EVALUATION OF kVp AND PPV IN MAMMOGRAPHY BEAMS USED FOR INSTRUMENTS CALIBRATION CHANGING THE ADDITIONAL FILTRATION MATERIAL

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Abstract: In this study has been done a comparison between the PPV (Practical Peak Voltage) values obtained in an industrial X-ray system, constant potential, used for instruments calibration, when the material of the additional filtration is changed. This system has the mammography qualities established on it, with molybdenum (Mo) and aluminum (Al) as additional filtration. To determine the PPV and kVp was used a non-invasive voltage measurer PTW, Diavolt Universal All-in-one QC Meter, which can be used in mammography. In this case it has three options for the system target-filtration combination. The Diavolt was placed 100 cm away from the focal spot (calibration distance), and it was taken ten measurers for each one of these combinations, to find out which one was the best to be used.

Keywords: mammography, PPV, peak voltage non-invasive meter, instruments calibration

1. INTRODUCTION

In the establishment of qualities used for instruments calibration, one of the first steps to take is the determination of the Practical Peak Voltage (PPV)[1]. Its measurement must be taken positing the PPV measurer in the X radiation beam, with no additional filtration.

Although, in a clinical situation, the same instrument is used to determine the PPV, but, in this case, usually is not possible to remove the additional filtration presents in the X-ray system. In mammography, the materials used are, normally, molybdenum (Mo) and rhodium (Rh), and sometimes, aluminum (Al).

This material changes the beam energy; different materials, different energies.

The objective of this study is to compare the behavior of the PPV in X ray beams used in calibration of instruments used in mammography quality control, when the material of the additional filtration is changed. Therefore, it is expected to understand a little more about the peak voltage and the PPV behavior.

The X ray system used in this study has the qualities RQR-M, using Mo and Al as additional filtration, established. But here it will be used another nomenclature; WAV, when using Al filtration, and WMV, when using Mo filtration. These codes are used by the German Primary Standard Dosimetry Laboratory *Physikalisch-Technische Bundesanstalt* (PTB) [2].

The code first letter indicates the anode material, the second letter indicates the additional filtration material, and the last one, shows if the beam is attenuated (H) or non-attenuated (V). For example, the code WAV 25 indicates a non-attenuated beam (letter 'V'), in a system that has a tungsten (W) anode, Al as additional filtration and the tube voltage is 25 kV. Likewise, the code WMV 30 indicates a non-attenuated beam, in the same system as before (tungsten anode), but now with Mo as additional filtration, and tube voltage of 30 kV.

2. MATERIALS AND METHODS

This study has been made in an X-ray system Pantak/Seifert, constant potential, tungsten anode (W target) in the mammography voltage range (25 kV, 28 kV, 30 kV and 35 kV). The radiation qualities in radiation beams emerging from the X-ray tube have been established using Mo and Al as additional filtration[3], following international recommendations [1,4] and using the half-value layer (HVL) given by PTB [2] . For the determination of PPV has been used a non-invasive voltage measurer PTW, Diavolt Universal All-in-one QC Meter model (see figure 1), that can be used in conventional radiology, CT, fluoroscopy, dental diagnostic and mammography. In this study, the option **mammography** has been used.

Figure 1: Non-invasive voltage meter PTW, Diavolt Universal All-in-one QC Meter model

The Diavolt, after being irradiated, give the values of the kVp maximum (kVp max), kVp mean, PPV, exposure time and dose, as shown in the figure 2.

For mammography, this device has three options for the combination target-filter, which can be selected on the options menu: Mo/30Mo (molybdenum target and filtration of 30 μmMo), Mo/0.5Al (molybdenum target and filtration of 0.5 mmAl) and Mo/1.5Al (molybdenum target and filtration of 1.5 mmAl), as shown in the figure 3.

Figure 2: Diavolt menu screen, showing the application (1) and the target-filtration combination (2)

Using a procedure presented by Corrêa, Lucena, Vivolo and Potiens [5] was determined which one of these options is the most adequate for the presented system, with the respective qualities established. This procedure consists in compare the kVp mean, given by the Diavolt, with the kVp max obtained using the spectrometry, considered a primary method to obtain this value [5,6]. For this system, without additional filtration, the best combination option is Mo/1.5Al.

