Tests with different kind of kVp-meters in standard X-rays beams used for instruments calibration, in diagnostic radiology level

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Abstract. In this work, tests were carried out in one X-ray system, Medicor Mövek Röntgengyara, Model Neo-Diagnomax, (single –phase, full wave rectified) that operate in the range from 40 kV to 100 kV, and fixed 6 mA in the fluoroscopic mode, with total filtration of 2.5 mmAl. It was used as reference system an invasive system from Radcal, model Dynalyzer III™. The equipments tested were three non-invasive instruments, one PTW, model Diavolt™, and two Victoreen, model NERO™. It was performed measurements with those equipments, in the range from 50 kV to 100 kV, in steps of 10 kV and current of 6 mA (fixed). The quantity measured was kVp_{max}. The results showed the maximum variation of 3 % for one NERO™ and 1 % for the other equipment of the same type, and 0,3 % for Diavolt™ related to the invasive reference measurement system. The differences in the obtained values could be caused by the different kind of equipment used in that, their manufacturer calibration and aged.

KEYWORDS: kVp-meters, X-ray beams, quality control, calibration.

1. Introduction

A quality control program applied to X-rays equipments and X-ray beams is desirable in instruments calibration laboratories, clinics and hospitals around the world with in order to assure a high quality of those services, such us: portable survey meters calibration and procedures used for radioprotection routines [1] and also for calibration procedures of dosimetric systems used in diagnostic radiology. Therefore, it is very important to check the performance of kVp-meters and similar devices periodically to permit a real verification of the calibration set-up [2].

The measurements of kVp may be done using different techniques, which can present advantages e disadvantages in their use. The invasive techniques made measurements inside the X-rays system through of monitors or oscilloscopes connected into the system and offering precise measurements, but their cost is high and low practical in their locomotion being used the effect of calibration [3].

To the non-invasive techniques use the kVpmeters positioned in front of the X-ray beam, and the measurements are taken. These meters can be spectrometers of X-ray, penetrameters, techniques what use fluorescence of X-rays and those using differential absorption of X-ray in an absorbent material with detection through of semiconductors detectors. The advantages of non-invasive techniques are their practicality and their low cost. However, they have the disadvantage of offering bigger uncertainties in the measurements than the invasive techniques and necessity of periodical calibration of the kVpmeters [4].

Considering the characteristics of invasive and noninvasive techniques discussed before, the use of an invasive kVpmeter as a reference for calibration of non-invasive meters can be used adequately. The meter can also be used as reference for X-ray devices evaluations.

The comparison between non-invasive kVpmeters and an invasive used as a reference in various settings of kVp may results in 3 different situations, where problems and solutions can be clearly highlighted:

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a) the measurements can agree with the reference instrument, showing a good behaviour of the instruments;

b) the measurements may present a constant shift for all values obtained, and the calibration can solves this problem;

c) the measurements present diffusion in their values in relation to the values from reference kVpmeter, suggesting a technical problem, and only the calibration can not solve this problem. In this case the equipment can needs repair or useless of the kVpmeter.

The cited situations assume a an adequate functioning of the X-ray system, but if there is any problem in its operation that can change the X-ray emission, the meters may present irregular data. However, as it is about comparisons among meters, all they must present irregular values following the same trends from reference meter, otherwise any or some of these meter would present problems, beyond of the showed at X-ray system.

This paper describes the realization of tests with 4 kVpmeters; one invasive (taken as reference) and 3 non-invasive. The aim is to examine a range of measurements of kVp for each meter and compare them. The obtained data of the invasive meter is going to be used to do a comparative analysis with the theoretical values selected in the X-ray system control panel having thus results of its technical conditions and/or calibration.

The comparison of the measurements were made following the norm IEC 61676 [5], which recommends that the obtained values by the non-invasive kVpmeters must be agreed with the values of invasive kVpmeter (considered as true values) and their maximum intrinsic errors by the relations 1 and 2.

The maximum relative intrinsic (I) error for voltages above 50kV is expressed by the equation:

$$|I| = \left| \frac{U_{meas} - U_{true}}{U_{true}} \right| \leq 0{,}02 \qquad (1)$$

where : U_{meas} is the measured value of kVp by the non-invasive instruments and U_{true} is the true value of kVp measured by the invasive instrument.

For voltages below 50kV, the maximum intrinsic error (E) shall not be greater than ±1kV over the effective range of voltages. This is expressed by the equation:

$$|E| = |U_{meas} - U_{true}| \leq 1\,\text{kV} \qquad (2)$$

where : U_{meas} is the measured value of kVp by the non-invasive instruments and U_{true} is the true value of kVp measured by the invasive instrument.

2. Materials and Methods

For the tests of performance of kVpmeters was used a X-ray system Medicor Mövek Röntgengyara, Model Neo-Diagnomax,(single–phase, full wave rectified) which operates in the range from 40 kV to 100 kV, with fixed 6 mA in the fluoroscopic mode, with total filtration of 2.5 mmAl. The invasive system from Radcal, model Dynalyzer III^{TM} was used as reference system. Three non-invasive instruments, one PTW, model Diavolt^{TM}, and two Victoreen, model NERO^{TM} were tested. All instruments response were compared with the invasive reference measurement system. Each meter provides information regarding dose, average dose, kVp and average kVp in each measurement. Besides of that, the Diavolt meter can provide values of the Practical Peak Voltage (PPV). In this study was considered only the values of kVpmax.

