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Calibration methodology application of kerma area product meters in situ: Preliminary results

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HIGHLIGHTS

- The Patient Dose Calibrator (PDC) is a new equipment from Radcal that measures KAP.
- This study aimed the calibration of KAP meters in situ using the PDC as a reference.
- The method used for the calibration of the KAP meters was the tandem method.
- This instrument calculates the dose that the patient receives during an X-ray examination.
- The calibration procedure is important to correct the measurements performed with KAP meters.

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ABSTRACT

The kerma-area product (KAP) is a useful quantity to establish the reference levels of conventional X-ray examinations. It can be obtained by measurements carried out with a KAP meter on a plane parallel transmission ionization chamber mounted on the X-ray system. A KAP meter can be calibrated in laboratory or in situ, where it is used. It is important to use one reference KAP meter in order to obtain reliable quantity of doses on the patient. The Patient Dose Calibrator (PDC) is a new equipment from Radcal that measures KAP. It was manufactured following the IEC 60580 recommendations, an international standard for KAP meters. This study had the aim to calibrate KAP meters using the PDC in situ. Previous studies and the quality control program of the PDC have shown that it has good function in characterization tests of dosimeters with ionization chamber and it also has low energy dependence. Three types of KAP meters were calibrated in four different diagnostic X-ray equipments. The voltages used in the two first calibrations were 50 kV, 70 kV, 100 kV and 120 kV. The other two used 50 kV, 70 kV and 90 kV. This was related to the equipments limitations. The field sizes used for the calibration were 10 cm, 20 cm and 30 cm. The calibrations were done in three different cities with the purpose to analyze the reproducibility of the PDC. The results gave the calibration coefficient for each KAP meter and showed that the PDC can be used as a reference instrument to calibrate clinical KAP meters.

1. Introduction

The kerma-area product (KAP) is a useful quantity to establish the reference levels of conventional X-ray examinations and it is a good indicator when dose limits for deterministic effects are reached in interventionist procedures. According to the International Atomic Energy Agency (IAEA), the air kerma–area product, PKA, is the integral of the air kerma over the area of the X-ray beam in a plane perpendicular to the beam axis, according to the following equation:

$$PKA = \int_A K(x,y)\,\mathrm{d}x\mathrm{d}y \quad (1)$$

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

The air kerma–area product has the useful property that it is approximately invariant with distance from the X-ray tube focus (when interactionsbetween air and extra focal radiation can be neglected), as long as the planes of measurement and calculation are not too close to the patient or phanton that it would have significant contribution from the backscattered radiation. It is a good indicator of stochastic risk and correlates with operator and staff doses (International Atomic Energy Agency, 2007, 2009; International Commission on Radiation Units and Measurements, 2005).

The KAP can be obtained by using the kerma-area product meter which monitors the patient's exposure during the examination. It is important to use one reference KAP meter to obtain a reliable quantity of doses on the patient. A KAP meter can be

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calibrated in laboratory or in situ, where it is used. However, normally, the KAP chamber is fixed to the X-ray equipment which means that it cannot be calibrated in a laboratory, that is only in situ (International Atomic Energy Agency, 2009; Canevaro, 2009).

Thus, the calibration is usually done in situ using the KAP quantity obtained from the measurements of the air kerma with a reference ionization chamber and the irradiated area on a film positioned at the same distance as the chamber (Canevaro, 2009).

The Patient Dose Calibrator (PDC) is a new equipment from Radcal that measures KAP. It was manufactured following the IEC 60580 recommendations (International Electrotechnical Commission, 2000). Its rated range of use is for tube voltages between 40 kV and 150 kV, but studies have shown that measurements can be done under 40 kV (Costa et al., 2011).

This is an instrument for field calibration of patient dose measurement and it has the advantage of being able to use different field sizes, radiation qualities and of having smaller energy dependence. There are few studies about the use of the PDC as it is a new device (Costa et al., 2011; Almeida et al., 2011; Toroi and Kosunen, 2009, 2010; Hetland et al., 2009).

