger percent difference is explicable having in mind that all thicknesses are included. ESAK and MGD from phantom data on Unit 1 exceed the limiting values; ESAK from patient study is slightly above, but MGD is below the limits (see Table 2). Patient ESAK for Unit 2 is above the limits; all other parameters are below the limits. Patient and phantom results for Unit 2 have comparable values. The observed differences between the two systems are most probably due to the more sensitive screen-film combination used on Unit 2. Some differences in the AEC settings of both units are another possible reason for this finding.

It is assumed in the European protocol on dosimetry in mammography that the 45 mm PMMA phantom simulates the standard breast, which has a composition of 50% adipose and 50% glandular tissues in the central region surrounded by a 5 mm thick superficial layer of adipose tissue and entire thickness of 50 mm. The same definition and conversion factors for calculation of MGD for the standard breast are suggested in

TRS 457 [15]. The last edition of the UK protocol [14] however gives different definition of a standard breast, represented with the same 45 mm PMMA phantom: it is 53 mm thick and has glandularity 29% in the central region, considered to be typical for women in the age range 50-64. As we saw a big part of the patient sample in our study is close to this age range. Different values of the conversion factors are mentioned as well. Dance et al. comment that for a screening population aged 50-64, the typical glandularity of breasts of thickness 5 cm is 33% [7]. Differences in conversion factors published by different authors due to different radiation transport codes, photon interaction data, photon spectra, composition and thickness of superficial layer in practice achieve about 15% [16]. Some uncertainty exists related to the definition of a standard breast as well as uncertainty due to different breast composition and conversion factors used that can explain the difference between phantom and patient measurement results. The observed difference at some degree may be due to errors in the measurements of CBT or phantom thickness (Faulkner and Cranley reported that 2% change in PMMA thickness would result in variations in MGD of +5% and −4% [13]).

Conclusions

The measurement procedures described in the European protocol on dosimetry in mammography [9], the European protocol for the quality control of the physical and technical aspects of mammography screening [11, 12] and the TRS 457 of the IAEA [15] are applicable in the conditions found in the country. Attention should be paid to the measurement set up.

A unified method for the measurement procedures and succeeding calculations should be established for the country. More comprehensive study including more mammography units of different ages and technical characteristics has to be performed for the establishment of national diagnostic reference levels.

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