INDIVIDUAL DOSES DURING MAMMOGRAPHY SCREENING EXAMINATIONS WITH SCREEN-FILM AND DR SYSTEMS

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Abstract

The aim of this study was the estimation of average glandular doses (AGD) received by women undergoing mammography examinations with the use of 10 mammography units equipped with full-field digital detectors, installed at facilities participating in the screening program in Poland. Moreover, for two mammography units the AGDs were recalculated three times: directly after the installation of the mammography unit, after the exchange of the image detector and after the upgrade of the mammography system software. For one mammography unit calculations were made twice: after the installation of the mammography unit and after the exchange of the image detector. All determined AGD values were compared with limiting values (acceptable and achievable) presented in the "European guidelines for quality assurance in breast cancer screening and diagnosis - Fourth edition". The clinical breast doses ranged from 0.12 mGy to 5.80 mGy with the mean value of 1.78 mGy. They did not exceed the limiting values for typical breasts at the acceptable level in 87.4% of cases and at the achievable level in 65.2% of cases.The upgrade of the software, the calibration and exchange of the image detector made by the manufacturer service introduced changes which induced increase of the doses received by women during examinations.

1. INTRODUCTION

In 2006, the framework of the *Polish National Breast Cancer Early Detection Program for Women aged from 50 to 69* was initiated. In order to create a structure for the administration of the screening program of the Ministry of Health, 16 regional Coordination Centres, covering the administrative regions of the country, were created. Also, a Central Coordination Centre, located at the Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology in Warsaw was set up. Thanks to such organization it was possible to contact all mammography facilities involved in the screening program, to receive the necessary data from them and to evaluate their equipment. Furthermore, it was possible to carry out a control of the physical and technical parameters of the mammography equipment and to collect data concerning the individual woman exposures. On this basis, it was possible to evaluate that in 2007, in the whole country, there were 320 mammography units used in the mammography screening program, and among them there were only 5 DM (Digital Mammography) systems. On the other hand, in 2010 and in 2011, in the Mazovia region alone the screening was carried out with 7 (out of 48) and 9 (out of 51) DM systems respectively. Two of them were installed at the Maria Skłodowska-Curie Memorial Cancer Center and the Institute of Oncology in Warsaw.

The literature data indicate evident advantages of the application of digital detectors in mammography. Apart from advantages linked with much simpler procedures of computer systems as far as processing, presentation, archiving and transmission of digital images are concerned, there are more important advantages of DM systems over SMF systems, namely: better image quality and lower doses of radiation received by the examined women. According to the published data [1, 2, 3, 4, 5], the average glandular dose (AGD) values are within 2.0 mGy per exposure allowing for detection of the objects of 0.1 mm of diameter, which is very satisfying. However, the results of some authors [6] indicate that the doses received by women examined with the systems equipped with a digital detector are higher than those when the screen-film detector is used. These discrepancies in the results called for further analysis of average glandular doses in mammography with DM systems.

2. DESCRIPTION OF MATERIALS, METHODS AND RESULTS

2.1. Clinical breast doses

The authors had an opportunity to determine the AGD values for exposures of individual women's clinical breast doses. These doses were determined for women examined with 10 mammography units equipped with full-field digital detectors (FFDM systems), installed at facilities taking part in the screening program in Poland. Determination of the clinical breast doses required the collection of all exposure parameters for the examined women. The collected data included the following parameters: anode material, additional filter type, tube potential value, tube load value, breast thickness after compression and birth year of a woman. For every mammography unit the data for 200 exposures (examination of 50 women) were collected. Subsequently, for every mammography unit the measurements of air kerma were performed (taking into account the linear dependence of air kerma on tube load) and also the measurement necessary for determination of half value layer for all tube potential values used during the exposures. The measurements were performed with a multimeter Piranha (type: 305; uncertainty: ±5%) from RTI Electronics AB and with aluminium filters from Gammex (6×0.10 mm thickness and Al purity ≥99.9%). The AGD values were calculated for every exposure made for 500 women (i.e., 2000 exposures) according to the method described in "European guidelines for quality assurance in breast cancer screening and diagnosis, Fourth edition" [7].

Subsequently, the estimated values of clinical breast doses for each exposure were compared to the levels listed in Table I. To determine the clinical breast dose limiting value for each breast thickness after compression the second-degree polynomial was fitted. The polynomial for acceptable level is given in Equation 1, and for the achievable level in Equation 2:

$$y = 0.091x^2 - 0.2326x + 1.1786 \quad (1)$$

$$y = 0.059x^2 - 0.012x + 0.402 \quad (2)$$

where:
y is the clinical breast dose limiting value for each breast thickness (mGy),
x is the breast thickness after compression (cm).

The correlation coefficient R^2 between the values given by the above formulas and the values listed in Table I was higher than 0.99 in every case.

For each of 10 DM systems (from 4 manufacturers indicated by consecutive numbers) the following parameters were collected: material of image detector, the percentage of exposures performed with a given anode/filter combination, the percentage of exposures for which the clinical breast doses did not exceed the acceptable and achievable limits. The results (presented in Table II) indicate that the maximal percentage of exposures which did meet the expected acceptable and achievable limits for DM systems were attained with the W/Rh combinations. However, an analysis of the results indicates that the doses received by the women depend not only on the type of the unit and on the particular manufacturer.

