# DEVELOPMENT OF A QUALITY CONTROL PROGRAM OF THE PATIENT DOSE CALIBRATOR

Nathalia Almeida Costa and Maria da Penha A. Potiens

*Instituto de Pesquisas Energéticas e Nucleares, IPEN – CNEN/SP, Brasil*

**Abstract** The kerma-area product (PKA) is a useful quantity to establish the reference levels in diagnosis of conventional X ray examinations. The PKA can be obtained by the use of the kerma-area product meter (KAP) which monitors the patient's exposure during the exam. It is important to use one reference KAP meter to obtain a reliable quantity of doses on the patient. The Patient Dose Calibrator (PDC) is new equipment from Radcal that measures PKA. The aim of this paper was to establish a quality control program of the PDC based on the British Standard BS EN 61674: 1998 IEC 61674: 1997 – Medical electrical equipment – Dosimeters with ionization chambers and/or semi-conductor detectors as used in X Ray diagnosis imaging in its chapter 5 (The Limits of Performance Characteristics). The measurements were performed in four radiation qualities in radiation beams emerging from the X Ray Source Assembly (RQR) at the *Laboratório de Calibração de Instrumentos* (LCI). The measurements done are within the required limits for the Standard studied. Although the Standard does not mention this kind of equipment, the PDC proved its good function in the characterization tests of a dosimeter with ionization chamber. These tests are an important tool for future studies with the PDC like the possibility of using this device to calibrate KAP meters.

Keywords: *Kerma-area product, Patient Dose Calibrator, Quality Control Program, Performance Characteristics.*

**Resumo**. O produto kerma área-(PKA) é uma grandeza útil para estabelecer os níveis de referência no diagnóstico de exames de raios X convencionais. O PKA pode ser obtido pela utilização do medidor de produto kerma área-(KAP) que monitora a exposição do paciente durante o exame. É importante utilizar um medidor KAP referência para se obter uma quantidade confiável de doses sobre o paciente. O *Patient Dose Calibrator* (PDC) é um equipamento novo da Radcal que mede PKA. O objetivo deste trabalho foi criar um programa de controle de qualidade do PDC com base na norma britânica BS EN 61674: 1998 IEC 61674: 1997 - *Medical electrical equipment – Dosimeters with ionization chambers and/or semi-conductor detectors as used in X Ray diagnosis imaging* em seu capítulo 5 (*The Limits of Performance Characteristics*). As medidas foram realizadas em quatro qualidades de radiação em feixes de radiação que emergem da fonte de raios X (RQR) no Laboratório de Calibração de Instrumentos (LCI). As medidas feitas estão dentro dos limites necessários para a norma estudada. Embora a norma não menciona este tipo de equipamento, o PDC comprovou sua boa função em testes de caracterização de um dosímetro com câmara de ionização. Estes testes são uma ferramenta importante para estudos futuros com o PDC, como a possibilidade de utilizar este dispositivo para calibração de medidores KAP.

Palavras-chave: Produto Kerma-área, *Patient Dose Calibrator,* Programa de Controle de Qualidade, Características de desempenho.

---

## 1. Introduction

The kerma-area product (PKA) 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. 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, thus, according to Equation 1:

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

Unit: J.kg$^{-1}$.m2. If the special name gray is used, the unit of air kerma–area product is 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 interactions in air and extra focal radiation can be neglected), as long as the planes of

measurement and calculation are not so close to the patient or phantom that there is a significant contribution from backscattered radiation. It is a good indicator of stochastic risk and correlates with operator and staff dose.[1,2,3]

The PKA can be obtained by the use of the kerma-area product meter (KAP) which monitors the patient's exposure during the exam. It is important to use one reference KAP meter to obtain a reliable quantity of doses on the patient. A PKA meter can be calibrated in laboratory or in situ, where it is used. However, in general, the PKA chamber is fixed to the X ray equipment which means that it can't be calibrated in a laboratory, just in situ. [3,4]

Thus, the calibration is usually done in situ using the PKA quantity obtained from the measurements of the air kerma with a reference ionization chamber and the irradiated area exposed on the film positioned in the same distance as the chamber. [4]

The Patient Dose Calibrator (PDC) is new equipment from Radcal that measures PKA. It was manufactured following the IEC 60580 recommendations. [5] Its rated range of use for the tube voltage is between 40 kV and 150 kV, but studies have shown that measurements can be done under 40kV. [6]

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 to have smaller energy dependence. There are few studies about the use of the PDC as it is a new device. [6,7,8,9,10,11]

Based on the British Standard BS EN 61674: 1998 IEC 61674: 1997, the quality control program of the PDC is being developed to ensure that this device is reliable and to show that it can be used to calibrate KAP meters. [12]

From this Standard, tests were done according to the Limits of Performance Characteristics (chapter five) in this study.

