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DEVELOPMENT OF A STANDARD OPERATING PROCEDURE FOR MAMMOGRAPHY EQUIPMENTS USED IN CALIBRATION OF IONIZATION CHAMBERS

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ABSTRACT

Mammography is one widely used technique in the detection of breast cancer. In order to optimize the results achieving better images with lower dose rates, a quality assurance programme must be applied to the equipments. Some control tests use ionization chambers to measure air kerma and other quantities. These tests can only be reliable if the ionization chambers used on them are correctly calibrated. In the present work, it was developed a Standard Operating Procedure (SOP) for quality control tests in a commercial mammography equipment installed in the Calibration Laboratory (LCI) at IPEN. Seven tests were performed in the equipment: Tube voltage and exposition time accuracy and reproducibility, linearity and reproducibility of Air kerma and Half Value Layer (HVL). Then, it was made a measurement of the air kerma in the mammography equipment, using a reference ionization chamber with traceability to a primary laboratory in Germany (Physikalisch-Technische Bundesanstalt - PTB), that was later compared with the air kerma measured in an industrial irradiator. This industrial X-ray generator was recently used in the implementation of X-radiation Standards beams, mammography level, following the Standard IEC 61267. The HVL values varied from 0.36 (25 kV) to 0.41 mmAl (35 kV), and the measured air kerma rates were between 9.78 and 17.97 mGy/min.

1. INTRODUCTION

Breast cancer is the second most common cancer among women worldwide. In 2010, it was estimated more than 49,000 new cases of cancer in Brazil, with a risk of 49 cases per 100,000 women [1]. Mammography is one of the most effective methods of early detection, and the Brazilian Ministry of Health suggests that women over 50 years old should do this exam annually or every two years, at least [2].

The mammography is a procedure in which a specific X-ray equipment is used in order to make an image for diagnosis. Therefore, in order to make the diagnosis the most effective possible, a routine of tests is necessary to verify the perfect condition of the machine as a whole.

The publication 453/98 of the National Agency of Sanitary Surveillance (ANVISA) [3] indicates some tests that should be performed periodically in mammography systems in order to maintain the quality of the mammogram and lower the dose in the patients. Several of these tests use ionization chambers and in order to obtain correct results in those tests, these chambers must be properly calibrated.

The Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN) is reference in calibration in Brazil. Many radiation qualities were implemented at LCI, which are used to calibrate various types of ionization chambers. The LCI recently purchased a mammography equipment which is being used in many experiments.

The main goal of this work is to create a Standard Operating Procedure (SOP), with the most important tests in order to assess the status of the device, checking the availability of its use in the projects developed at LCI, as well as in calibrations. Similar procedures, of internal circulation, were implemented at the University Hospital, in Federal University of Sergipe in 2009 [6], which are now being modified and adapted to the current needs of the facility.

2. MATERIALS AND METHODS

The tests on the proposed procedure were made using three devices: a Radcal ionization chamber, model RC6M, with 6cm³ of sensitive volume, a Kethley electrometer, model 6517A and a PTW non-invasive PPV meter, model Diavolt Universal All-in-one QC Meter T43014. The mammography equipment used in this work is an analogical VMI Graph-Mammo AF.

2.1. Standard Operating Procedure for Quality Control

The National Surveillance Agency determines a list of control quality tests that has to be done in order to preserve the mammography equipment in good conditions [3]. As the mammography equipment will only be used in experiments, there's no need to do all the tests. Therefore, only three main parameters were submitted to reproducibility, linearity and accuracy tests: Air kerma, tube voltage and exposition time.

2.1.1. Linearity and Reproducibility of the Air Kerma Rate

The air kerma rate was made as indicated in the procedure, which was based on ANVISA's methodology [4] with some modifications from the IAEA's TRS-457 [7]. The ionization chamber was placed in the center, at 4 cm from the edge of the support, 5cm high as depicted in the Fig. 1. The applied voltage was 28 kV and the current 80 mA. Measurements were taken with 4 different exposition times, varying from 0,5s to 2s. The reproducibility was obtained by calculating the variation coefficient (VC) given by the division of the measurement error by the average of the kerma measurements for each mAs selected (equation 1). The calculated VC should be lower than 0.05.

