COMPARISON OF A KAP METER AND A PDC BEHAVIOR USING MATHEMATICAL SIMULATION IN REFERENCE DIAGNOSTIC RADIOLOGY QUALITIES

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Abstract

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. The objective of this study was to evaluate the performance of two KAP meters, one reference instrument (PDC) and a clinical KAP meter, in diagnostic radiology radiation qualities from 50 to 150 kV. The spectra of four reference radiation qualities (IEC 61267) were measured and the parameters of the KAP meters were determined 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.

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 (IAEA, 2007):

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

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) (IAEA, 2007;ICRU, 2005). It is important to use the reference KAP meter to obtain a reliable quantity of doses on the patient (Toroi and Kosunen, 2010; Hetland et al, 2009; Costa and Potiens, 2014a, 2014b].

The objective of this study was to evaluate the performance of two KAP meters, one reference instrument (PDC) and a clinical KAP meter, in diagnostic radiology radiation qualities from 50 to 150 kV. The spectra of four reference RQR radiation qualities (IAEA, 2007) were measured and the parameters of the KAP meters were determined using the Monte Carlo method.

2 Materials and Methods

The instrument used as a reference to measure the KPA was the Patient Dose Calibrator from Radcal [Costa and Potiens, 2014b; Radcal, 2009). 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. The other KAP meter analyzed was a clinical instrument, VacuDAPduo, VacuTec Messtechnik. Figure 1 shows the PDC and the KAP used. They were positioned at the same time in the radiation field to determine their parameters. The Tandem Method, using the Pantak X radiation system, 160 kV was used to calibrate the clinical KAP meter. The geometry used is showed in Figure 2. The PDC was placed at 100cm and the KAP at 50 cm.

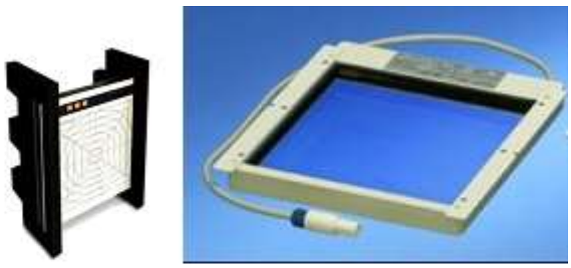

Figure 1 - Patient Dose Calibrator (Left side) and Kerma Area Product Meter (Right side)

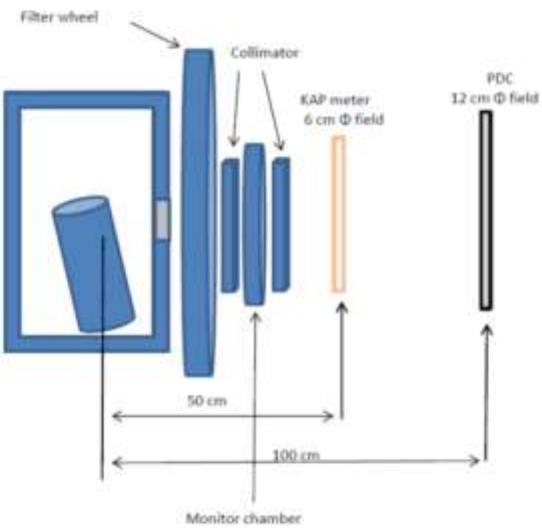

Figure 2 - Set up used to measure the parameter Pantak X radiation system.

The calibration and the spectra measurements were performed for the RQR radiation qualities established at the Calibration Laboratory following the recommendations of the IAEA, TRS 457 (IAEA, 2007), from 50 to 150 kV. Their main characteristics are in Table 1 (Corrêa, 2010). The spectrometer system used was one hyperpure germanium detector, HPGe, with an analogic multichannel analyzer (MCA). The detector was subjected to different rates of radiation so that no dead time is exceeded 5%. The hole collimator diameter was 50 µm.

Table 1 – The main characteristics of the RQR radiation qualities established.