As the Diavolt operational manual is not very clear about the method used by it to obtain the kVp values, it was decided to use the kVp mean in this comparison, instead of the kVp max. This is because, according to what was observed in a series of measurements, the kVp mean presented by the Diavolt is the average of all the voltages measured by it. Therefore, with this procedure, it is guaranteed that the value given by the Diavolt, used in the comparison, is as close as possible to the real value.

The Diavolt was positioned one meter away from the X-ray tube, as shown in the figure 2. This is the distance used in radiology diagnostic calibration.

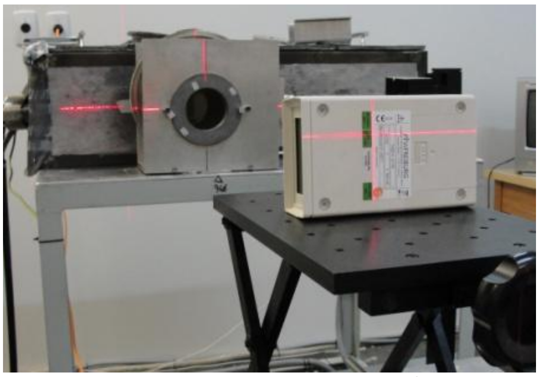

Figure 2: Experimental arrangement used for the tests

In this case the same procedure was adopted; the results obtained, with each combination target-filtration, were compared with the kVp values obtained using the spectrometry, to verify if there is any change in the Diavolt behaviour. The combination that presented a result closer to that obtained from the spectrometry was used to determine the kVp and PPV in these conditions.

Have been taken ten measures, for each quality, and the mean and the standard deviation have been calculated.

3. RESULTS

The initial tests showed that there are two combinations that must be used to determine the kVp and PPV of this system, using Mo filtration: Mo/0.5Al (WMV 28 and WMV 30) and Mo/1.5Al (WMV 35). For the qualities using Al filtration, the best combination is Mo/1.5Al. The results for this initial test are showed in table 1.

Table 1: Comparison between the kVp values obtained using the Diavolt and the spectrometry

Radiation quality	Combination target-filtration	kVp mean Diavolt (kV)	kVp max spectrometry (kV)	Variation (%)
WMV 25	***	***	26.2 ± 1.4	***
WMV 28	Mo/0.5Al	29.2 ± 0.6	29.2 ± 1.0	0.03
WMV 30	Mo/0.5Al	33.0 ± 0.7	31.2 ± 0.5	5.54
WMV 35	Mo/1.5Al	36.8 ± 0.7	36.2 ± 0.7	1.58
WAV 25	Mo/1.5Al	27.1 ± 0.5	26.2 ± 1.4	3.17
WAV 28	Mo/1.5Al	30.1 ± 0.6	29.2 ± 1.0	2.96
WAV 30	Mo/1.5Al	32.2 ± 0.6	31.2 ± 0.5	3.11
WAV 35	Mo/1.5Al	37.3 ± 0.7	36.2 ± 0.7	2.89

In table 1 are showed only the best combinations to be used. It is possible to observe that, for the qualities WMV 28 and WMV 30, the result is different from that obtained without additional filtration. This possible happened because, in these cases, the beam energy is lower, so the Mo additional filtration caused a higher influence in the beam characteristics.

For the other qualities, the variation between the value presented by the Diavolt and by the spectrometry was not higher than 3.17 %.

It was not possible to obtain the values for the WMV 25 quality. This happened because the Diavolt did not detect the radiation; probably it was because the high attenuation caused by the high density Mo additional filtration.

After this initial test it was possible to obtain the kVp mean, kVp max and the PPV, with the Diavolt, using the best option for the target-filtration combination.

The results are showed in tables 1, 2, 3 and 4, four the qualities using 25 kV, 28 kV, 30 kV and 35 kV, respectively.