$$VC = \sigma(Gy) \big/ K_{average}(Gy) \qquad (1)$$

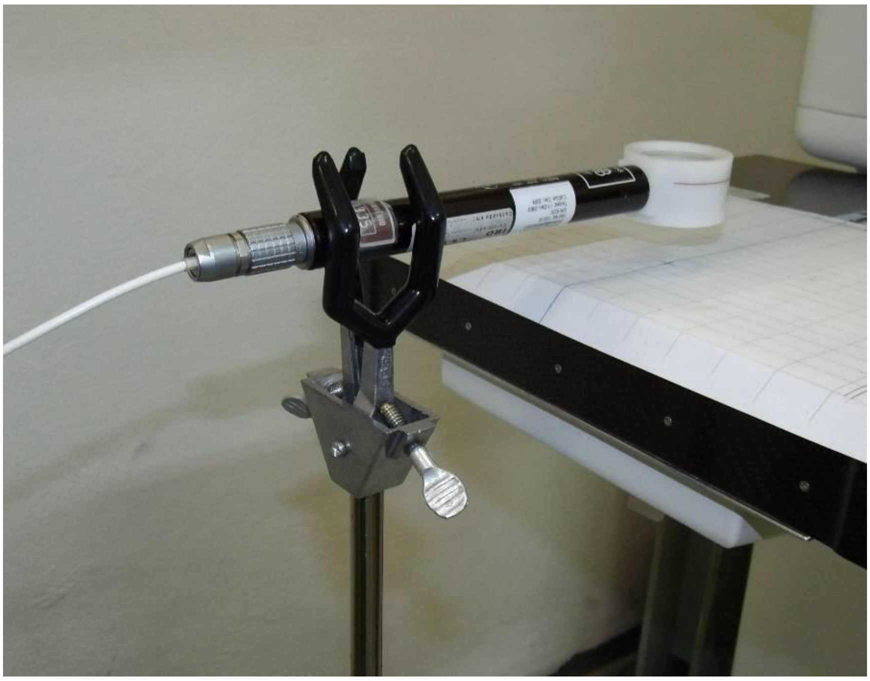

Figure 1. Ionization chamber placed in the right position.

Linearity (L(%)) was calculated with the equations below. Each kerma average was divided by its respective mAs value (R factor of the equation 2). A comparison was made between the maximum and the minimum value of R (equation 3) and its result is expected to be below 10%.

$$R = K(Gy)/mAs \tag{2}$$

$$L(\%) = 200 \cdot (R_{max} - R_{min})/(R_{max} + R_{min}) \tag{3}$$

2.1.2. Tube Voltage and Exposition time accuracy and reproducibility

Tests of reproducibility and accuracy of the tube voltage and exposure time were also made using the methodology of ANVISA [4]. The center of the sensitive area of the PPV meter was place at 4 cm from the edge of the support (Fig. 2). The tube current was set to 80mA and the nominal exposure time to 1000ms. Four exposures were made with a tube voltage of 28kV and the average and deviation of the measurements were calculated. The same was done with 30kV and 32kV.

Figure 2. PPV meter on the support.

The accuracy (d(%)) of both the quantities was obtained with the equation 4, where "A" is the quantity in question. The reproducibility of the tube voltage was calculated by the use of the variation coefficient (VC) equation (equation 5) and the reproducibility (R(%)) of the exposition time was obtained by taking the highest and the lowest measurements value for each voltage and applying them in the equation 6.

$$d(\%) = 100 \cdot (A_{nom} - A_{average}) / A_{nom} \quad (4)$$

$$VC = \sigma(V) / kVp_{average} \quad (5)$$

$$R(\%) = 200 \cdot (t_{\max} - t_{\min}) / (t_{\max} + t_{\min}) \quad (6)$$

2.2. Kerma values for comparison with calibration data

An IEC International Standard [5] presents all the information needed to establish radiation qualities for calibration of ionization chambers used in mammography (RQR-M). These qualities are described in terms of Molybdenum target with a total (Molybdenum) filtration of 0.032mm ± 0.002mm. As we don't know details about the inherent filtration of the LCI mammography equipment, we can only estimate qualitatively if the equipment is in perfect condition as shown by the tests of the operating procedure.

