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PERFORMANCE OF X-RAY EQUIPMENTS USED FOR CONVENTIONAL RADIOGRAPHIC EXAMINATIONS OF CHILDREN

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ABSTRACT

The performance of X-ray equipments that are used for conventional X-ray examinations of children in four hospitals of Belo Horizonte, Brazil, was evaluated. The methodology proposed by the Brazilian authority for radiation protection in diagnostic radiology was adopted. The performance tests were carried out in six X-ray machines and they consisted of measurements and determination of the X-ray tube output, linearity and constancy of radiation output, accuracy and reproducibility of the exposure time and tube potential, half-value layer (HVL), light field / X-ray field alignment and accuracy of the X-ray field indicator. It was observed that only one hospital had the suitable equipment for X-ray examinations of children. Results showed that all six equipments of the four hospitals presented unsatisfactory performance in some quality control tests. Only for some combinations of the exposure parameters, generally employed in pediatric X-ray examinations, some equipments complied with the authority requirements.

1. INTRODUCTION

The implementation of Quality Assurance (QA) programs in a radiology department is mandatory for improvement of medical attendance. Routine quality control tests of X-ray equipments is a fundamental part of a QA program, once the performance of the machines interferes in image quality and radiation dose imparted to patient in diagnostic radiology [1, 2].

The peculiarities of pediatric radiology demand the use of machines with powerful generators and tubes, as well as optimal rectification and accurate time switches. Low mA.s techniques and collimated X-ray beam should be employed. Total tube filtration of about 2.5 mm Al + 0.1 mm Cu or equivalent is recommended [1, 3].

The aim of this work was to evaluate the performance of the X-ray equipments used for conventional radiographic procedures of children in 4 hospitals of Belo Horizonte city, Brazil. Results were compared with the performance criteria provided by Brazilian standard [2].

2. MATERIALS AND METHODS

Table 1 presents the main characteristics of the X-ray equipments of the four hospitals studied. Hospital A is a general hospital and the other three (B, C, D) are pediatric dedicated ones.

Table 1. Characteristics of the equipments of the four hospitals studied.

HOSPITAL / ROOM	EQUIPMENT
Hospital A	SIEMENS – 3-phase – high-frequency
Hospital B	
Room 1	MEDICOR – Single-phase – full wave rectified
Room 2	MEDICOR – Single-phase – full wave rectified
Hospital C	
Room 1	VMI – Single-phase – full wave rectified
Room 2	SIEMENS – Single-phase – full wave rectified
Hospital D	INTECAL – Single-phase – full wave rectified

The following quality control tests were performed in the four hospitals studied: (a) X-ray tube output; (b) linearity and constancy of radiation output; (c) accuracy and reproducibility of the exposure time and tube potential; (d) half-value layer (HVL) and; (e) X-ray / light beam alignment and accuracy of the X-ray field indicator. It was used for this purpose the protocol published by Brazilian Ministry of Health [4].
For the tests (a), (b) (c) and (d), it was used the kV and time exposure meter RADCAL/MDH model 4083 with 40X5-W sensor. At the same X-ray exposure, air kerma readings were recorded using electrometer / ionization chamber RADCAL / MDH models 9010 / 10X5-6, respectively. The mentioned equipments have calibration traceable to a secondary standard national laboratory.

3. RESULTS AND DISCUSSIONS

The Fig. 1 shows the X-ray tube output at 80 kV for the equipments of the hospitals studied. The results are presented for 3 current values: mA-1, mA-2 and mA-3, in crescent order (covering all range clinically used in each hospital). In the Fig. 2 and 3 the results of the Linearity and Constancy of radiation output are presented. Fig. 4 shows the results of accuracy and reproducibility of the exposure time. In Fig. 5 and 6 the results of accuracy and reproducibility of tube potential are presented. Tab. 2 presents the HVL and exposure parameters used for the measurements. Tab. 3 presents the results of X-ray / light beam alignment and accuracy of the X-ray field indicator for the equipments of the hospitals.

