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Evaluation of the voltage quantities measured with different noninvasive meters for quality control at a calibration laboratory

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ABSTRACT

In this work the peak kilovoltage (kVp), practical peak voltage (PPV) and air kerma rate were measured with the noninvasive meters Radcal Accu-kV® Diagnostic Sensor™ model 40 × 12-W, and PTW Diavolt. The results were compared in order to ensure the quality control, compare the meters and establish the new quantity PPV, at the Calibration Laboratory of IPEN. These tests were performed using the standard diagnostic radiology quality beam RQR5, and the results are in good agreement.

1. Introduction

Quality control of X-ray equipment is necessary to ensure accurate and safe operation. A quality control program applied to X-ray equipments is necessary in calibration laboratories, hospitals and clinics. This program helps to assure a high quality of services, such as the calibration of portable detectors used in radioprotection, and calibration of dosimetric systems used in diagnostic radiology.

One of the most important parameters in the quality control is to verify the tube voltage, because this parameter strongly influences the dose given to patients and the exposure of the image receptor. The tube voltage is responsible for the equipment performance and the minimum dose to patients submitted to X-ray exams. Therefore, the tube voltage measurement is essential in optimization of patient doses, quality assurance and radiation protection (IAEA, 2007; Toroi et al., 2008).

The measurement of the X ray tube and generator voltage cannot be rigorous because the term itself is not consistently defined (Hourdakis, 2011). There are some definitions of this voltage that are largely used, but these quantities are ambiguous or have no relation to the properties of the radiological image. Thus a new quantity that is recently being used at Laboratories, the practical peak voltage (PPV), has been proposed by Kramer and collaborators (IAEA, 2007; Kramer et al., 1998). The PPV is defined as the constant potential producing the same contrast as the waveform under test (IEC, 2005). It has the advantage of being a quantity that can be measured and standardized by any laboratory (IAEA, 2007).

Nowadays, the PPV quantity is recommended by the IEC 61267 (IEC, 2005) and the International Atomic Energy Agency (IAEA, 2007) as a standard of the voltage applied to X-ray tubes in the characterization of X-ray beams used for the calibration procedures.

The objective of this work was to compare measurements of kVp, PPV and air kerma rate using two types of non-invasive meters.

2. Materials and methods

All experiments in this work related to kVp, PPV and air kerma rate were performed using a Pantak/Seifert X-ray system, model MXR-160/22 (constant potential) of the Calibration Laboratory of IPEN (LCI). The standard diagnostic radiology radiation quality RQR5 (70 kV; 2.8 mmAl of additional filtration; (37.88 ± 0.32) mGy/min) was utilized (IEC, 2005). This radiation quality is used as one of the reference radiation qualities at the LCI, and it was established utilizing a parallel plate ionization chamber with 1.0 cm^3 of sensitive volume, PTW, model 77334. This ionization chamber was calibrated at the German primary standard laboratory Physikalisch-Technische Bundesanstalt (PTB).

The non-invasive meters used during the measurements were a PTW Diavolt and a Radcal Accu-kV® Diagnostic Sensor™ model 40 × 12-W (Fig. 1).

For the measurements, the meters were positioned at the distances of 0.5, 1, 1.5, 2 and 2.5 m, while all the other parameters remained fixed, including the tube current (10 mA). In this test 10 measurements were taken at each distance.

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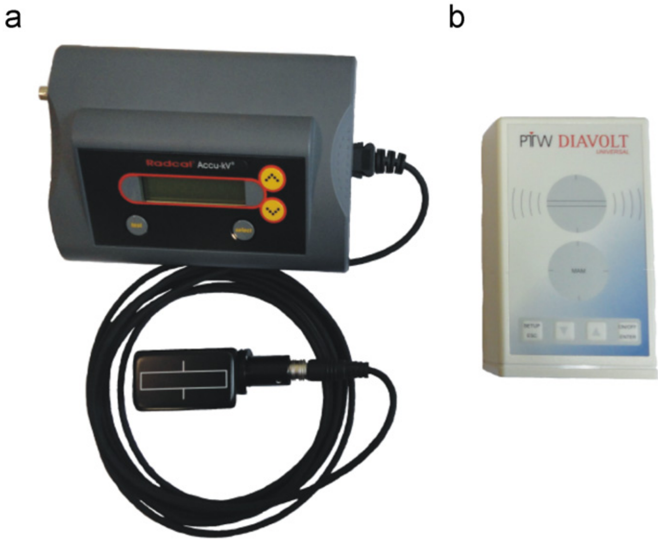

Fig. 1. Non-invasive meters utilized in this work: Accu-kV® (a) and Diavolt (b) equipments.