Radiation Quality	Nominal Voltage (kV)	Current (mA)	HVL (mmAl)	Energy (keV)	Additional Filtration (mmAl)
RQR 3	50	10	1.78	29.7	2.40
RQR 5	70	10	2.58	34.0	2.80
RQR 8	100	10	3.97	38.1	3.20
RQR 10	150	10	6.57	45.0	4.20

The MCNP5 (MCNP, 2004) 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 plan of the KAP meter. From these data, the air kerma-area product (KAP) and the calibration coefficient for the KAP Meter were calculated and compared with those obtained experimentally.

3 Results

The X-ray tube was easily modeled using the Monte Carlo code MCNP5 as seen in Figure 3. In the same way the complete tandem calibration set up was possible to obtain as seen in Figure 4 that shows the 2D and the 3D set up lateral view.

Figure 3 – MCNP view for the X-ray tube simulation.

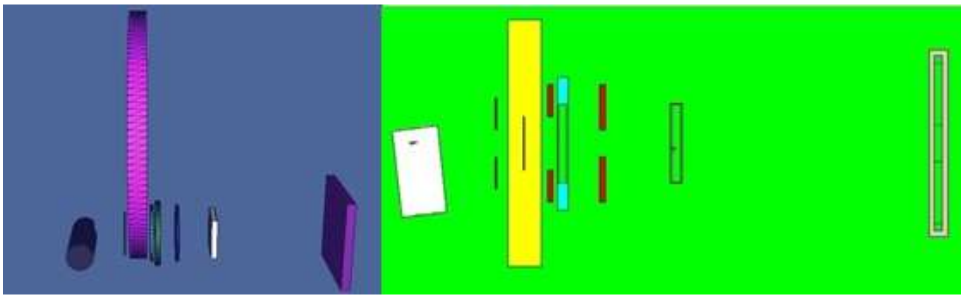

Figure 4 - Tandem Calibration method set up by Monte Carlo Simulation, 3D and 2D lateral view.

After that the X radiation fields during the KAP Meter Tandem Calibration were simulated as showed in Figure 5 considering the two KAP meters positioning. This figure represents all of the RQR radiation qualities tested in this work.

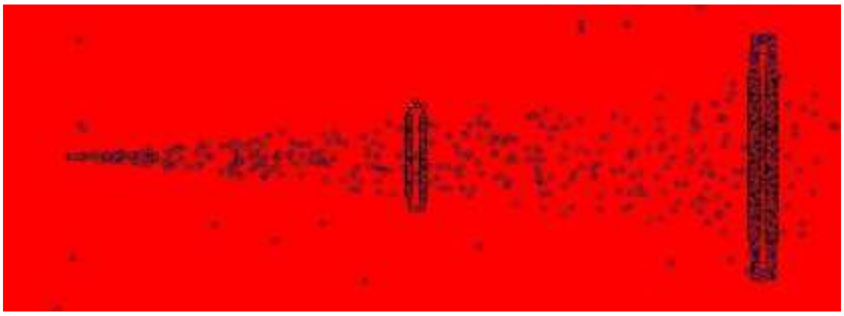

Figure 5 - X ray beam by Monte Carlo Simulation during the KAP Meter Tandem Calibration.

The spectra of the diagnostic radiology RQR reference qualities measured are showed in Figures 6 to 9. These spectra were used as a source definition in the input card for the Monte Carlo simulation. The Table 2 shows the Kerma area product quantity reference values and the clinical KAP meter calibration coefficients obtained experimentally and by Monte Carlo simulation. The differences between those values were about 2%, except for RQR 10 (5.45%). The uncertainties in Monte Carlo simulation were less than 0.5% in all cases and the FOM (Figure of Merit) was constant for a number of histories of 1 million.

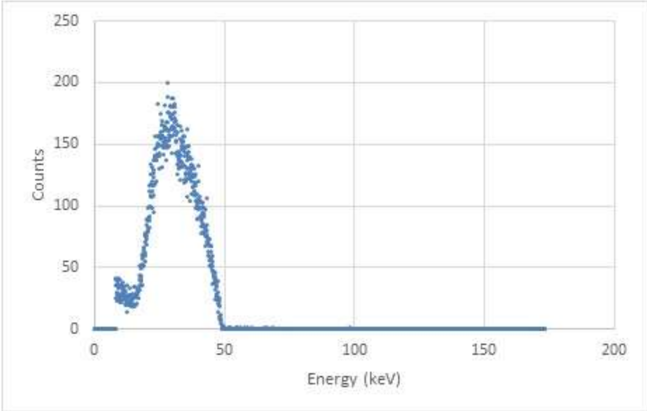

Figure 6 - Measured Spectra of the Diagnostic radiology RQR3 reference quality.

