Quality Control Methodology and Implementation of X-radiation Standards Beams, Mammography Level, Following the Standard IEC 61267

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Abstract

A quality control program was developed and applied for the X-ray system (160 kV, constant potential, target of tungsten) of the Calibration Laboratory of IPEN (LCI) in the energy range relative to mammography beams (from 25 kV to 35 kV). The X radiation standards beams, mammography level, using molybdenum and aluminum as additional filtration, were established after the application of this quality control program following national and international recommendations. The reference ionization chamber has traceability to the Primary Standard Dosimetry Laboratory, PTB, and was regularly submitted to quality control tests for evaluation and analysis of its performance. The radiation qualities emerging from the X-radiation assembly (RQR-M), based on a phantom made up of an aluminum added filter (RQA-M), narrow beam condition (RQN-M) and broad beam condition (RQB-M), following the recommendations of the international standard IEC 61267 (2005) and the International Atomic Energy Agency, IAEA, code of practice, TRS 457 (2007) were established. For the implantation of RQN-M and RQB-M radiation qualities, a mammography phantom was developed. The half-value layers found are those presented by the German primary laboratory PTB, and varied from 0.35 mmAl to 1.21 mmAl. The air kerma rates were obtained for all the 15 implanted qualities.

Keywords : mammography, quality control, diagnostic radiology, calibration

1. Introduction

Mammography is the breast radiography, which allows premature breast cancer detection, by the fact that it is capable to show injuries in an initial stage, very small[1]. It is made in an appropriate x-rays system, called mammograph. But, to obtain premature and trusted diagnostic, it is necessary that the mammograph be calibrated and working properly.

For this reason, a good quality control of these equipments is very important, especially in terms of the radiation generated by it. This control must be done using a special ionizing chamber, specific for mammography, which also must be calibrated.

The calibration of these instruments must be done periodically, in a laboratory with the proper equipments.

In Brazil, there are just a few laboratories have mammography qualities established in their systems. One of these laboratories is the Calibration Laboratory of IPEN (LCI), which calibrated, in 2009-2010 period, about 40 mammography ionizing chambers. And it is important to highlight that this number represents about 80 % of this kind of ionizing chambers in Brazil.

Thinking is this has been made this study, which the objective is to establish mammography qualities at LCI X-rays calibration system, which is provided with a tungsten (W) target, according to the new international standard IEC 61267, “Medical diagnostic X-ray equipment – Radiation conditions for use in the determination of characteristics”, by the International Electrotechnical Commission (IEC)[2], and the International Atomic Energy Agency (IAEA) code of practice, Technical Report Series No. 457, “Dosimetry in Diagnostic Radiology: An International Code of Practice”[3].

Furthermore, it is expected to provide knowledge so future studies could be developed in this area, since there are only a few laboratories in Brazil that has mammography qualities established in their systems.

2. Materials and Methods

The X-ray system is a Pantak/Seifert, with tungsten (W) target. The tube has an inherent filtration of 0.138 mm of aluminium and a window of 0.8 mm of beryllium. These characteristics have already been determined in previous studies[4,5].
This equipment can generate voltages up to 160 kV, but in this study have been used the voltages referent to mammography (25 kV, 28 kV, 30 kV and 35 kV). The current used was 10 mA, since this is the value used in instruments calibrations in diagnostic radiology.

Has been used a 6 cm^3 ionizing chamber, specific for mammography, Radcal, RC6M model. This chamber has a thin window of Mylar®, which must be put to the beam. The electrometer used was a Keithley, 6517A model.

For the kVp and PPV measurements has been used a non-invasive measurer PTW, Diavolt Universal All-in-one QC Meter model. It was positioned one meter away from the anode (calibration distance). Previous studies showed that the best setup option to make this measurement is Mo/1.5Al[6].
Have been used aluminium (Al) and molybdenum (Mo) filters for the additional filtration, with 99.99 % of purity. The Al filters have also been used to determine the half-value layer (HVL).

To determine the addition filtration using Mo filters different thickness have been tested, until the correct filtration has been found. This is known making a measurement with and without the HVL. The correct thickness is found when the beam intensity is reduced to (50 $\pm$ 1.5) %. The same idea is used for the Al filters. The HVL used to check the additional filtration were those presented by the primary standard dosimetry laboratory *Physikalisch-Technische Bundesanstalt* (PTB).

The next step is to determine the air-kerma rate. For this, it is necessary to obtain the k_Q value, since PTB, on the chamber calibration, gave this value for only two qualities. These values, given by PTB, were put in a graphic, and a linear fit has been made. Using the given equation it was possible to determine the k_Q values.

Finally, using the equation 1, it is possible to determine the air-kerma rate for each quality.

$$K = L_c \times F_{t,p} \times N_k \times k_Q \qquad (1)$$

In the equation 1, L_c is the measurement made using the electrometer, $F_{t,p}$ is the temperature and pressure correction factor, N_k is the chamber calibration coefficient and k_Q is the radiation quality coefficient.

For the establishment of the qualities based on a phantom made up of an aluminum added filter (RQA-M), have been used the same filtrations from the RQR-M, but now, a 2 mm Al filtration must be added. The air-kerma rates have been calculated using the same procedure presented previously.

For the RQN-M and RQB-M qualities, the ionizing chamber has been positioned 600 mm away from the tube, and the phantom has been used. The charge collect has been made, but it was not possible to determine the air-kerma rate, because the chamber does not have traceability for these qualities. An important difference between these two qualities is that, in the first one, the phantom is about in the middle of the way between the anode and the ionizing chamber, and the beam is well collimated. In the second case, the phantom is leaning against the chamber, and beam is not so well collimated.