This study aimed to calibrate KAP meters in situ using the PDC as a reference. The study was developed in Brazil, with the calibration of four KAP meters in different diagnostic X ray equipments. Three of them were portable and one was a KAP meter coupled to the X ray device.

2. Materials and methods

2.1. Materials

2.1.1. Patient Dose Calibrator (PDC)

The instrument used to measure the KAP was the Patient Dose Calibrator from Radcal. The PDC is a reference class instrument for field calibration of patient dose measurement and control systems to ensure the validity of inter-institution patient dose comparisons. Fig. 1 shows the PDC (Radcal Corporation, 2009).

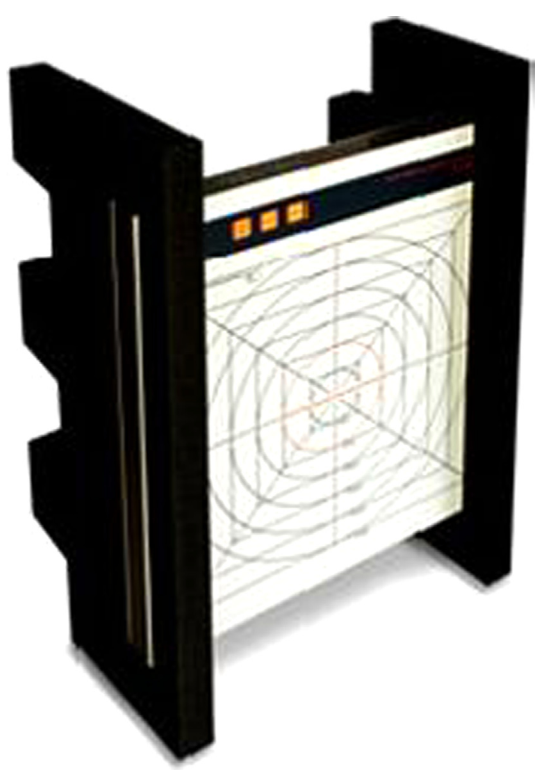

Fig. 1. Patient Dose Calibrator.

2.1.2. KAP meters and radiation systems

The KAP meters used for calibration were as follows:

- KAP meter model Diamentor E2 from PTW that belongs to Universidade Federal de São Paulo- UNIFESP. The radiation system used was Philips Compact Plus 500 VMI.
- KAP meter model Kermax plus TinO (Two in one) 120–205 from IBA Dosimetry, that belongs to Instituto Federal da Bahia in Salvador. The radiation system used was a RAEX 300D.
- KAP meter model Diamentor E2 from PTW that belongs to the Universidade Federal de Pernambuco in Recife. The radiation system used was a EDR 750B.
- KAP coupled to an interventional X-ray equipment model Philips Allura Xper FD10 that belongs to the Hospital São Paulo in São Paulo.

2.2. Methods

The method used for the calibration of KAP meters was described by Toroi and Kosunen (2009). The method is called the tandem method. In this method the KAP meter is placed on the tube housing. The PDC, used as reference, is placed above the KAP meter and over the patient's table. The tests conducted in UNIFESP had the PDC positioned over the table. The tests conducted in DEN had the PDC positioned in its holder and the ones conducted in IFBA used both positions. Both instruments were irradiated simultaneously. The main reason to use this method is to maintain the same geometry and positioning as the measurements with the patients. Fig. 2 shows the array for the method. In Table 1, the parameters found for each place are described where the calibration was conducted.

For the calibration with a KAP meter coupled with the X ray equipment, the calibration is similar but the attenuation by the

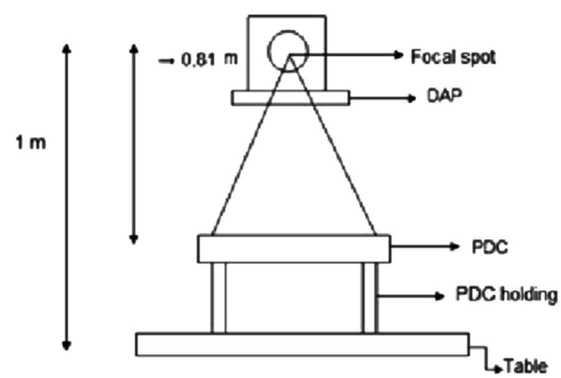

Fig. 2. Tandem calibration methodology array.