The meters were positioned at 1 meter of the focal spot of the X-ray tube and for each non-invasive kVpmeter were made measurements in the range from 40kV to 100kV (except the meter Diavolt, which can not be used below 50kV) together with the invasive meter. The measurements were increased in steps of 10kV. The tests were made in fluoroscopic mode with durations of 15 seconds for each measurement. For each kV selected in X-ray equipment were takeN 5 measurements for each kVpmeter.

For the 5 sequential measurements were calculated the averages values and standard deviations associated. With the calculations of the averages values of all measurements and of the maximum intrinsic errors were plotted graphics of kV by kVp, where the kV is associated with the kV selected in the X-ray equipment control and the kVp associated with the measurements obtained on each meter used. With the increase in the kV selected in the X-ray equipment is expected to have an increase in kVp in a linear behaviour. Thus, this study analyzes whether the items relating to invasive meters are covered by the measurements of non-invasive meter and their maximum intrinsic errors and the repeatibility of the measurements to analyze the reliability of the data acquired through their standard deviations..

3. Results and Discussion

The Table 1 and 2 shows the results obtained. All measurements were made with 1 m of focal spot distance and 6 mA of current. The measurements obtained with the invasive instrument (Dynaliser) were taken during the irradiation of the non-invasive instruments showed in Table 1 .

Table 1: Average values of the measurements of the maximum kVp of each non-invasive kVpmeters and its standard deviations.

	Maximum kilovoltage (kVp)		
kV (control panel of the **X-ray system)**	***Diavolt***	***Nero (1)***	***Nero (2)***
50	-	42,34 ± 0,42	41,73±0,31
60	54,08 ± 0,16	45,68 ± 0,22	44,64±0,48
70	63,64 ± 0,13	58,32 ± 1,66	56,48±0,26
80	71,5 ± 0,16	65,08 ± 0,13	63,48±0,33
90	81,22 ± 0,18	81,70 ± 0,61	76,54±0,59
100	88,76 ± 0,05	83,96 ± 0,59	79,38±0,47

Table 2: Average values of the measurements of the maximum kVp of the invasive kVpmeter and its maximum intrinsic error.

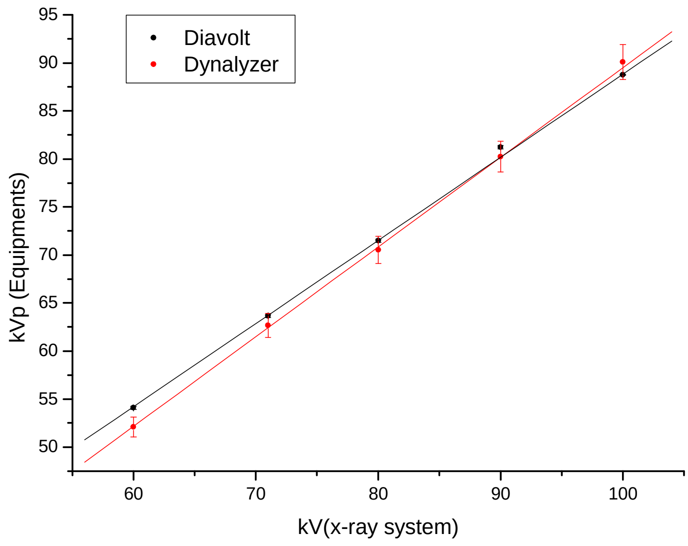
	Maximum kilovoltage (kVp)		
kV (control panel of the **X-ray system)**	***Dynalyzer plus Diavolt***	***Dynalyzer plus Nero (1)***	***Dynalyzer plus Nero (2)***
50	-	43,01 ± 0,86	43,20 ± 0,86
60	52,08 ± 1,04	51,98 ± 1,04	52,08 ± 1,04
70	62,67 ± 1,25	62,70 ± 1,25	62,80 ± 1,26
80	70,53 ± 1,41	70,78 ± 1,42	70,98 ± 1,42
90	80,24 ±1,60	80,63 ± 1,61	80,70 ± 1,61
100	90,09 ± 1,80	90,28 ± 1,80	90,57 ± 1,81

The obtained values of kVp are always lower than the values selected in the X-ray system control panel. This occurs, probably due to the aging of the X-ray system, or its non calibration causing loses of efficiency over time, but this doesn't interferes in the tests , considering that it was only compared the values of the non - invasive equipment with the value of the invasive instrument.

The Diavolt showed the lowest standard deviations with a maximum deviation of 0.3% and a minimum of 0,06% showing to be an equipment with good accuracy. Already the Nero (1) presented standard deviations maximum and minimum of the approximately 3% and 2% respectively, those values are bigger than the Diavolt values, showing low accuracy in the measurements, in other words, great dispersion in that values obtained. For the Nero (2) its standard deviations maximum and minimum had been of approximately 1% and 0.5% respectively. The Figures 1,2 and 3 shows the results obtained.

