

DEVELOPMENT OF A CALIBRATION METHODOLOGY AND TESTS OF KERMA AREA PRODUCT METERS

N.Costa, M.Potiens

Instituto de Pesquisas Energéticas e Nucleares, Universidade de São Paulo. IPEN/CNEN/USP,
São Paulo-Brazil.

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ABSTRACT

The quantity kerma area product (KAP) is important to establish reference levels in diagnostic radiology exams. This quantity can be obtained using a KAP meter. The use of such meters is essential to evaluate the radiation dose in radiological procedures and is a good indicator to make sure that the dose limit to the patient's skin doesn't exceed. Sometimes, these meters come fixed to X radiation equipment, which makes its calibration difficult. In this work, it was developed a methodology for calibration of KAP meters. The instrument used for this purpose was the Patient Dose Calibrator (PDC). It was developed to be used as a reference to check the calibration of KAP and air kerma meters that are used for dosimetry in patients and to verify the consistency and behavior of systems of automatic exposure control. Because it is a new equipment, which, in Brazil, is not yet used as reference equipment for calibration, it was also performed the quality control of this equipment with characterization tests, the calibration and an evaluation of the energy dependence. After the tests, it was proved that the PDC can be used as a reference instrument and that the calibration must be performed in situ, so that the characteristics of each X-ray equipment, where the KAP meters are used, are considered. The calibration was then performed with portable KAP meters and in an interventional radiology equipment that has a KAP meter fixed. The results were good and it was proved the need for calibration of these meters and the importance of in situ calibration with a reference meter.

1- INTRODUCTION

The use of kerma area product (KAP) meters is essential to evaluate radiological doses in radiology procedures (INTERNATIONAL ATOMIC ENERGY AGENCY, 2007 and TOROI, KOSUNEN, 2010). The KAP is usually measured using an ionization chamber and this ionization chamber is mounted at the radiation beam output, after the beam collimator covering the whole radiation field.

To work accurately, KAP meters must have an appropriate calibration. The methods used for calibrating KAP meters are: in laboratory, using a reference ionization chamber and using a reference KAP meter. Some KAP meters are coupled to the X-ray equipment, so they can't be calibrated at the laboratory, just in situ. The calibration with a reference KAP meter is effective because it is performed in the X ray equipment that the KAP meter is used so it is possible to

keep the same beam geometry as used with patients and also consider specific characteristics of extra focal and scattering radiation from the X ray equipment (TOROI *et al*, 2008)

This study developed a calibration methodology and tests of KAP meters using the Patient Dose Calibrator (PDC) as reference. This instrument was developed by Radcal (RADCAL CORPORATION, 2009) to calibrate KAP meters used in patient dosimetry.

2- METHODOLOGY

2.1- Materials

Reference materials

1) PDC

2) Ionization chamber model RC6 from Radcal which presents rastreability to a Primary Laboratory.

Tested Instruments

A) KAP meter model Diamentor E2 from PTW dosimetry and X radiation system model Philips 500 VMI

B) KAP meter model KermaX plus TinO (two in one) 120-205 from IBA dosimetry and X radiation system model RAEX 300D

C) KAP meter model Diamentor E2 from PTW dosimetry and X radiation system model EDR 750B

Figure 1 shows the equipments.



Figure 1: In 1 the Patient Dose Calibrator; 2 the ionization chamber RC6; A the KAP meter Diamentor E2; B the KAP meter KermaX plus TinO 120-205 and C another KAP meter Diamentor E2

2.2- Methods

At first, the quality control program of the PDC was performed to verify its proper operation. It was performed using the standards BS EN 61674:1998 IEC 61674:1997 (INTERNATIONAL ELECTROTECHNICAL COMMISSION, 1997) and IEC 60580 (INTERNATIONAL ELECTROTECHNICAL COMMISSION, 2000). The items analysed were: relative intrinsic error; repeatability; resolution of reading; stabilization time; reset; leakage current; drift of indicated values, response time and spatial uniformity of response. Then, the energy dependence (COSTA, POTIENS, 2013) of the PDC was also evaluated as well as the PDC performance for mammography radiation qualities (COSTA, POTIENS 2011).

