Influence of the exposure time in the area monitors at radiodiagnostic

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Abstract: Area monitoring ensures radiation exposure at an acceptable level, which must be lower than the legal limit. Experimental measurements were taken in a ionizing radiation calibration laboratory. The specified reference radiation to radiation protection N80 was used. Five area monitors were used. The ranges of dose rate inaccuracy measured in rate mode for times ≤ 2 and ≥ 3 s were from 10 to 48 % and from 1 to 15 %, respectively. The inaccuracy ranges measured in integrated mode for times ≤ 2 and ≥ 3 s were from 4 to 8 % and from 0 to 22 %, respectively.

Keywords: Area monitoring, Radiodiagnostic, Occupational exposure.

1. INTRODUCTION

These Medical exposures, among all the practices that involve ionizing radiation, are responsible for the greatest contribution to population exposure [1]. The International Atomic Energy Agency (IAEA) [2] recommend monitoring areas related with medical exposure in addition to supervising public areas. In this regard, the Secondary Standards Dosimetry Laboratory (SSDL) for each country has responsibility to ensure that area monitors are traceable and properly calibrated.

Area monitors are used for the real-time monitoring of exposure and hence to estimate the potential risk to which members of the public and employees are exposed. The IAEA's Technical Reports [3] states that for survey meters, a required accuracy of 20 % in dosimetry measurements should be sufficient. Besides, there is no unified protocol for the calibration procedure of survey meters in SSDLs. The IAEA's Reports [4] shows that exposure times for calibration vary between 5 and 60 s.

For area monitoring at radiodiagnostic, the lowest possible time and current (mA) are generally used to prevent possible harm to the X-ray tube during the completion of the test, with the great majority of area monitoring studies using ionization chambers conducting the test for times less than 2.5 s and in rate mode [5,6]. This means that the survey meter must be capable of measuring exposures lasting seconds or fractions of seconds. Various factors must be considered (range, calibration, energy dependence, etc.) in selecting the appropriate survey meter for area monitoring. There are few studies examining the dependency of the ionization chamber and of solid-state detectors for the measures taken in rate or integrated mode at low exposure times. This paper shows the influence of exposure time on area monitors during dose rate measurement in rate and integrated modes for a tension 80 kV used at radiodiagnostic and interventional facilities.

2. MATERIALS AND METHODS

Experimental measures were taken in LabProsaud, an ionizing radiation calibration laboratory [7]. The instruments of Labprosaud are directly traceable to primary standards maintained at the national metrology institute of Germany, Physikalisch – Technische Bundesanstalt (PTB) [8], with uncertainty within 3 % and a 95 % confidence interval. A General Electric ISOVOLT TITAN E X-ray system with ISOVOLT 160 M2 tube, with output voltage range from 5 to 160 kV, output current range from 0.2 to 10 mA and high frequency was used. The radiation quality required and the calibration arrangement comply with the requirements of reference standards ISO 4037-1, 2 and 3 [9]. The specified reference radiations for the narrow spectrum series dedicated to radiation protection, N80 was used, with the following characteristics: 65 keV, tube potential 80 kV, additional filtration 2.0 mmCu, first HVL 0.58 mmCu and second HVL 0.62 mmCu.

The study assessed five area monitors. The technical characteristics of these systems were taken from the manufacturer manuals. The meters are identified by letters Atomtex AT 1123 (A), Fluke Biomedical 451P (F), PTW 32002 (P), Radcal 9010X5-180 (R) and Radcal 9010X5-1800 (R2). They were positioned at 200 cm from the focal spot of the X-ray system and using reference points and orientations as specified by the manufacturer.

The P ionization chamber is directly traceable to primary standards PTB. The total traceable uncertainties for the P ionization chamber were 6 and 4 % for rate and integrated mode respectively (at a 95 % confidence interval). Hence, calculations of the inaccuracy of measurements were taken as against the values obtained for the PTW chamber. Meters A, F, R and R2 were calibrated at Labprosaud.

The measurements were taken at the normal working rate for each meter and corrected for pressure and temperature and for ambient dose equivalent H*(10), which is used as an estimate of ambient dose equivalent at 10 mm depth [10,11].

The measurements of the dose (D) and dose rate (DRm) were measured in integrated and rate modes, respectively. For each detector evaluated, five measurements were taken at each exposure time of 1, 2, 3 and 5 s, respectively, with 0.7 mA for N80 radiation quality.

The calculated dose rate values (DRc) were calculated using the quotient between D measured in integrated mode divided by experiment time. Experiment time was measured by PTW equipment (NOMEX, T11049) directly traceable to primary standards maintained at the PTB, with uncertainty within 1 % with a 95 % confidence interval. The values of experiment time were 1.145, 2.143, 3.146 and 4.953 s for nominal times of 1, 2, 3 and 5 s, respectively.

3. RESULTS AND DISCUSSION

3.1. Rate mode measurements

Figure 1 shows the measurements taken for 80 kV. When exposure time was increased, the DRm became closer to the true value. The highest dose rate inaccuracy was 48 % for the A detector at 1 s with respect to the P meter, and the lowest inaccuracy was -1 % for the R2 meter at 5 s.

