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PERFORMANCE EVALUATION OF A KERMA-AREA METER IN THE MAMMOGRAPHY RADIATION QUALITIES

Nathalia Almeida Costa[1], Eduardo de Lima Correa[2] and Maria da Penha A. Potiens[3]

Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
1 nacosta@ipen.br
2 educorrea1905@gmail.com
3 mppalbu@ipen.br

ABSTRACT

The kerma-area product (P_{KA}) is a useful quantity to establish the reference levels in diagnosis of conventional X ray examinations and it is a good indicator when the dose limits for deterministic effects are achieved in interventionist procedures. The P_{KA} can be obtained by measurements carried out with a kerma-area product meter (KAP) with a plane-parallel transmission ionization chamber mounted on the X ray system. The KAP meter is used for patient exposure monitoring during fluoroscopy, conventional radiology and dental radiology procedures. To have a reliable measurement of patient dose the KAP needs to be properly calibrated. The objective of this study was to evaluate the performance of the reference KAP meter in several radiation qualities in the range of mammography. The intention was to determine the parameters concerning the utilization of this kind of instrument. The measurements were done in all RQR-M, RQA-M from 25 to 35 kV, performed at 100 cm and the calibration coefficients were determined to all radiation qualities using an industrial X ray system.

1. INTRODUCTION

The kerma-area product (P_{KA}) is a useful quantity to establish the reference levels in diagnosis of conventional X ray examinations and it is a good indicator when the dose limits for deterministic effects are achieved in interventionist procedures. According to the International Atomic Energy Agency (IAEA), the air kerma–area product, P_{KA}, is the integral of the air kerma over the area of the X ray beam in a plane perpendicular to the beam axis, thus, according to Equation 1:

$$P_{\mathrm{KA}} = \int_A K(x,y)\,\mathrm{d}x\,\mathrm{d}y \tag{1}$$

Unit: $J \cdot kg^{-1} \cdot m^2$. If the special name gray is used, the unit of air kerma–area product is $Gy \cdot m^2$.

The air kerma–area product has the useful property that it is approximately invariant with distance from the X ray tube focus (when interactions in air and extrafocal radiation can be neglected), as long as the planes of measurement and calculation are not so close to the patient or phantom that there is a significant contribution from backscattered radiation. It is a good indicator of stochastic risk and correlates with operator and staff dose.(1,2,3)

The P_{KA} can be obtained by the use of the kerma-area product meter (KAP) which monitors the patient's exposure during the exam. It is important to use one reference KAP meter to obtain a reliable quantity of doses on the patient. A P_{KA} meter can be calibrated in laboratory or in situ, where it is used. However, in general, the P_{KA} chamber is fixed to the X ray equipment which means that it can't be calibrated in a laboratory, just in situ.(1,8)

Thus, the calibration is usually done in situ using the P_{KA} quantity obtained from the measurements of the air kerma with a reference ionization chamber and the irradiated area exposed on the film positioned in the same distance as the chamber.(4)

In the present study, the Patient Dose Calibrator (PDC) was used as a reference KAP meter to evaluate the mammography performance in eight radiation qualities. This is a recent instrument for field calibration of patient dose measurement and it has the advantage of being able to use different field sizes, radiation qualities and to have smaller energy dependence. There are few studies about the use of the PDC as it is a new equipment.(5,6, 7,9)

The PDC measures $P_{KA.}$ Its rated range of use for the tube voltage is between 40 kV and 150 kV. The aims of this study were to use the Radiation Qualities in radiation beams emerging from the X Ray (RQR) and the Radiation Qualities based on a phantom made up of an aluminum (Al) added filter (RQA) both for mammography (RQR-M and RQA-M), which work with 25 kV, 28 kV, 30 kV and 35 kV, even this voltages being out of the range for the PDC, according to the manual.(9) The temperature and pressure were automatically corrected by the instrument.

The four RQR-M and four RQA-M used were established at the Laboratório de Calibração de Instrumentos (LCI) in a study performed at the Instituto de Pesquisas Energéticas e Nucleares (IPEN) in Brazil in 2010, which follows the IEC 61267 regulation.(10)

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Patient dose calibrator (PDC)

The instrument used to measure the P_{KA} was the Patient Dose Calibrator from Radcal. The PDC is a reference class instrument for field calibration of patient dose measurement and control systems thus ensuring the validity of inter-institution patient dose comparisons. Figure 1 shows the PDC. [9]

Figure 1. Patient Dose Calibrator

2.1.2. X Radiation system

The X Radiation system used was a Pantak/Seifert located at the LCI, with a voltage up to 160 kV, a tungsten target, a constant potential, an inherent filtration of 0.138 mmAl and a 0.8 mm beryllium window. As the measures were done to RQR-M, a molybdenum (Mo) filter was added at the beam exit. The Figure 2 shows the X Radiation system.