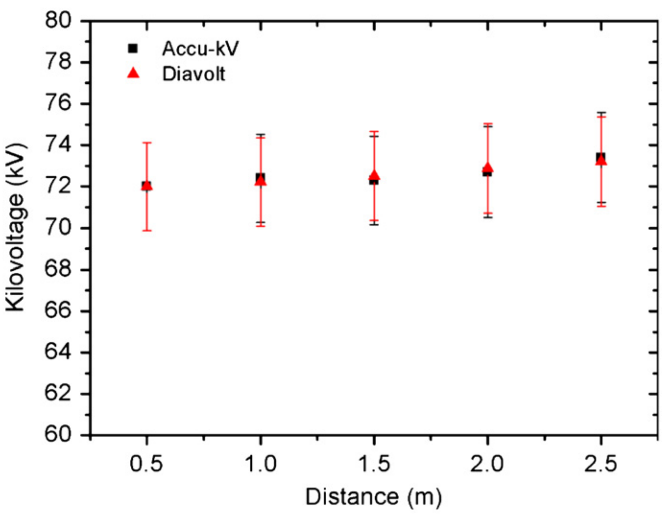

Fig. 2. Kilovoltage as a function of the distance between focal point and meter for the Accu-kV® and Diavolt equipments.

The mean values and their associated mean standard deviations were calculated from the 10 sequential measurements. For each distance, the air kerma rate, kVp and PPV measurements were obtained, and the results compared. In order to evaluate the kVp values, the results were compared with the measurements taken with a spectrometer, which is a primary standard method for determining the peak kilovoltages.

A spectrometric system, EG&G Ortec, model NOMAD-PLUS 92X, using a high purity germanium semiconductor detector (HPGe) model GLP-16195/10P was utilized in this work (Lucena et al., 2010).

3. Results and discussion

The kilovoltage was measured as a function of distance, and the results are presented in Fig. 2. The maximum difference between the results of the two meters was only 0.3% (Table 1). Comparing the results obtained with the meters and the nominal applied voltage, the maximum difference was 4.6%, for the Accu-kV® at 2.5 m. At the calibration distance (1.0 m), the difference between the measured and the nominal applied voltage (70.0 kV) was 3.3% for the Accu-kV® and 3.0% for the Diavolt.

Table 1
Mean values of the kilovoltage (kVp), measured with the Accu-kV® and Diavolt meters.

Distance (m)	kVp (kV)		Difference (%)
	Accu-kV®	Diavolt	
0.5	72.0 ± 2.1	72.0 ± 2.1	0
1.0	72.4 ± 2.1	72.2 ± 2.1	0.3
1.5	72.3 ± 2.1	72.5 ± 2.1	0.3
2.0	72.7 ± 2.2	72.9 ± 2.1	0.3
2.5	73.4 ± 2.2	73.2 ± 2.2	0.3

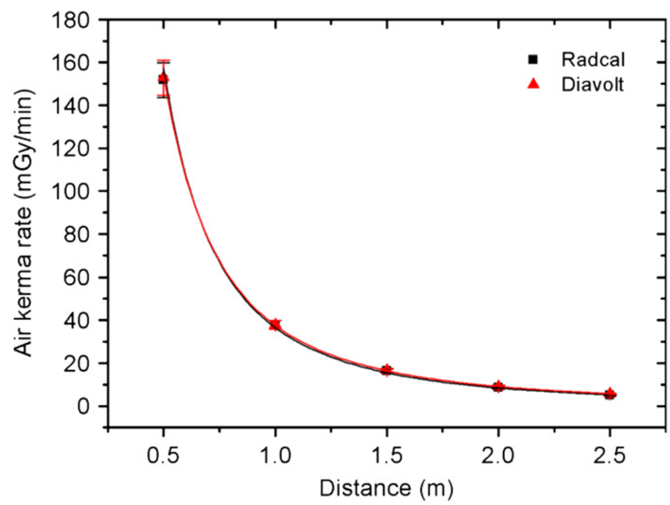

Fig. 3. Air kerma rate as a function of the distance between the focal point and the meter in the cases of the Accu-kV® and Diavolt equipments.