## 2. Materials and Methods
### 2.1. Materials
#### 2.1.1. Patient dose calibrator (PDC)

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. [11]



Figura 1. Patient Dose Calibrator.

#### 2.1.2. X Radiation system

The X Radiation system used was a Pantak/Seifert located at the LCI, with a voltage up to 160 kV, a tungsten target, a constant potential, an inherent filtration of 0.138 mmAl and a 0.8 mm beryllium window. The Figure 2 shows the X Radiation system.
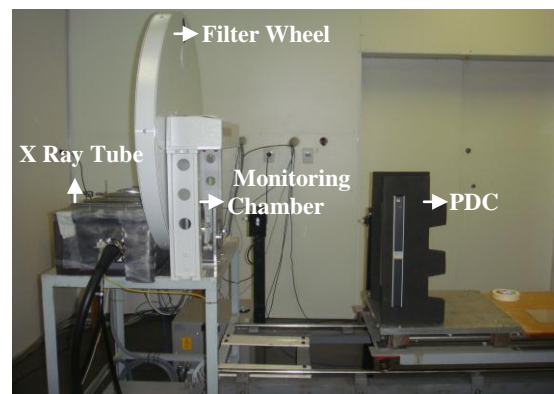


Figure 2. X Radiation system Pantak/Seifert

### 2.2. Methods

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 current of 10 mA, distance of 1 meter, irradiations of 30 seconds and five irradiations for each energy. The temperature and pressure were automatically adjusted by the PDC. Figure 3 shows the PDC properly positioned.



Figure 3. Position of the PDC on the X Ray Beam

The measurements were performed in four radiation qualities in radiation beams emerging from the X Ray Source Asselmbly (RQR) at the

*Laboratório de Calibração de Instrumentos* (LCI). The four RQR used (3, 5, 8 and 10) corresponding to 50 kV, 70kV, 100kV and 150kV respectively, were established at the LCI in a study performed at the *Instituto de Pesquisas Energéticas e Nucleares* (IPEN) in Brazil in 2010, which follows the IEC 61267 regulation.[13]

This study used The British Standard BS EN 61674: 1998 IEC 61674: 1997 to qualify the PDC. The measurements were done according to the following items that matched to the standard: [12]

• Relative intrinsic error: comparing the measurements to the standard test conditions with the average of at least five readings of the instrument.

• Repeatability: make repetitions with the measurements under unaltered conditions.

• Resolution of reading: reading the whole effective range of indicated values.

• Stabilization Time: switching on the instrument and verifying the limits of variation response.

• Reset: resetting the instrument and checking the full scale reading.

• Effects of Leakage Current: level of leakage current after any compensation adjustment.

The Relative Intrinsic Error and the Repeatability are calculated according to the Air Kerma value, as it is shown in Table 1 below:

Table 1: Range of measurement and its form of calculation

| Relative Intrinsic Error | $K < 1$ µGy $I = \pm (10-5k)\%$ | |
|---|---|---|
| Repeatability | Air Kerma Rate | |
| | $K < 1$ µGy/s | $1,11(4.7-2K)\%$ |
| | $K \geq 1$ µGy/s | $3\%$ |
| | Air Kerma | |
| | $K < 10$ µGy | $0.1667(16-K)\%$ |
| | $K \geq 10$ µGy | $1\%$ |

Another measurement checked with the PDC was the variation of the area. It was used three different areas of 25 cm² (squared) and 113,04 cm² and 221,55 cm² (circular).

## 3. Results

The British Standard BS EN 61674: 1998 IEC 61674: 1997 shows the limits of performance characteristics for dosimeters with ionization chambers used in X ray diagnosis imaging in its chapter 5. [12]

Using the obtained values from the measurements the characteristics included in Table 2, from the British Standard BS EN 61674:

1998 IEC 61674: 1997 were calculated. Table 2 also shows the maximum percentage of each characteristic which are the limits that each one can reach to be accepted as a detector used in X ray diagnosis imaging.

Table 2: Characteristics studied and its limits

| Characteristics | RQR | Limits (%) | |
|---|---|---|---|
| Relative Intrinsic Error | RQR3 | 8.25 | |
| | RQR5 | 6.95 | |
| | RQR8 | ±5 | |
| | RQR10 | ±5 | |
| | | Rate | Acc |
| Repeatability | RQR3 | 4.83 | 2.6 |
| | RQR5 | 4.52 | 2.56 |
| | RQR8 | 3.95 | 2.47 |
| | RQR10 | 3 | 2.32 |
| Resolution of Reading | All | ≤1 | |
| Stabilization Time | All | ±2 | |
| Reset | All | ≤1 | |
| Effects of Leakage Current | All | ≤5 | |

After knowing the limits of each item, the characteristics were evaluated for the PDC with tests of quality control, as it is a dosimeter with ionization chambers. Table 3 shows the percentage found for every characteristic analyzed in this study.