The ionization chamber used in the tests has traceability to PTB (Physikalisch-Technische Bundesanstalt), so kerma values of this institute were compared to the kerma values obtained with LCI's mammography system in the same conditions. Some correction factors were applied, such as correction of temperature and pressure ($f_{T,P}$), calibration factor (f_C), a distance factor (f_D), because PTB uses a standard focus-detector distance of 1m, while the mammography equipment has only 0.618cm, and a factor related to the tube current (f_{mAs}). This last one was introduced because PTB uses 10mA and gives the result in mGy/s, but in the LCI equipment we used 80 mA with 1 second of exposition time. Therefore, the Kerma is given by the equation 7.

$$K(Gy) = \bar{q} \cdot f_{T,P} \cdot f_C \cdot f_D \cdot f_{mAs} \tag{2}$$

3. RESULTS

3.1. Air Kerma results

Table 1 shows the charge collected and its respective kerma value with corrections for temperature and pressure.

Table 1. Obtained Kerma Values

mAs	Collected charge[a] (nC)	Kerma[b] (mGy)
40	0.916 ± 0.004	4.02 ± 0.02
80	1.866 ± 0.004	8.18 ± 0.02
120	2.812 ± 0.005	12.34 ± 0.02
160	3.769 ± 0.007	16.54 ± 0.03

a. Average of four measurements.
b. Laboratory conditions: T = 20.2°C; P = 92.49kPa.

The variation coefficients (VC) and the calculated reproducibility of the kerma are shown in the table 2.

Table 2. Calculated variation coefficients for reproducibility of Air Kerma

mAs	VC	R[c]
40	0.0022	**9.43202E-05**

80	0.0007	9.47449E-05
120	0.0008	9.49739E-05
160	0.0008	**9.53826E-05**

c. In bold, the higher and lower values used to calculate the linearity.

It is expected for the variation coefficients to be less than 0.05 for any mAs used [4]. Using the highest and the lowest values to calculate the R factor, the linearity obtained was 1.12%, which it is expected for mammography equipment in good conditions of use to be ±10% [4].

3.2. Reproducibility and Accuracy of tube Voltage and Exposition time

The variation coefficients (VC) and accuracy values for tube tension are shown in the table 3. A VC value lower than 0.02 and accuracy between ± 5% are the expected values [4].

Table 3. VC and Accuracy of tube Voltage

kV	$kPv_{average}$ (V)	VC	Accuracy (%)
28	28.40 ± 0.01	0.000352	1.43
30	30.50 ± 0.01	0.000328	1.67
32	32.68 ± 0.01	0.000383	2.11

The results for exposure time are presented in the table 4. The expected values are R ≤ 10% and an accuracy value lower than 10% [4].

Table 4. Reproducibility and Accuracy of Exposition Time

kV	$t_{average}$ (ms)	R (%)	Accuracy (%)
28	1006 ± 5	0.40	0.65
30	1006 ± 8	0.60	0.58
32	1007 ± 6	0.50	0.70

3.3. Kerma comparison with PTB Standard values

The collected charge and respective kerma value for all four RQR-M qualities are shown in the table 5.

Table 5. Comparison with PTB values

Quality	Tube voltage (kV)	Average charge (nC)	Kerma rate (mGy/s)	PTB Kerma rate (mGy/s)
RQR-M 1	25	1.302 ± 0.003	0.30	0.30
RQR-M 2	28	1.873 ± 0.006	0.43	0.41
RQR-M 3	30	2.334 ± 0.006	0.53	0.50
RQR-M 4	35	3.551 ± 0.005	0.81	0.74

4. DISCUSSION

From the results obtained from the tests, it can be said that the mammography equipment is in perfect condition, what makes it available to be used in experiments. The Standard Operating Procedure will be available in the laboratory soon and a routine of tests will be implemented. As the equipment will be used in some research projects, it may be necessary to modify the procedure by adding, for instance, a test to analyze its half-value layer (HVL).

A comparison was made between the kerma rates using the mammography equipment and the standard values from PTB. We can see that the kerma values are not equal to the PTB ones, which is expected as the mammography equipment doesn't have the same characteristics (like filtration) of the apparatus from PTB. Nonetheless, from the results obtained it can be said that the equipment is in good conditions of use, as the values are close to the standard. If the half-value layer is obtained, the LCI commercial equipment could be used, with some adjustments, on calibration of ionization chambers for the qualities related to mammography.

5. CONCLUSIONS

A Standard Operating Procedure was created in order to establish a routine of tests for quality control of mammography equipment. It will be implemented at the Laboratory of Calibration (LCI) at IPEN, and the laboratory's equipment was submitted to 6 different tests. All results showed the equipment is in perfect condition, what is expected because the machine was recently acquired. Comparisons made with a standard kerma rate value from PTB confirms the good condition of the equipment and opens the possibility of future works aiming to implement the RQR-M qualities using a commercial mammography equipment.

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