The phantom used is that presented by the IEC 61267. It consists of 5 plates with 5 mm thickness each one, 120 mm width and 80 mm length.

3. Results

The thickness found for the additional filtration, k_Q values obtained and air-kerma rate determined are shown in table 1 (for Al) and 2 (for Mo).

Table 1: Additional filtration (in mmAl), kQ and air-kerma rate found for each quality

Quality	Voltage (kV)	Additional Filtration (mmAl)	k_Q	air-kerma rate (mGy/min)
RQR-M 1	25	0.57	0.999	23.19 ± 0.66
RQR-M 2	28	0.57	1.000	30.95 ± 0.85
RQR-M 3	30	0.58	1.001	35.56 ± 0.98
RQR-M 4	35	0.62	1.002	45.77 ± 1.24

Table 2: Additional filtration (in mmMo), kQ and air-kerma rate found for each quality

Quality	Voltage (kV)	Additional Filtration (mmAl)	k_Q	air-kerma rate (mGy/min)
RQR-M 1	25	0.07	0.9998	9.78 ± 0.27
RQR-M 2	28	0.07	1.000	12.20 ± 0.36
RQR-M 3	30	0.07	1.0003	13.83 ± 0.38
RQR-M 4	35	0.07	1.001	17.97 ± 0.50

Comparing the results it is possible to notice that the air-kerma rate is higher when an Al filter is used, since the Mo is much denser than Al. The uncertainties have been calculated using the type A and type B uncertainties, and the combined and expanded uncertainties.

For the attenuated beams, the air-kerma rate obtained is showed in tables 3 (for Al) and 4 (for Mo).

Table 3: k_Q and air-kerma rate found for attenuated beams with Al

Quality	Voltage (kV)	Additional Filtration (mmAl)	k_Q	air-kerma rate (mGy/min)
RQA-M 2	28	0.57 + 2	1.000	3.03 $\pm$ 0.09
RQA-M 3	30	0.58 + 2	1.002	4.05 $\pm$ 0.11
RQA-M 4	35	0.62 + 2	1.009	7.18 $\pm$ 0.21

Table 4: k_Q and air-kerma rate found for attenuated beams with Mo

Quality	Voltage (kV)	Additional Filtration		k_Q	air-kerma rate (mGy/min)
		(mmMo)	(mmAl)		
RQA-M 1	25	0.07	2	0.999	0.470 $\pm$ 0.013
RQA-M 2	28	0.07	2	1.000	0.671 $\pm$ 0.019
RQA-M 3	30	0.07	2	1.002	0.845 $\pm$ 0.023
RQA-M 4	35	0.07	2	1.009	1.470 $\pm$ 0.040

In tables 5 and 6 are shown the collected charges in RQN-M and RQB-M using Al as additional filtration.

Table 5: Collected charges for RQN-M quality, with Al filtration

Quality	Voltage (kV)	Additional Filtration (mmAl)	Collected Charges (pC/min)
RQN-M 1	25	0.57	208.8 $\pm$ 1.4
RQN-M 2	28	0.57	365.8 $\pm$ 1.2
RQN-M 3	30	0.58	487.2 $\pm$ 2.4
RQN-M 4	35	0.62	823.5 $\pm$ 5.0

Table 6: Collected charges for RQB-M quality, with Al filtration

Quality	Voltage (kV)	Additional Filtration (mmAl)	Collected Charges (pC/min)
RQB-M 1	25	0.57	787.5 $\pm$ 11.3
RQB-M 2	28	0.57	1401.3 $\pm$ 6.2
RQB-M 3	30	0.58	1880.7 $\pm$ 15.7
RQB-M 4	35	0.62	3234.9 $\pm$ 23.3

In tables 7 and 8 are shown the collected charges in RQN-M and RQB-M using Mo as additional filtration.

Table 7: Collected charges for RQN-M quality, with Mo filtration

Quality	Voltage (kV)	Additional Filtration (mmMo)	Collected Charges (pC/min)
RQN-M 1	25	0.07	61.2 $\pm$ 0.7
RQN-M 2	28	0.07	86.1 $\pm$ 0.6
RQN-M 3	30	0.07	107.1 $\pm$ 0.4
RQN-M 4	35	0.07	177.3 $\pm$ 0.8

Table 8: Collected charges for RQB-M quality, with Mo filtration

Quality	Voltage (kV)	Additional Filtration (mmAl)	Collected Charges (pC/min)
RQB-M 1	25	0.07	229.7 ± 1.2
RQB-M 2	28	0.07	325.3 ± 2.7
RQB-M 3	30	0.07	407.8 ± 2.3
RQB-M 4	35	0.07	693.9 ± 4.9

It is possible to note that, in both cases, the system collected less charges in the RQN-M qualities. This result was expected, because in the RQB-M qualities the chamber is also detecting the scattered radiation.

4. Conclusions

The non-attenuated beams, RQR-M, have been established, using both Al and Mo filtration. It is expected to provide not only more calibration options for the LCI clients, and an appropriate calibration service, but also knowledge so new studies can be performed in this area.

Some problems have occurred in the attenuated beams establishment, because the beam intensity reduction, after the insertion of the HVL, was near to the maximum edge. Although, only the quality RQA-M 1, using Al filtration, could not be established.

Tests of the qualities that use the phantom have been made. The results were within expectations, with more charges being collected in the RQB-M qualities. This is because, in this case, the chamber detected both direct and phantom scattered beam.

The air-kerma rates were not calculated, because the reference chamber has not been calibrated in these qualities. However, the other characteristics have been determined, such as distance, filtration, voltage and collected charges.

Acknowledgements

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