The ranges of DRm inaccuracy for the area monitors with respect to the true value (PTW) for times ≤ 2 s and ≥ 3 s were from 10 to 48 % and from 1 to 15 %, respectively. The R chamber was not able to measure dose rate for times ≤ 2 s at 80 kV. The average values for dose rate inaccuracy for each area monitors for times ≤ 2 s and ≥ 3 s were 36, 32 and 18% for A, F and R2,

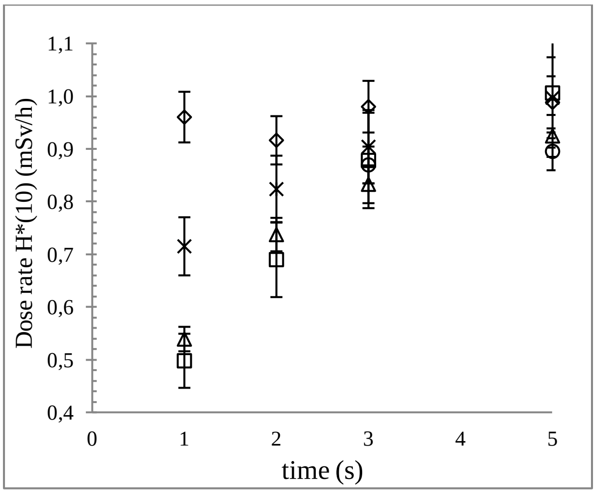

Figure 1: Average dose rate (DRm) and standard deviation (sd) values measured in dose rate mode for different area monitor meters Atomtex (□), Fluke (Δ), PTW (◊), Radcal 180 cc (○) and Radcal 1800 cc (x) at different exposure times with a tension of 80 kV.

respectively and 6, 11, 10 and 4% for A, F, R and R2, respectively.

At 80 kV, the greatest percentage difference between the readings for the P chamber was 7 % between 2 and 5 s. The greatest percentage differences for dose rate for the A detector, F and R2 ionization chamber were 50, 42 and 28 % between 1 and 5 s, respectively. The percentage differences for each area monitor for the dose rate between 3 and 5 s were 13, 10, 3 and 9 % for the A, F, R and R2, respectively.

3.2. Integrated mode measurements

Figure 2 shows the dose rate calculated taken at 80 kV using integrated mode. The dispersion of DRc values is lower than the dispersion of values obtained at figure 1.

The ranges of in accuracy between the DRc measurements for integrated mode (figure 2) were lower than DRm measurements for rate mode (figure 1). The inaccuracy ranges of the area monitors with respect to the true (PTW) value for times ≤ 2 s and ≥ 3 s were from 4 to 8 % and from 0 to 22 %, respectively. On taking integrated mode measurements at 80 kV, the R

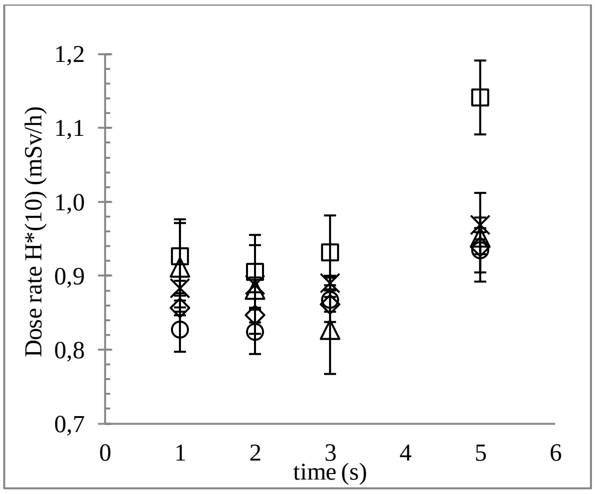

Figure 2: Mean dose rate (DRc) and standard deviation (sd) values calculated in integrated mode for different area monitor meters Atomtex (□), Fluke (Δ), PTW (◊), Radcal 180 cc (○) and Radcal 1800 cc (x) at different exposure times with a tension of 80 kV.

meter was able to measure the dose for all exposure times used.

The average values for DRc inaccuracy for times ≤ 2 s and ≥ 3 s were 8, 5, 3 and 4% for Acal, Fcal, Rcal and R2cal, respectively and 15, 3, 0 and 3% for the Acal, Fcal, Rcal and R2cal, respectively.

For integrated mode, only one measurement (6%) has a deviation in accuracy of more than 20 %, while for rate mode (figure 1), 36 % of measurements had a deviation in accuracy of more than 20 %.

The greatest percentage difference between the readings for the Pcal meter was 10 % between 2 and 5 s. The percentage differences in DRc for the Acal, Fcal, Rcal and R2cal were 19 and 21 %, 4 and 7 %, 11 and 12 % and 9 and 8% for times of 1 and 2 s in comparison with the 5 s readings for each meter, respectively. The percentage differences in DRc between 3 and 5s were 18, 13, 7and 8 % for the Acal, Fcal, Rcal and R2cal monitors, respectively.

4. CONCLUSIONS

All the area monitors evaluated in this study show a tendency to underestimate dose rate when measurements are taken in rate mode for times ≤ 2 s. On taking integrated mode measurements, the dispersion of dose rate values is lower than for the values obtained in rate mode. Moreover, in integrated mode it was possible to calculate dose rate for all exposure times and different radiation beam qualities.

The values obtained in rate and integrated modes (figures 1,2) suggest that this type of evaluation is necessary to develop knowledge regarding each area monitor and to improve the accuracy and precision of measurements. The results of this study show that it is highly recommendable to work in integrated mode and precautions must be taken if area monitoring is performed in rate mode with exposure times of ≤ 2 s.

The results of this study coincide with the international recommendations [12,13], which recommends measuring using exposure times greater than 3 s and advise that measurements of the monitored area should be taken in integrated mode.

4. ACKNOWLEDGMENTS

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