Clinical breast dose values calculated for 10 mammography units equipped with DR systems ranged from 0.12 mGy to 5.80 mGy with the mean value of 1.78 mGy. They did not exceed the limiting values for typical breasts at the acceptable level in 87.4 % of cases and at the achievable level in 65.2% of cases. For comparison, clinical breast doses have been calculated for 50 women examined with the use of one SFM unit. This mammography unit was installed in the Coordination Centre of the Screening Program in Poland in 2007. The mammography unit and the accessories (film processor, viewing box, amplifying screens and films) were of good quality. They were systematically controlled and fulfilled all quality criteria given in "European guidelines for quality assurance in breast cancer screening and diagnosis - Fourth edition" [7]. The clinical breast dose values determined for the SFM unit ranged from 0.40 mGy to 4.22 mGy with the mean value of 1.68 mGy. They did not exceed the limiting values for typical breasts at the acceptable level in 98% of cases, and at the achievable level in 95% of cases.

2.2. The modifications in DM systems versus the clinical breast doses

During the period of use of the DM systems the manufacturer service upgrades the software, performs the calibration of the image detector and, in particular situations, exchange the image detector. All these activities should not influence the dose received by the examined women. However, the authors noticed that the service actions result in the increase of the clinical breast doses. For three mammography units the manufacturer service performed alterations of the image detector and the allied software. For two mammography units the clinical breast doses were recalculated three times: directly after the installation, after the exchange of the image detector and after the upgrade of the mammography system software, and for one system twice: after the installation and after the exchange of the image detector.

TABLE I. AGD LIMITING VALUES FOR EQUIVALENT BREAST THICKNESSES [7]

PMMA thickness (cm)	Equivalent breast thickness (cm)	Maximum AGD for equivalent breast thickness (mGy)	
		Acceptable level	Achievable level
2.0	2.1	< 1.0	< 0.6
3.0	3.2	< 1.5	< 1.0
4.0	4.5	< 2.0	< 1.6
4.5	5.3	< 2.5	< 2.0
5.0	6.0	< 3.0	< 2.4
6.0	7.5	< 4.5	< 3.6
7.0	9.0	< 6.5	< 5.1

TABLE II. MATERIAL OF IMAGE DETECTOR, THE PERCENTAGE OF EXPOSURES PERFORMED WITH A GIVEN ANODE/FILTER COMBINATION, THE PERCENTAGE OF EXPOSURES FOR WHICH THE CLINICAL BREAST DOSES DID NOT EXCEED THE ACCEPTABLE AND ACHIEVABLE LIMITS FOR 10 DR SYSTEMS

Unit number/ manufacturer number	Material of image detector	The percentage of total numbers of exposures with given combination anode/filter (%)	The percentage of exposures not exceeding acceptable level (%)	The percentage of exposures not exceeding achievable level (%)
Unit 1/Manufacturer 1	amorphous selenium	100.0 (W/Rh)	99.0	89.0
Unit 2/Manufacturer 2	amorphous selenium	84.0 (Mo/Mo) 16.0 (Mo/Rh)	49.0	32.0
Unit 3/Manufacturer 2	amorphous selenium	7.5 (Mo/Mo) 92.5 (Mo/Rh)	80.5	47.0
Unit 4/Manufacturer 3	amorphous selenium	100.0 (W/Rh)	92.0	85.5
Unit 5/Manufacturer 4	amorphous silicon	1.0 (Mo/Mo) 15.0 (Mo/Rh) 84.0 (Rh/Rh)	80.0	52.5
Unit 6/Manufacturer 2	amorphous selenium	50.5 (Mo/Mo) 49.5 (Mo/Rh)	76.5	57.0
Unit 7/Manufacturer 1	amorphous selenium	100.0 (W/Rh)	99.5	97.0
Unit 8/Manufacturer 2	amorphous selenium	64.5 (Mo/Mo) 35.5 (Mo/Rh)	97.5	92.05
Unit 9/Manufacturer 3	amorphous selenium	100.0 (W/Rh)	100.0	100.0
Unit 10/Manufacturer 3	amorphous selenium	100.0 (W/Rh)	100.0	99.0

The data analysis indicate that the mean values of clinical breast doses for one mammography unit after the replacement of the image detector and after the upgrade of the software increased, in relation to the doses determined after the installation of mammography unit, by 44% and 50% accordingly. At the same time, the number of exposures meeting the acceptable limit diminished from

22% to 1% and those meeting the achievable limit from 1% to 0%. In the case of another mammography unit, the mean clinical breast dose value after the upgrade of the software decreased by about 4% as compared to the mean clinical breast dose determined after the installation of the unit. On the other hand, after the replacement of the image detector, the mean value of the clinical breast dose increased by 8% in relation to the clinical breast doses calculated after the installation of the unit. The percentage values of exposures fulfilling the acceptable limits decreased after consecutive changes from 66% to 38% and 23% and for the achievable limits from 41% to 13% and 12%. For yet another mammography unit, the small decrease (i.e., 3% and 4%) of the number of exposures meeting the acceptable and achievable limits was observed after the exchange of the image detector.

3. CONCLUSIONS

The frequently cited opinion that women examined with the use of DM systems receive smaller doses of radiation than women examined with SFM systems is not generally true. Furthermore, the SFM system presented here generated small clinical breast doses while simultaneously fulfilling the quality requirements formulated by the "European guidelines for quality assurance in breast cancer screening and diagnosis - Fourth edition" [7].

Taking into account the three DM systems mentioned above, two from the same manufacturer, it is possible to conclude that during the upgrade of the software, calibration and exchange of image detector made by the manufacturer services changes were introduced which, as a consequence, induced an increase in the doses received by the women during examinations. Therefore, it is reasonable to determine the clinical breast dose values after every manufacturer service intervention into the software and the image detector in order to be able, in case of increased doses, to optimize the exposure parameters.

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