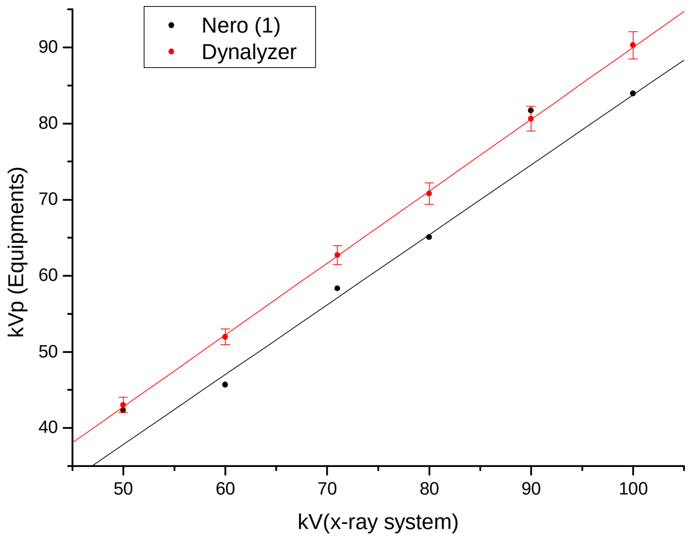
The values of the measurements obtained with Diavolt (Figure 1) had been within the bar errors of the values obtained with Dynalyzer equipment, with exception of the first measurement of kVp that it was above the bar errors. This can occur due to difficulty of equipment to read values in the low limit of the scale, therefore it was not done measurements with values below of 50 kV, in as much as the equipment does not make the reading below this value (Table 1).

Figure 1: Average value of the measurements of kVp from Diavolt instrument and from Dynalyzer instrument and its respective maximum intrinsic errors in function of the kV selected in X-ray control panel.



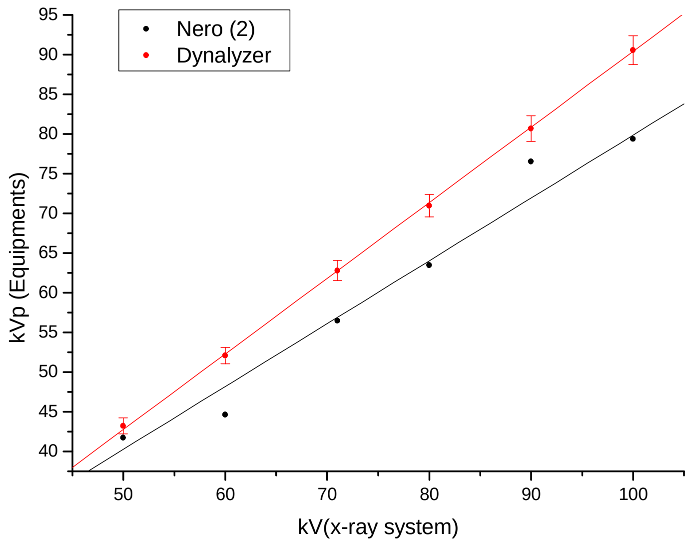
The calculated average values obtained of kVp of the Nero (1) (Figure 2) had not been within the bars errors of the measurements of the Dynalyzer, with exception of the first and of the fifth measurement of kVp. The values had also been distant of the straight average that represents the collection of data relating to Nero (1). These variable may not only mean an uncalibrated equipment, but also a problem due to lack of consistent reproducibility of the measures what it suggests a necessity of maintenance or adjustment technical of the equipment.

Figure 2: Average value of the measurements of kVp from Nero (1) instrument and from Dynalyzer instrument and its respective maximum intrinsic errors in function of the kV selected in X-ray control panel.



The calculated average values of the measurements of the Nero (2), as well as the ones of the Nero (1), had not been within the bars errors of the measurements of the Dynalyzer, with exception of the first measurement of kVp. The values had also been distant of the straight average that represents the collection of data relating to Nero (2). The straight still showed a slope distant of the slope of the average straight that represents the collection of data relating to Dynalyzer. As well as in the Nero (1), these variable may not only mean a uncalibrated equipment, but also a problem due to lack of consistent reproducibility of the measurements what it suggests a necessity of maintenance or adjustment technical of the equipment.

Figure 3: Average value of the measurements of kVp from Nero (2) instrument and from Dynalyzer instrument and its respective maximum intrinsic errors in function of the kV selected in X-ray control panel.



4. Conclusion

Non-invasive instruments need to be calibrated periodically. To be calibrated the instrument should be in good technical conditions, in other words, depend only of the shift of the data set measuring, or better, the results obtained in the tests. In case that the data do not obey this criterion, the instrument must receive, calibration, adjusts or maintenance or not to be used any more. In this work it is possible verify that the Diavolt device is functioning adequately not needing even calibration due its accuracy compared to Dynalyzer for values above of 50kV. Already the others 2 devices (Nero (1) and Nero (2)) had shown unsatisfactory data, demonstrating the needing of adjusts, maintenance or at last out of order.

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