Table 1: kVp and PPV values using a voltage of 25 kV

	No filtration	WAV 25 (0.57mmAl)	Variation WAV 25	WMV 25 (0.07mmMo)	Variation WMV 25
kVp mean (kV)	26.1 ± 1.6	27.1 ± 1.7	3.79 %	***	***
kVp max (kV)	26.4 ± 1.6	27.6 ± 1.5	4.39 %	***	***
PPV (kV)	25.7 ± 1.6	26.6 ± 1.5	3.50 %	***	***

As said before, the Diavolt could not make the measurement at the quality WMV 25, due to the beam low energy and the 0.07 mmMo as additional filtration.

Table 2: kVp and PPV values using a voltage of 28 kV

	No filtration	WAV 28 (0.57mmAl)	Variation WAV 28	WMV 28 (0.07mmMo)	Variation WMV 28
kVp mean (kV)	28.9 ± 1.8	30.1 ± 1.8	4.15 %	29.1 ± 1.7	0.59 %
kVp max (kV)	29.2 ± 1.8	30.6 ± 1.8	4.86 %	30.3 ± 1.7	3.84 %
PPV (kV)	28.5 ± 1.8	29.7 ± 1.9	4.21 %	27.5 ± 1.7	3.40 %

Table 3: kVp and PPV values using a voltage of 30 kV

	No filtration	WAV 30 (0.57mmAl)	Variation WAV 30	WMV 30 (0.07mmMo)	Variation WMV 30
kVp mean (kV)	30.8 ± 1.9	32.2 ± 1.8	4.55 %	33.0 ± 1.9	7.08 %
kVp max (kV)	31.0 ± 1.9	32.7 ± 1.8	5.45 %	34.3 ± 1.9	10.74 %
PPV (kV)	30.4 ± 1.9	31.7 ± 1.9	4.24 %	31.3 ± 1.7	2.86 %

Table 4: kVp and PPV values using a voltage of 35 kV

	No filtration	WAV 35 (0.57mmAl)	Variation WAV 35	WMV 35 (0.07mmMo)	Variation WMV 35
kVp mean (kV)	35.2 ± 2.2	37.3 ± 2.2	5.99 %	36.8 ± 2.3	4.52 %
kVp max (kV)	35.6 ± 2.2	37.9 ± 2.3	6.32 %	37.8 ± 2.3	6.26 %
PPV (kV)	35.0 ± 2.5	36.7 ± 2.3	4.97 %	35.5 ± 2.5	1.49 %

4. CONCLUSIONS

It is possible to notice that, using 25 kV as nominal voltage and Mo as additional filtration, the Diavolt could not make any measurement. That is because the energy is too low, and the radiation that reached the Diavolt detector was not enough to sensitize it.

Using Mo as additional filtration, the variation between the kVp mean was from 0.59 % (WMV 28) to 7.08 % (WMV 30). For the kVp max, the variation was from 3.84 % (WMV 28) to 10.74 % (WMV 30). And, for the PPV, the variation was from 1.49 % (WMV 35) to 3.4 % (WMV 28).

For the Al, the variation between the kVp mean was from 3.79 % (WAV 25) to 5.99 % (WAV 30). For the kVp max, the variation was from 4.39 % (WAV 25) to 6.32 % (WAV 35). And, for the PPV, the variation was from 3.50 % (WAV 25) to 4.97 % (WAV 35).

The physical quantity more used in medical clinics, the PPV, presented a maximum variation of less than 5 % both for Al and Mo as additional filtration. Although, the kVp max presented a variation of more than 10 % (WMV 30). This value is higher than that presented by the Portaria 453[7], from ANVISA (Agência Nacional de Vigilância Sanitária), in Brazil.

The results show the importance of a deeper study of the non-invasive kVp meters. Despite the fact that an instrument like the Diavolt is very precise (in some measurements the standard deviation was zero), the values presented by it depends a lot on the combination target-filtration selected in its options menu.

The best solution for this problem would be to make the spectrometry of every system where the Diavolt is used (mammography, conventional X- ray, CT system etc.) and comparer the results, but it is clear the impossibility to include this test in a quality control procedure, mainly for two reasons: first, it is too expensive to buy a good spectrometer to use in a medical clinic, and second, obtaining the kVp maximum using a spectrum is a very difficult procedure.

For now, the best that can be done is to create a quality control procedure to the non-invasive kVp meters in the current Brazilian calibration laboratory, and try to reproduce, in these laboratories, the same conditions found in the medical clinics.

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