After verifying the good performance of the PDC, it was necessary to calibrate it. This calibration was performed using an ionization chamber model RC6 as reference and following the code of practice TRS 457 (INTERNATIONAL ATOMIC ENERGY AGENCY, 2007). Initially, the kerma rate was measured for all beam qualities with the chamber positioned 1 m from the X ray source and a lead aperture of 4 cm² positioned 9 cm ahead the chamber (0,91 m from the X ray source). The values were corrected and equation 1 found the $N_{PKA,Q}$ using the distance chamber-source (1 m) as d_r and the distance aperture-source (0,91 m) as d_a and divided by the PDC readings that were measured under the same conditions as the chamber RC6. The correction factors were found dividing the $N_{PKA,Q}$ of each radiation quality by the $N_{PKA,Q}$ of the quality reference.

$$N_{PKA,Q} = \frac{KA(d_r/d_a)^2}{M_{PKA}k_{TP}^{PKA}}$$

Finally, the calibration of KAP meters using the PDC as reference was carried out in three different clinical systems. The method used was the tandem method (TOROI, KOSUNEN, 2010) where the KAP meter and the reference KAP meter are irradiated at the same time. Figure 2 illustrates the tandem method. Table 1 shows the irradiation conditions for all laboratories. The measurements were carried out according to the limitations of each equipment. The uncertainties type A and B were considered for the measurements.

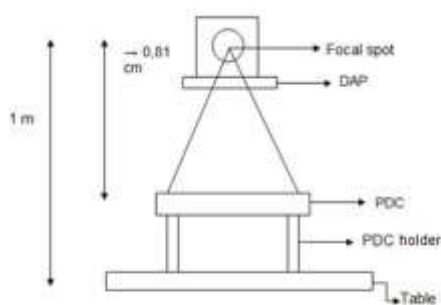


Figure 2: Setup of KAP meter calibration using the PDC

Table 1: Irradiation conditions for KAP calibration

Irradiation Conditions for Portable KAP meters			
	A	B	C
Voltagess (kV)	50, 70, 100, 120	50, 70, 90	50, 70, 90
Distance (m) (with and without the holder)	1/0,81	0,90 /0, 71	1/0,81
Field size (cm ²)	10, 20, 30	10, 20, 30	10, 20, 30
Current (mA)	200	100	50
Time (s)	0,1	0,225	0,08

The calibration of a KAP meter that is coupled to an interventional radiology system was also performed using the tandem method. Figure 3 shows the setup of the method.

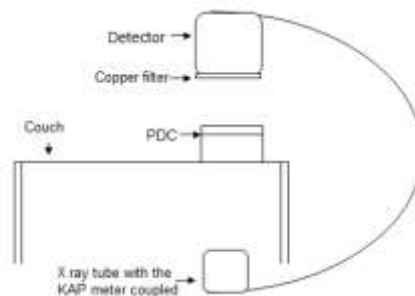


Figure 3. Setup of the DAP calibration that is coupled to an interventional system

3- RESULTS

Table 2 shows the results for the quality control program performed with the PDC. The results confirm that the PDC works according to the recommendations. Table 3 shows the calibration coefficient and the quality correction factor found with the calibration of the PDC, following the code of practice TRS 457 (INTERNATIONAL ATOMIC ENERGY AGENCY, 2007). This calibration allowed the PDC to be used as reference to calibrate other KAP meters.

Table 2. Performance characteristics, limits by IEC 61674 and IEC 60580, and the results from the PDC

IEC 61674 + IEC 60580					
Characteristics	Radiation Qualities	Limits (%)	Obtained values (%)		
Relative intrinsic error	RQR3	±25	±0,2		
	RQR5	±35	±1,1		
	RQR8	±5	±5		
	RQR10	±5	±0,7		
Repeatability		Rate Accum	Rate Accum		
	RQR3	±3	±2,5	±2,13	±2,25
	RQR5	±3,5	±2,56	±1,85	±2,08
	RQR8	±3,5	±2,47	±3,01	±2,4
	RQR10	±3	±2,32	±2,36	±1,34
Resolution of reading	RQR3		±0,12		
	RQR5		±0,05		
	RQR8		±0,44		
	RQR10		±0,04		
Stabilization time	All	±2	All 0		
Reset	All	±1	All 0		
Leakage current	All	±5	All 0		
IEC 60580					
Drift of indicated values	All	Smaller than 10% for at least 1 hour	No change		
Response time	All	Within 3 seconds, 90% of the final value	Less than 2 seconds		
Spatial uniformity of response	All	±5%	0		

Table 3. Calibration coefficient and correction factors of the PDC

Nota: 1,018 ± 0,007 Gy.m²/s.u.