Table 3: Obtained percentage for the PDC after quality control tests.

| Characteristics | | RQR 3 (%) | RQR 5 (%) | RQR 8 (%) | RQR 10 (%) |
|---|---|---|---|---|---|
| Relative Intrinsic Error | | 6.02 | 4.1 | 1.5 | 1.87 |
| Repeatability | Rate | 2.13 | 1.85 | 3.01 | 2.36 |
| | Acc. | 2.25 | 2.09 | 2.4 | 1.34 |
| Resolution of Reading | | 0.12 | 0.05 | 0.44 | 0.64 |
| Stabilization Time | | 0 | 0 | 0 | 0 |
| Reset | | 0 | 0 | 0 | 0 |
| Effects of Leakage Current | | 0 | 0 | 0 | 0 |

Comparing the air kerma rate to the different areas measured, it was found a linear behaviour in the measurements.

## 4. Discussão e Conclusões

This study had the aim to make a quality control program of a new instrument in the

market called Patient Dose Calibrator that measures PKA and Air Kerma.

The British Standard BS EN 61674: 1998 IEC 61674: 1997 was the document that was used to evaluate the PDC characteristics.

Comparing the values of table 3 to table 2, the measurements done are within the required limits for medical electrical equipment – dosimeters with ionization chambers used in X ray diagnosis imaging.

Although the Standard studied does not mention this kind of equipment, the PDC proved its good function in the characterization tests of a dosimeter with ionization chamber. These tests are an important tool for future studies with the PDC like the possibility of using this device to calibrate KAP meters.

Thus, the importance of this study is that the measurements taken in accordance to the standard will be done periodically to testify its performance before making it an instrument to calibrate KAP meters.

## References

1. INTERNATIONAL ATOMIC ENERGY AGENCY. Dosimetry in diagnostic radiology: an international code of practice. Technical Reports Series N° 457, IAEA, Vienna, 2007.
2. INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS. Patient Dosimetry for X Rays Used in Medical Imaging. Rep. 74, ICRU, Bethesda, MD (2006).
3. INTERNATIONAL ATOMIC ENERGY AGENCY. Establishing guidance levels in X ray guided medical interventional procedures: a pilot study. Safety Reports Series N° 59, IAEA, Vienna, 2009.
4. CANEVARO LV. Aspectos Físicos e Técnicos da Radiologia Intervencionista. Rev Bras Fis Med. 2009; 3(1): 101-15.Heshmati HM, Hofbauer LC. Multiple endocrine neoplasia type 2. Eur J Endocrinol 1997; 137(6):572-8.
5. INTERNATIONAL ELECTROTECHNICAL COMMISSION. Medical electrical equipment – Dose area product meters. IEC 60580, Second edition, Geneva, Switzerland, 2000.
6. COSTA, N.A., CORREA, E. L., POTIENS, M.P.A. Performance Evaluation of a Kerma-area meter in the mammography radiation qualities. International Nuclear Atlantic Conference. Belo Horizonte, 2011.
7. ALMEIDA JN et all. Estudo da calibração indireta de medidores clínicos do produto kerma-área. Rev Bras Fis Méd. 2011; 44(3):75-8.
8. TOROI P, KOSUNEN A. The energy dependence of the response of a patient dose calibrator. Phys.Med.Biol. 54: (2009) N151-N156.
9. TOROI P, KOSUNEN A. Calibration of kerma-area product meters with a patient dose calibrator. Book of Extended Synopses Standards, Applications and Quality Assurance in Medical Radiation Dosimetry, IDOS, Vienna, Austria, 2010.
10. HETLAND P O et all. Calibration of reference KAP-meters as SSDL and cross calibration of clinical KAP-meters. Acta Oncologica. 48:289-294, 2009.
11. RADCAL CORPORATION. Manual os Instructions. Monrovia, CA, 2009. <http://www.radcal.com/PDC.html>
12. BRITISH STANDARD. Medical electrical equipment-Dosimeters with ionization chambers and/or semi-conductor detectors as used in X-ray diagnosis imaging. BS EN 61674 : 1998 IEC 61674 : 1997
13. FRANCISCATTO P.C. . Caracterização das qualidades de radiação X seguindo as recomendações da norma IEC 61267 no laboratório de calibração do IPEN. Master Thesis - Instituto de Pesquisas Energéticas e Nucleares, Universidade de São Paulo, São Paulo. (2009).

**Contato:**
Nathalia Almeida Costa
*nathaliaac@ymail.com*

Maria da Penha A. Potiens
*mppalbu@ipen.br*