Table 2
Mean values of the dose rates, measured with the Accu-kV® and Diavolt meters.

Distance (m)	Air kerma rate (mGy/min)		Difference (%)
	Accu-kV®	Diavolt	
0.5	151.8 ± 8.1	152.8 ± 8.1	0.7
1.0	37.9 ± 2.0	37.9 ± 2.0	0
1.5	16.5 ± 0.9	16.7 ± 0.9	1.5
2.0	8.5 ± 0.5	9.2 ± 0.5	6.9
2.5	5.0 ± 0.3	5.7 ± 0.3	12.5

The kVp obtained with the spectrometric measurements was (71.3 ± 1.1) kV. Comparing this result with the data of Table 1, it is possible to observe that the maximum difference, at the calibration distance (1.0 m), is 1.5% for the Accu-kV® and 1.3% for the Diavolt meters.

The results for air kerma rates as a function of distance are shown in Fig. 3 and Table 2. The results were obtained using the reference ionization chamber, PTW, model 77334.

The values are within the theoretical prediction (inverse square law). For the Accu-kV® the exponent is (-2.11 ± 0.04), and for the Diavolt, (-2.04 ± 0.01). The results obtained experimentally and by the theoretical prediction are in good agreement, with a small difference, very probably due to the air column between the detector and the focal spot of the X ray unit that attenuated the radiation field intensity.

The results of the PPV as a function of distance are shown in Table 3. The maximum difference between the measurements

Table 3
Mean values of the practical peak voltage, PPV, measured with the Accu-kV® and Diavolt meters.

Distance (m)	PPV (kV)		Difference (%)
	Accu-kV®	Diavolt	
0.5	71.8 ± 1.9	71.8 ± 2.1	0
1.0	72.0 ± 1.9	71.7 ± 2.1	0.4
1.5	71.9 ± 1.9	71.7 ± 2.1	0.3
2.0	72.2 ± 1.9	71.8 ± 2.1	0.5
2.5	72.9 ± 1.9	71.8 ± 2.1	1.5

Table 4
Difference between kVp and PPV, measured with the Accu-kV® and Diavolt meters.

Distance (m)	Difference between kVp and PPV (%)	
	Accu-kV®	Diavolt
0.5	0.3	0.3
1.0	0.6	0.7
1.5	0.6	1.1
2.0	0.7	1.5
2.5	0.7	1.9

obtained with the kV meters was 1.5%, for a distance of 2.5 m. At the calibration distance (1.0 m), the difference was only 0.4%.

The differences between the kVp and PPV values are shown in Table 4. The differences are low for both meters, showing that, even with differences in their software and geometry, they are very precise in determining the new PPV quantity.

4. Conclusions

A quality control program of X-ray equipment is essential to ensure reliable calibration procedure of radiation detectors. In this work, the PPV quantity was established at LCI, utilizing two different non-invasive kVp meters. The results were in good agreement between these meters, for the kVp, air kerma rates and PPV quantities. At the calibration distance, there was a difference of only 0.3% for the kVp, and 0.4% for the PPV, between the meters. The maximum difference, in kVp, between the meters and the spectrometric results was 1.5% for the Accu-kV® and 1.3% for the Diavolt equipments. The air kerma rate values showed good agreement with the theoretical prediction. Increasing the distance between the focal point and the meter, the air kerma rate decreased exponentially while the PPV and the kVp maintained their values constant. The results were within the predictions, and the PPV and the kVp presented a variation of 0.6% for the Accu-kV® and of 0.7% for the Diavolt, at the calibration distance (1.0 m). Considering the nominal voltage, applied to the X-ray tube, the differences were 3.3% and 3.0% for the Accu-kV® and Diavolt meters, respectively. Both meters were very precise and easy to handle.

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