Radiation qualities	Voltage (kV)	Half-value layer (mmAl)	Correction factor K _Q
RQR 3	50	1,78	1,03
RQR 5	70	2,58	1
RQR 8	100	3,97	0,97
RQR 10	150	6,57	0,94

s.u.: scale unit

Figure 4 shows the energy dependence of the PDC. The maximum variation found was 6% and IEC 60580 recommends an energy dependence to be up to 8%.

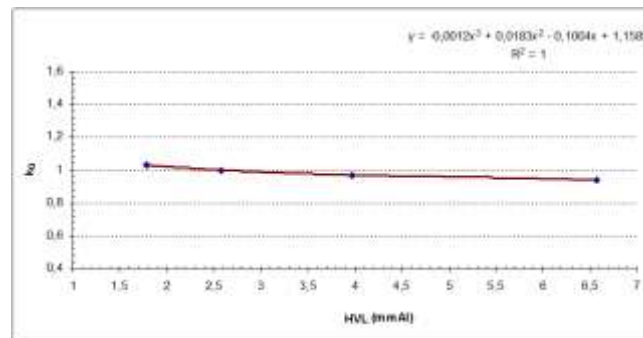


Figure 4: Energy dependence of the PDC

Table 5 shows the calibration coefficient of different KAP meters used in this study. For the KAP meter A the highest variation was 16% for a 10 x 10 cm field. For C, the highest variation found was 11% for a 10 x 10 cm field and for B the highest variation found was 42% for measurements performed without the holder in a 10 x 10 cm field and 26% for measurements performed with the holder for a 10 x 10 cm field.

Table 5. Calibration coefficients found for KAP meters

KAP meter	Voltages	Calibration Coefficient (N _k)					
		Field size 10 cm	Field size 20 cm	Field size 30 cm	With holder 10 cm	With holder 20 cm	With holder 30 cm
A	50kV	0.92	1.05	1.05	*	*	*
	70kV	0.84	0.94	1.00	*	*	*
	100kV	0.86	0.98	1.02	*	*	*
	120kV	0.87	1.01	1.05	*	*	*
B	50kV	1.40	1.42	1.21	1.26	1.21	1.00
	70kV	1.27	1.36	1.16	0.92	1.08	1.10
	90kV	1.19	1.37	1.18	1.11	0.90	1.16
C	50kV	*	*	*	0.99	1.08	1.06
	70kV	*	*	*	0.94	0.97	1.01
	90kV	*	*	*	1.10	0.96	0.89

Table 6 shows the results of the calibration of a KAP meter that is coupled to an interventional system. It must be said that the couch attenuation was considered in this measurements to be 30%, according to TRS 457 and to the half-value layer.

Table 6. Measurements performed at an interventional system with the DAP coupled to it

Voltage (kV)	Current (mA)	PDC ($\mu\text{Gy}\cdot\text{m}^2$)	DAP ($\text{mGy}\cdot\text{cm}^2$)	HVL (mmAl)	N _k
80	6.6	20.12 ± 0.1	277.4 ± 1.2	8.5	0.854

4- CONCLUSION

This study and the tests performed with the PDC show its metrological reliability. After going through quality control program and characterization tests, performance evaluations, calibrations and evaluation of the energy dependence, it proved to have an excellent functionality and that it can be used as reference to calibrate KAP meters, especially those that are coupled to an X-ray clinical system.

The quality control program must be done periodically in order to evidence its use as reference. The calibration coefficients found, varying between 0.84 and 1.42 show the necessity and importance of calibrating KAP meters.

The methodology application of the calibration performed in this study demonstrates the importance of correcting the measurements that are carried out with KAP meters.

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