A comparison between two Brazilian calibration systems for diagnostic radiology level

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Abstract: A very important step in a quality control program, at calibration laboratories, is the establishment of laboratory intercomparisons. In this work, a comparison between the calibration laboratories of IPEN/CNEN-SP and CDTN/CNEN-MG was carried out, as part of the quality control program in the metrological network established by the project "*National Institutes of Science and Technology - Radiation Metrology in Medicine*". The comparisons were undertaken for direct and attenuated diagnostic radiology quality beams RQR and RQA. The results showed a good agreement between both calibration laboratories.

Keywords: Laboratory intercomparison, Diagnostic radiology, Quality control program, PPV

1. INTRODUCTION

According to the UNSCEAR (2008), medical exposures contribute about 20% of the average annual per caput dose to the global population. Annually there are approximately 3.1 billion diagnostic medical radiological examinations. Therefore, it is very important to maintain and develop a quality control program for the maintenance and verification of x-ray machines. Besides the quality control programs established at clinics, it is also very important to establish a permanent and effective quality control program at calibration laboratories. They are responsible for the calibration of the dosimeters that will be used in medical equipment dosimetry.

One of the steps for an effective quality control program is the comparison between results of laboratories, by using itinerant standards. Dosimetry intercomparisons are essentially designed to establish the accuracy and precision of dosimetric procedures at a given level in the metrology chain and to assess consistency among centres.

In this work, two laboratories, the Laboratory for Calibration of Instruments of the Nuclear and Energy Research Institute (LCI at IPEN/CNEN-SP) and the Laboratory for Calibration of Dosimeters of the Development Center of Nuclear Technology (LCD at CDTN/CNEN-MG), both part of the Brazilian Commission of Nuclear Energy, compared their direct and attenuated radiation beam qualities, diagnostic radiology level. Both laboratories are part of the project "*National Institutes of Science and Technology in Radiation Metrology in Medicine*", Brazil (INCT/MRM). One of the main goals of

this program is the establishment of a national radiation metrology network for the quality control assurance at calibration laboratories.

The LCI is a calibration laboratory responsible for the calibration of dosimeters utilized in diagnostic radiology, radiotherapy, radioprotection, beta applicators and also for the development of new radiation detectors [PERINI *et al*. (2014)]. Although the LCI is not part of the IAEA/SSDL network, there are several reference standards calibrated at primary standard laboratories as the Physikalisch-Technische Bundesanstalt (PTB), Germany, and the Bureau International des Poids et Mesures (BIPM), France. Furthermore, the LCI has a high demand in calibrating radiation detectors. With this high demand of calibration services, an effective and continuous quality control program was already established.

The LCD is a calibration laboratory located at Belo Horizonte, Brazil, that offers calibration services of radiation detectors utilized for dosimetry in diagnostic radiology and radioprotection. As the LCI, the LCD also belongs to the Brazilian network of calibration laboratories; it maintains reference standard dosimeters traceable to the Brazilian secondary standard dosimetry laboratory - LNMRI, at the Instituto de Radioproteção e Dosimetria (IRD), Rio de Janeiro, Brazil. The LDC provides the metrological framework for radiation beam dosimetry for regulatory and research purpose [CAMPOS *et al*. (2011)].

Due to the fact that the practical peak voltage (PPV) is an unambiguous measuring quantity, it may be traceable to national electrical standards, and it may be standardized. These characteristics turned out this quantity as a parameter of comparison of x-ray tube voltages among calibration laboratories. The PPV attends the main characteristics of a measurable standard quantity for x-ray tube voltages [IAEA (2007)]: capability to define a reproducible physical method for voltage measurement; easy measurement technique; clinical relevance of the definition; and relevancy to technical aspects of the x-ray system and parameters.

The main goal of this work was to compare the x-ray parameters for the direct and attenuated radiation beam qualities of both calibration laboratories in their quality control programs. This comparison was carried out in terms of the determination of the air kerma calibration factors (N_k) of the two itinerant standards and through the PPV quantity.

2. MATERIALS AND METHODS

The equipment at IPEN is an industrial x-ray unit, Pantak Seifert, model ISOVOLT 160HS. It operates from 5 to 160 kV, and has a 0.8 mmBe window thickness. The equipment at LCD is also an industrial Pantak Seifert x-ray unit, but model ISOVOLT 320HS that operates from 5 to 320 kV, with a 7 mmBe window thickness. Both present a W-anode angle of 21º.

The PPV quantity was measured directly with a non-invasive meter PTW, Diavolt Universal All-in-One QC meter model, which can be used in conventional radiology, computed tomography, fluoroscopy and mammography beams; for each one of these applications, it is possible to select a different target-filtration combination. The PPV quantity was established utilizing this non-invasive kV-meter in both calibration laboratories. This quantity was measured only for the RQR radiation qualities, because the filtration used at the LCD and LCI for the RQA was not available at the PPV meter.

