EVALUATION METHODOLOGY AND PERFORMANCE TESTS OF IONIZATION CHAMBERS OF THE AIR KERMA AREA PRODUCT USING MATHEMATICAL SIMULATION

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Abstract

The Monte Carlo method was used to study the dependence of the calibration coefficient on tube voltage, radiation beam size, additional filtration, energy and reference plane in simplified geometries modeling a KAP meter. The MCNP5 code was used to calculate the imparted energy in the air cavity of KAP meter and the spatial distribution of the air collision kerma in entrance and exit plans of the KAP meter and on a plane close to the patient. From these data, the air kerma-area product (PKA) and the calibration factor were calculated and its dependencies with the tube voltage, radiation beam size, additional filtration and energy were analyzed. There was a variation of the calibration factor as a function of the tube voltage when the additional filter was used. The additional filter placed next to KAP meter decreased the calibration coefficient for the patient's plane compared to the additional filtration in the output of the beam. The effect of the beam aperture was small in terms of patient and negligible to the exit plane.

Key Words: Kerma area product, air kerma, Monte Carlo Method, quality control

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. 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. The objective of this study was to evaluate the performance of the reference KAP meter in several radiation qualities and study those parameters using the Monte Carlo method. 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[(1)]:

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

Uncertainties of 7% or lower (coverage factor, k =) are recommended for air kerma and KAP measurements in diagnostic X ray imaging, and the uncertainty of calibration coefficient should not exceed 5% (k = 2)[1,2]. It is important to use the reference KAP meter to obtain a reliable quantity of doses on the patient. [3,4]

2. MATERIALS AND METHODS

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 and the set up used to measurements.

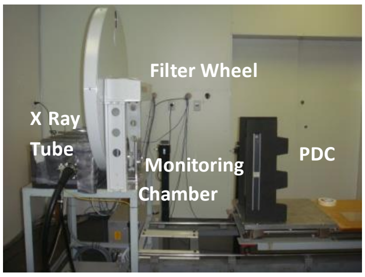

Figure 1. Patient Dose Calibrator and the set up used to measure the parameters

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 100 cm, irradiations of one minute and ten irradiations for each energy. The MCNP5 code was used to calculate the imparted energy in the air cavity of KAP meter and the spatial distribution of the air collision kerma in entrance and exit plans of the KAP meter and on a plane close to the patient. From these data, the air kerma-area product (PKA) and the calibration factor were calculated and its dependencies with the tube voltage, radiation beam size, additional filtration and energy were analyzed. The geometry used is showed in Figure 2.

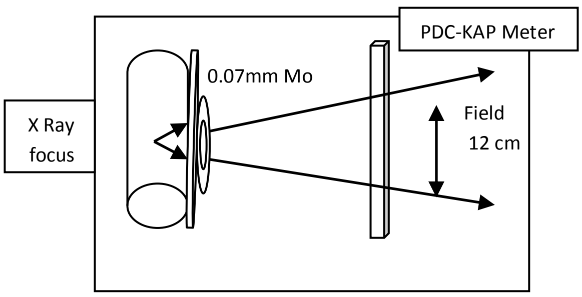

Figure 2. Schematic view of the geometry used.

3. RESULTS AND DISCUSSION

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(6) 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

Using the MCNP5(7) it was simulated the RQR-M2 (28 kV) based on the spectrum experimental measurements(6) and varying the field diameter from 1 to 8 cm. It was considered for simulation 45.000 histories. The values are showed in Figure 3. The KAP meter behavior was linear as expected.

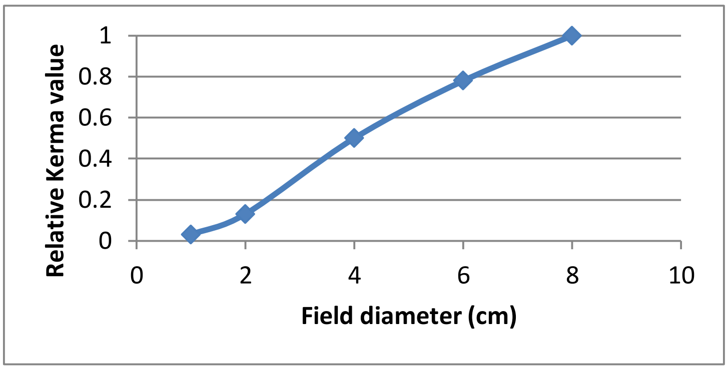

Figure 3. Simulated KAP meter behavior varying the field diameter.

4. CONCLUSIONS

The quantities for each RQR-M and RQR-A tested are reproducible for the air kerma rate and for the accumulated air kerma. This preliminary results show that the Monte Carlo Method can be used to simulate some KAP meter characteristics as part of its quality control program. The next step will be the simulation for all radiation qualities established and the analysis of their parameters.

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