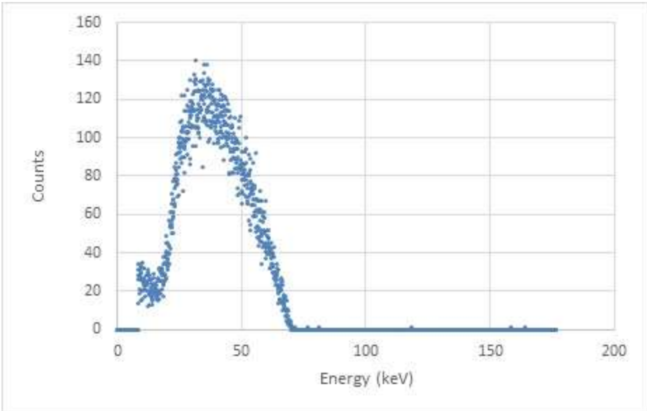

Figure 7 - Measured Spectra of the Diagnostic radiology RQR5 reference quality.

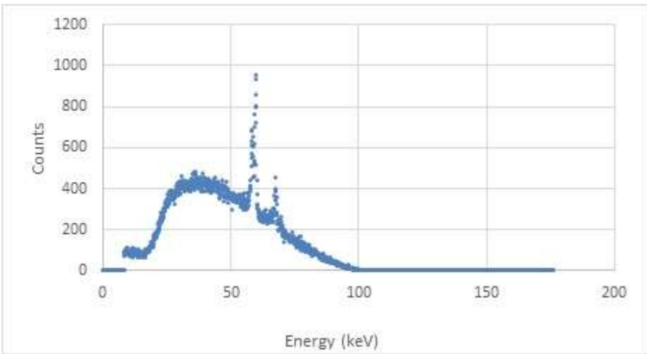

Figure 8 - Measured Spectra of the Diagnostic radiology RQR8 reference quality.

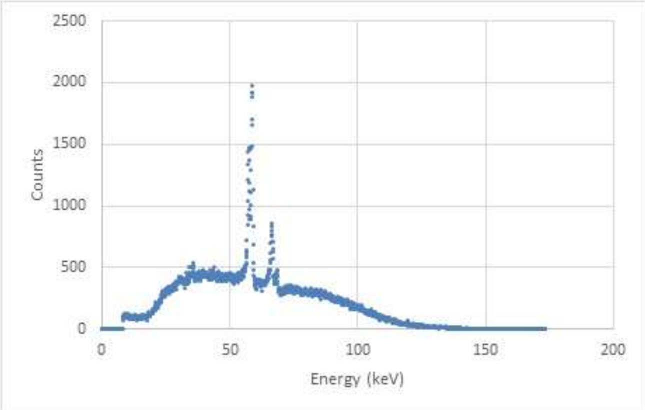

Figure 9- Measured Spectra of the Diagnostic radiology RQR10 reference quality.

Table 2 - Kerma area product quantity reference values and the clinical KAP meter calibration coefficients obtained experimentally and by Monte Carlo simulation

Radiation Quality	Reference PDC Kerma Area Product ($mGy.m^2$)	Experimental KAP meter Calibration Coefficient	Monte Carlo KAP meter Calibration Coefficient	Difference (%)
RQR 3	134.2	1.107	1.081	2.35
RQR 5	274.1	1.054	1.031	2.17
RQR 8	542.8	1.073	1.097	2.12
RQR 10	754.3	1.100	1.160	5.45

4 Discussion and Conclusions

This study shows the possibility to use the MCNP5 code to simulate the KAP meters parameters, the set up used to their calibration and the X-ray beam characteristics. The small difference between the experimental and the simulation calibration coefficient shows reliability in the use of mathematical simulation as an important support to experimental calibrations.

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