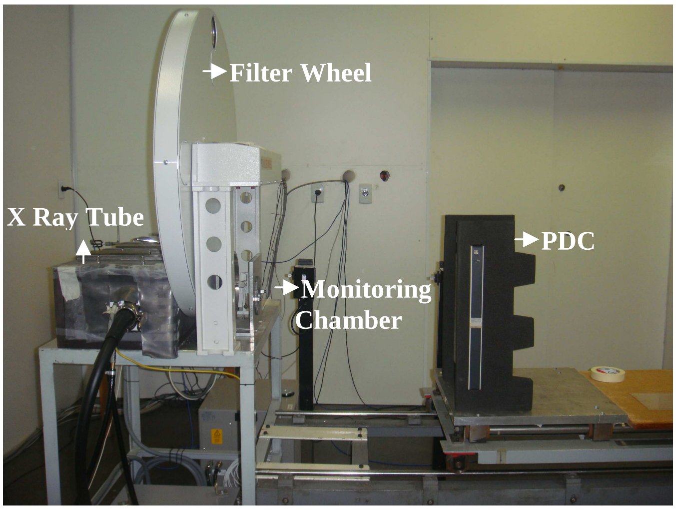

Figure 2. X Radiation system Pantak/Seifert

2.2. Methods

The PDC was placed in front of the X ray equipment with the central beam positioned on the PDC's center. All the measurements were done using a 0.07 mm molybdenum filter, a current of 10 mA, distance of 1 meter, irradiations of one minute and ten irradiations for each energy. The temperature and pressure were automatically adjusted by the PDC. Figure 3 shows the PDC properly positioned. Figure 4 shows the molybdenum filter used at the exit of the X ray beam.

Figure 3. Position of the PDC on the X Ray Beam

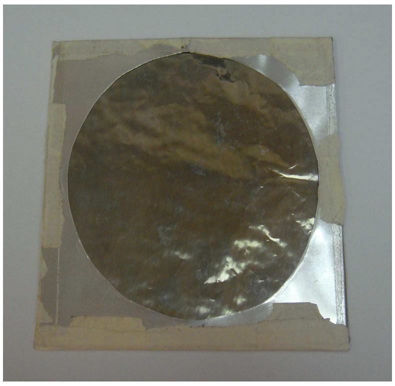

Figure 4. Molybdenum filter

The first test was done for the RQR-M with 25 kV, which is the RQR-M 1. Following it, 28 kV, 30 kV and 35 kV. Thus, it was used all the RQR-M for mammography.

The second test was done in the same sequence and features as the first test but for the RQA-M and with 2 mm aluminum filter positioned after the monitor ionization chamber. Figure 5 shows the aluminum filter. It was used the voltages 25 kV, 28 kV, 30 kV and 35 kV.

All these radiation qualities were established using the LCI secondary standard ionization chamber for mammography range, Radcal, model RC6M traceable to the German Primary Laboratory *Physikalisch-Technische Bundesanstalt* (PTB). The reference air kerma rate was also obtained using this instrument.[11]

Figure 5. Aluminum Filter

3. RESULTS

The measurements indicate that the PDC is able to display P_{KA} in voltages under 40 kV once the manual doesn't present it.

The standard deviation and the equipment resolution were used to calculate the uncertainties assuring that they didn't exceed the recommended values.

The quantities for each RQR-M tested are reproducible for the air kerma rate and for the accumulated air kerma (measured in one minute). Table 1 shows the average quantity for each voltage, the reference air kerma rate for RQR-M and the calibration coefficient (N_k), which is known from the reference air kerma rate divided by the air kerma rate.

Table 1. Obtained values for RQR-M

Radiation Qualities	Voltage (kV)	Air Kerma Rate (mGy/min)	Accumulated Air Kerma (mGy)	Reference Air Kerma Rate (mGy/min)	Calibration Coefficient (N_k)
RQR-M 1	25 kV	6.7 ± 0.15	6.732 ± 0.13	9.78	1.45
RQR-M 2	28 kV	8.5 ± 0.17	8.512 ± 0.17	12.20	1.43
RQR-M 3	30 kV	9.7 ± 0.19	9.729 ± 0.19	13.83	1.42
RQR-M 4	35 kV	12.9 ± 0.25	12.91 ± 0.25	17.97	1.39

For RQA-M the voltages 28 kV, 30 kV and 35 kV are also reproducible for the air kerma rate and the accumulated air kerma (measured in one minute). Table 2 shows the average quantity for each voltage, the reference air kerma rate for RQA-M and the calibration coefficient (N_k), which is known from the reference air kerma rate divided by the air kerma rate.

Table 2. Obtained values for RQA-M

Radiation Qualities	Voltage (kV)	Air Kerma Rate (mGy/min)	Accumulated Air Kerma (mGy)	Reference Air Kerma Rate (mGy/min)	Calibration Coefficient (N_k)
RQA-M 1	25 kV	0.35 ± 0.07	0.356 ± 0.07	0.470	1.34
RQA-M 2	28 kV	0.5 ± 0.01	0.540 ± 0.01	0.671	1.34
RQA-M 3	30 kV	0.7 ± 0.014	0.707 ± 0.01	0.845	1.20
RQA-M 4	35 kV	1.3 ± 0.026	1.311 ± 0.02	1.47	1.13

The standard deviation and the equipment resolution were also used to calculate the uncertainties for the RQA-M and they didn't exceed the recommended values.

4. CONCLUSIONS

It is possible to realize that the PDC is an instrument that can also be used for measurements in mammography once the manual of its instrument says that the voltages function from 40 kV to 150 kV, considering the calibration coefficient. According to ICRU 2005 and IAEA 2007, the measurements performed were within the recommended for the uncertainties. The kerma rate and the accumulated kerma for the RQR-M and the RQA-M quantities were also reproducible.

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