The use of Mathematical Simulation to Evaluate the Calibration Parameters of a Kerma-Area Product Ionization Chamber

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Abstract. 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 and study those parameters using the Monte Carlo method. 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.

1 Introduction

The kerma-area product (KAP) 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 KAP 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. According to the International Atomic Energy Agency (IAEA), the air kerma–area product, KAP, 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 :

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

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)

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2 Materials and Methods

The instrument used to measure the PKA 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.

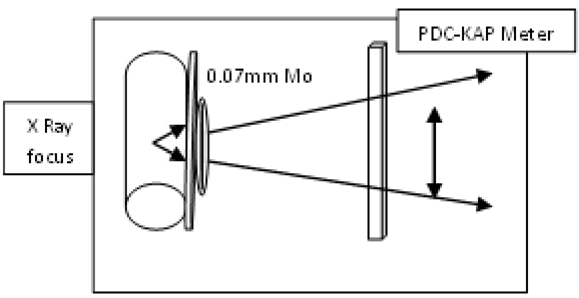

Figure 2. Schematic view of the geometry used.

3 Results

The obtained results for air kerma rates (Kair) and the air kerma length product (PKL) are presented in Table 1. Additionally the entrance surface air kerma (Ke) were determined using the pediatric phantom. The ionization chamber was positioned outside the phantom. The CT air kerma indices Ca,100, CW (free in air and in phantom) and Cvol (derived from CW), were calculated according to TSR457 [1], are in Table 2.

Table 1. Radiation qualities characteristics, air kerma rates (Kair), air kerma length product (PKL) and the entrance surface air kerma rates (Ke).

Radiation qualities	Tube Voltage (kV)	Filter	HVL (mmAl)	K_{air} Gy/min	Ke Gy/min	Pkl
RQT 8	100	3.2mm Al + 0.3 mm Cu	6.90	0.018	0.008	0.18
RQT 9	120	3.5mm Al + 0.35mm Cu	8.40	0.027	0.010	0.27
RQT 10	150	4.2mm Al + 0.35mm Cu	10.1	0.045	0.017	0.45

Table 2. CT air kerma indices Ck, CPMMA, CW (free in air and in pediatric phantom) and Cvol (derived from CW).

Radiation qualities	Ck	CPMMA	CPMMA,P	Cw	Cvol
RQT 8	0.018	0.023	0.032	0.008	0.18
RQT 9	0.027	0.035	0.048	0.010	0.27
RQT 10	0.045	0.058	0.079	0.017	0.45

4 Discussion and Conclusions

The CT air kerma indices Ck, CPMMA, and CW (free in air and in the pediatric phantom) and the air kerma-length product (PKL) were determined in this study allowing the possibility of the use of a calibration standard beam for CT measurements in order to establish methods to analyze CT parameters. In addition, measurements at the pediatric phantom surface developed at IPEN were done to obtain the entrance surface air kerma (Ke).

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