Mammography calibration qualities establishment in a Mo-Mo clinical system

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Abstract: In this study the mammography calibration qualities were established in a clinical mammography system. The objective is to provide the IPEN instruments calibration laboratory with both mammography calibration methods (using a clinical and an industrial system). The results showed a good behavior of mammography equipment, in terms of kVp, PPV and exposure time. The additional filtration of molybdenum is adequate, air-kerma rates were determined and spectra were obtained.

1. Introduction

Second most frequent in the world, breast cancer is most common among women, accounting for 22 % new cases each year. Prognosis is relatively good if diagnosed and treated properly [1].

Mammography procedure allows the premature breast cancer detection, due to its capability to show injuries in its initial stage [2]. Currently, mammography is the only modality approved for screening application [3]. But, in order to obtain premature and reliable diagnosis, assurance that the mammography system is calibrated and working properly is necessary, and makes a good quality control of these equipment very important.

In Brazil, few laboratories have mammography qualities established in their systems. One of these laboratories is the Laboratório de Calibração de Instrumentos (LCI), at IPEN, which has calibrated about 40 mammography ionizing chambers during 2013/ 2014, and this number means about 80% of this sort of ionizing chambers in Brazil. Mammography chambers calibration are performed in an industrial X-ray system, with a tungsten anode and additional filtration of aluminum and molybdenum [2].

This study presents the results obtained during mammography qualities establishment in a clinical X-ray system, which has already been used in a homemade mammography chamber tests [4]. The goal is to provide information for comparative studies between calibrations performed in an industrial system, which presents low uncertainties and high accuracy, but different energy spectra and measurement geometry, and in clinical equipment, with same irradiation conditions found in hospitals but higher uncertainties.

2. Materials and methods

Mammography qualities were established based on the international standard IEC 61267[5], and the International Atomic Energy Agency (IAEA) code of practice, Technical Report Series No. 457 [6].

2.1. Mammography clinical equipment

Calibration qualities were established in a Philips VMI Graph Mammo AF system with a molybdenum target and molybdenum additional filtration. The voltage can be set from 20 kV to 35 kV. During the tests it presented a temporary malfunction in the Automatic Exposure Control (AEC) system. Therefore the determination of the mean glandular dose and the incident kerma was not possible.

Radiation field intensity variation has already been studied as part of quality control tests [7].

2.2. Voltage and exposure time measurements

For the mean and maximum kVp (peak voltage), PPV (Practical Peak Voltage) and exposure time measurement a non-invasive kVp meter PTW, Diavolt model, was used. This instrument has presented a good behavior both in mammography and conventional radiology beams [8, 9].

Five exposures for each one of four mammography calibration voltages (25 kV, 28 kV, 30 kV and 35 kV) were made. In this system is not possible to set the exposure time directly, but the values of current and current.time were set in order to obtain one second of exposure time. Tube current was set to 80 mA and the product current.time was of 80 mAs.

2.3. Verification of the additional filtration and air-kerma rate determination

Dose measurement was made using an ionization chamber Radcal, RC6M model, with 6 cm^3. This chamber was calibrated at the Physikalisch-Technische Bundesanstalt (PTB), Germany. For this reason same PTB mammography nomenclature (MMV N, where 'N' is the voltage applied to X-ray tube) and half-value layers (HVL) were used [10].

HVL was determined for every four voltages used in mammography to verify if the additional filtration of molybdenum is appropriate for this system. Aluminum attenuators thickness uncertainties were below 5 μm, in accordance with TRS-457 [6].

For air-kerma rate ($\dot{k}$) determination equation 1 was used.

$$k = M f_{t,p} N_k k_Q \quad (1)$$

where M is the measurement made with the reference ionization chamber, $f_{t,p}$ is the correction factor for the pressure and temperature, N_k is the calibration coefficient and k_Q is the factor that indicates the beam quality. Both N_k and k_Q were given by PTB after chamber calibration.

2.4. Spectroscopy

It is important to obtain the system spectra in order to know the energy distribution. It is known that different ionization chambers present different behavior when the combination anode-filtration is changed [11].

For the spectroscopy a CdTe spectrometer Amptek, XR-100T model, connected to an Amptek digital pulse processor, PX4 model, was used.