Table 1
Irradiation conditions for calibration methodology.

Irradiation conditions for portable KAP meters			
	UNIFESP	DEN	IFBA
Voltages (kV)	50, 70, 100, 120	50, 70, 90	50, 70, 90
Distance (m) (with and without the holder)	1/0,81	1/0,81	0,90/0, 71
Field size (cm²)	10, 20, 30	10, 20, 30	10, 20, 30
Current (mA)	200	50	100
Time (s)	0,1	0,08	0,225

Table 2
Calibration coefficient found for each place where the methodology was performed.

Calibration coefficient (N_K)							
	Voltages (kV)	Field size 10 cm	Field size 20 cm	Field size 30 cm	With holder 10 cm	With holder 20 cm	With holder 30 cm
UNIFESP	50	0.92	1.05	1.05	–	–	–
	70	0.84	0.94	1.00	–	–	–
	100	0.86	0.98	1.02	–	–	–
	120	0.87	1.01	1.05	–	–	–
DEN	50	–	–	–	0.99	1.08	1.06
	70	–	–	–	0.94	0.97	1.01
	90	–	–	–	1.10	0.96	0.89
IFBA	50	1.40	1.42	1.21	1.26	1.21	1.00
	70	1.27	1.36	1.16	0.92	1.09	1.10
	90	1.19	1.37	1.18	1.11	0.93	1.15

table must be considered for over couch installations. The Code of Practice TRS 457 (International Atomic Energy Agency, 2007) states that this attenuation can reach up to 30%. The following parameters were used:

- distance PDC-source: 80 cm;
- distance detector-source: 100 cm;
- PDC positioned over the table and in its holder;
- magnification modes of 15 cm, 20 cm and 25 cm;
- fluoroscopy modes low, normal and high;
- image acquisition of 15 frames per second;
- 30 s for each irradiation;
- copper filter of 1 mm and 2 mm to protect the detector;
- voltages between 62 kV and 80 kV;
- current between 3.8 mA and 7.1 mA (voltage and current were automatically set by the equipment).

3. Results

The tandem method was used. All the measurements were performed in situ with clinical X-ray equipments and all the quantities obtained had their values corrected. The equation used to find the calibration coefficient was

$$N_{\mathrm{PKA,Q}} = \frac{M_{\mathrm{Q}}^{\mathrm{PKA_{ref}}}}{M_{\mathrm{Q}}^{\mathrm{PKA}}} N_{\mathrm{PKA,Q_0}}^{\mathrm{ref}} k_{\mathrm{Q}}^{\mathrm{ref}} \qquad (2)$$

where M_Q^{PKA} is the reading for the KAP meter, $M_Q^{PKA_{ref}}$ is the reading for the PDC (reference KAP meter), $N_{PKA,\,Q_0}^{ref}$ is the calibration coefficient for the reference KAP meter obtained for the radiation weightage used and k_Q^{ref} is the correction factor for the response of the radiation quality.

Table 2 shows the coefficient calibration found for each instrument calibrated. For the calibration of the coupled KAP meter, the value of the half-value layer available was for the voltage of 80 kV. So the coefficient calibration is calculated only for this voltage and it is shown in Table 3. Eq. (2) is also used to find the calibration coefficient.

Table 3
Calibration coefficient found for a coupled KAP meter.

Voltage (kV)	Current (mA)	PDC (μGy m²)	DAP (mGy cm²)	CSR (mmAl)	N_k
80	6.6	20.12 ± 0.1	277.4 ± 1.2	8.5	0.854

4. Conclusion

The calibration of KAP meters must be considered since this type of instrument is essential in calculating the dose that a patient receives during an X-ray examination. The PDC is the instrument that should be used as a reference to calibrate KAP meters since with its use it is possible to perform this calibration in situ. The calibration coefficients found in this work, performed in four different X ray machines in Brazil, show that the calibration of KAP meters is necessary.

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