For the calibration of the itinerant systems, the distances were set to 100.0 cm from the x-ray focus, which is the standard calibration distance for the diagnostic radiology qualities RQR and RQA. The characteristics of these qualities are listed in Table 1.

Table 1. RQR and RQA radiation qualities established at the LCI and LCD

Radiation Quality	Tube Voltage (kV)	LCI		LCD	
		HVL† (mmAl)	$\dot{K}_{air}$‡ (mGy/min)	HVL† (mmAl)	$\dot{K}_{air}$‡ (mGy/min)
RQR3	50	1.78	21.71±0.36	1.77	19.83±0.30
RQR5	70	2.58	37.49±0.63	2.60	31.47±0.47
RQR8	100	3.97	68.01±1.14	3.96	53.71±0.81
RQR10	150	6.57	118.08±1.97	6.48	97.49±1.46
RQA3	50	3.80	3.83±0.04	3.82	1.46±0.02
RQA5	70	6.80	3.60±0.01	6.77	1.59±0.02
RQA8	100	10.10	5.67±0.02	10.21	2.06±0.03

†Half-Value Layer; ‡Air Kerma Rate

The RQR and RQA radiation qualities where established at the LCI with a RADCAL RC6 ionization chamber, calibrated at the PTB. The RQR qualities at the LCD where established with a RADCAL RC6 ionization chamber and for the RQA qualities with a RADCAL RC60 ionization chamber, both calibrated at the LMNRI/IRD.

The systems used as itinerant standards were a RADCAL 10X5-6 ionization chamber linked to an electrometer RADCAL model 9015 for the RQR radiation qualities and a RADCAL RC60 ionization chamber linked to a Keithley model 6517A for the RQA radiation qualities, both from the LCI. All uncertainties presented in this work are expanded uncertainties of type A and B, using a coverage factor of 2.

3. RESULTS AND DISCUSSION

3.1. Determination of the air kerma calibration factors

The N_k of the itinerant ionization chambers were determined in order to compare the calibration systems, at LCI and LCD, for the RQR and RQA diagnostic radiology qualities. The RQRs were compared utilizing the Radcal 10X5-6 ionization chamber, and the RQAs were evaluated with the Radcal RC60 ionization chamber. All measurements were taken using the calibration conditions of each laboratory, with their own filtration and equipment.

The N_k values obtained for the RQR and RQA radiation qualities are shown in Table 2. Except for the RQA8 radiation quality, which presented a difference of only 1.0%, all values were within a difference of 3.0%. These results are satisfactory showing that both laboratories present similar radiation qualities.

3.2. Evaluation of the PPV quantity

For the determination of the PPV quantity, the diavolt equipment was positioned at 0.5 m from the x-ray tube focus. Due to the fact that the x-ray system of the LCI has a filter wheel, and a similar equipment was not available at the LCD, positioning the equipment directly outside the x-ray system would produce measurements at different distances from the focal spot. In order to maintain a fixed reference distance, under reproducible conditions, the diavolt equipment was used at a distance of 0.5 m. VIVOLO *et al.* (2012) determined the PPV quantity as a function of distance, and the results at 0.5 m and 1.5 m were within a difference of 0.4%. These results showed that the PPV may be determined at this distance without altering significantly the results.

Table 2. Comparison of the N_k and PPV values at the LCI and LCD laboratories

Radiation Quality	N_k		Difference (%)	PPV		Difference (%)
	LCI	LCD		LCI	LCD	
RQR3	0.991±0.018	0.964±0.015	2.7	51.7±1.5	51.7±1.3	0.02
RQR5	0.994±0.018	0.968±0.015	2.7	71.3±2.1	71.8±1.8	0.77
RQR8	1.006±0.019	0.975±0.016	3.0	101.4±3.0	101.7±2.5	0.34
RQR10	1.015±0.019	0.984±0.017	3.0	-	-	-
RQA3	0.949±0.013	0.921±0.014	2.9	-	-	-
RQA5	0.943±0.009	0.918±0.014	2.6	-	-	-
RQA8	0.932±0.009	0.923±0.014	1.0	-	-	-

The PPV values obtained are presented in Table 2 for the RQR3, RQR5 and RQR8 radiation qualities. The RQR10 radiation quality uses a tube voltage of 150 kV, which is beyond the upper limit detection of the Diavolt equipment. The highest difference was 0.77% for the RQR5 radiation quality, showing that both irradiation systems are very similar.

4. CONCLUSION

In this work, the calibration systems of two different laboratories were compared for the diagnostic radiology quality beams, RQR and RQA. This comparison was carried out by means of the determination of the N_k values of two itinerant standards for RQR and RQA radiation qualities, and of the PPV quantity for the RQR radiation qualities. The results obtained showed a maximum difference of 3.0% for the N_k values and of 0.77% for the PPV quantity. It is possible to conclude that both laboratories are within an acceptable range for their calibration systems, at diagnostic radiology level.

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