3. Results and discussions

3.1. Voltage and exposure time measurement

Results obtained for kVp, PPV and exposure time are shown in table 1.

Table 1. Mammography system kVp, PPV and exposure time values obtained using Diavolt. Uncertainties for kVp and PPV were smaller than 4.0 %.

Nominal Voltage (kV)	kVp (kV)	PPV (kV)	Exposure Time (ms)
25	25.7 ± 1.0	25.2 ± 1.0	1005.6 ± 45.3
28	28.4 ± 1.1	28.1 ± 1.1	1006.2 ± 52.3
30	30.5 ± 1.2	30.2 ± 1.2	1007.4 ± 40.3
35	35.8 ± 1.4	35.5 ± 1.4	1005.8 ± 50.3

Results present in table 1 show a good response of this equipment in terms of the presented quantities. The maximum variation between the nominal voltage and the values obtained with the Diavolt was of 0.8 kV, for 35 kV, which is in accordance to standard IEC 61267 [5].

For a current of 80 mA and product current.time of 80 mAs an exposure time of one second was expected. In this case maximum variation was 0.7 %, for 30 kV.

3.2. Verification of the additional filtration and air-kerma rate determination

The results for these tests are shown in table 2.

Table 2. Beam intensity reduction (after the HVL is placed) and the air-kerma rate obtained for each quality.

Nominal Voltage (kV)	HVL PTB (mmAl)	Intensity reduction (%)	kQ	Air-Kerma rate (mGy/min)
25	0.29	50.7 ± 0.9	1.000	387.0 ± 25,2
28	0.32	50.9 ± 0.8	1.000	551.3 ± 28.1
30	0.33	52.0 ± 0.8	1.000	678.6 ± 32.5
35	0.37	51.1 ± 0.7	1.000	1020.3 ± 58.2

According to TRS-457[5], beam intensity reduction must be of (50.0 ± 1.5) % when the HVL is inserted. This test showed the reduction is in accordance to TRS-457 for all qualities (when uncertainties are considered). Air-kerma rate was determined for all calibration qualities and can now be used as reference mammography ionization chambers calibration.

3.3. System spectroscopy

System spectroscopy was made for all mammography calibration qualities, and result is presented in figure 1.

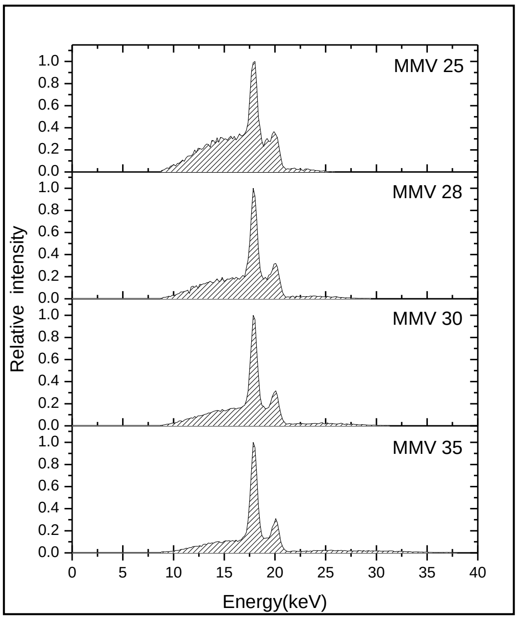

Figure 1. Clinical system spectroscopy made for all mammography calibration qualities.

The spectrometry results show what is expected for Mo-Mo system. Molybdenum energy peaks, due to the anode material, can be noted, and the count reduction in the region after 20 keV, due to the k-edge effect [12].

4. Conclusions

The mammography qualities MMV 25, MMV 28, MMV 30 and MMV 35 were established in the clinical equipment. HVL reductions were within the range for all qualities, and the air-kerma rates were obtained using the calibration coefficient given by PTB. The spectra obtained were according to what is expected from a Mo-Mo mammography system. Despite the problem presented by AEC the results obtained indicate that this mammography system is working properly, and can be used in calibration procedures. More studies will be made in order to develop a calibration method as close as possible to procedures used in medical clinics and hospitals.

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