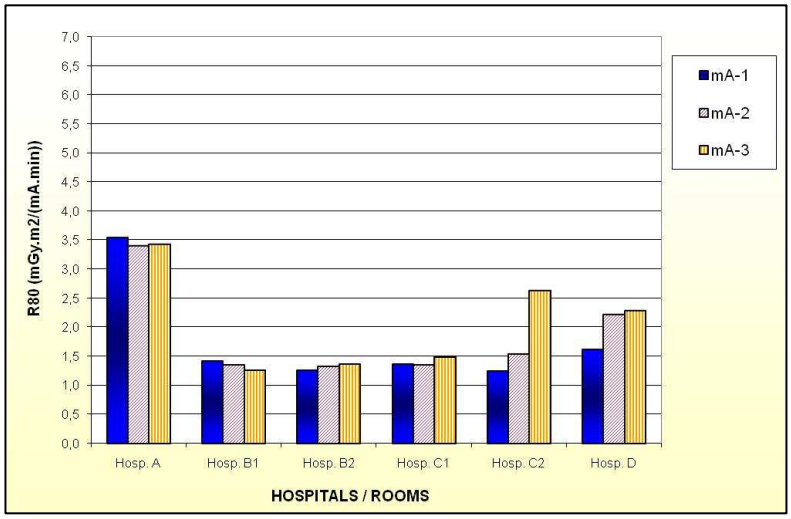

Figure 1. X-ray tube output at 80 kV for the hospitals studied. Current values: mA-1 < mA-2 < mA-3 (covering all range clinically used in each hospital).

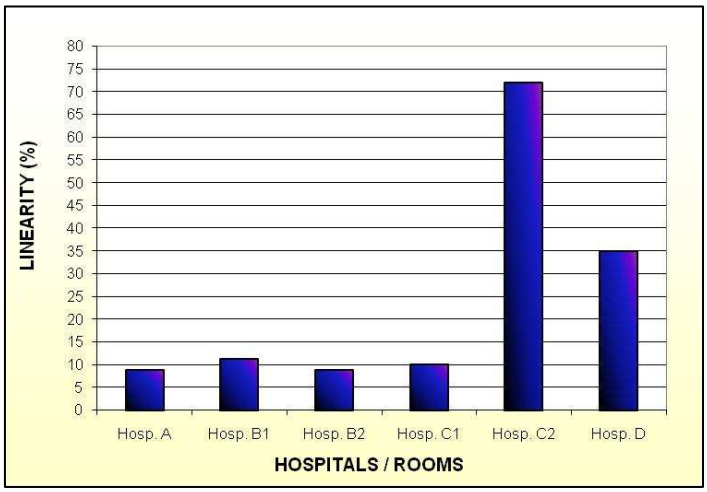

Figure 2. Linearity of radiation output with the tube current and time product (mAs).

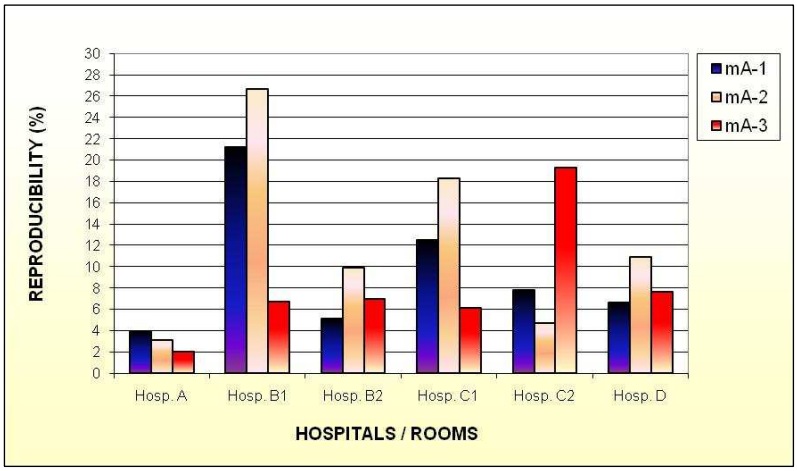

Figure 3. X-ray tube output constancy. Current values: mA-1 < mA-2 < mA-3 (covering all range clinically used in each hospital).

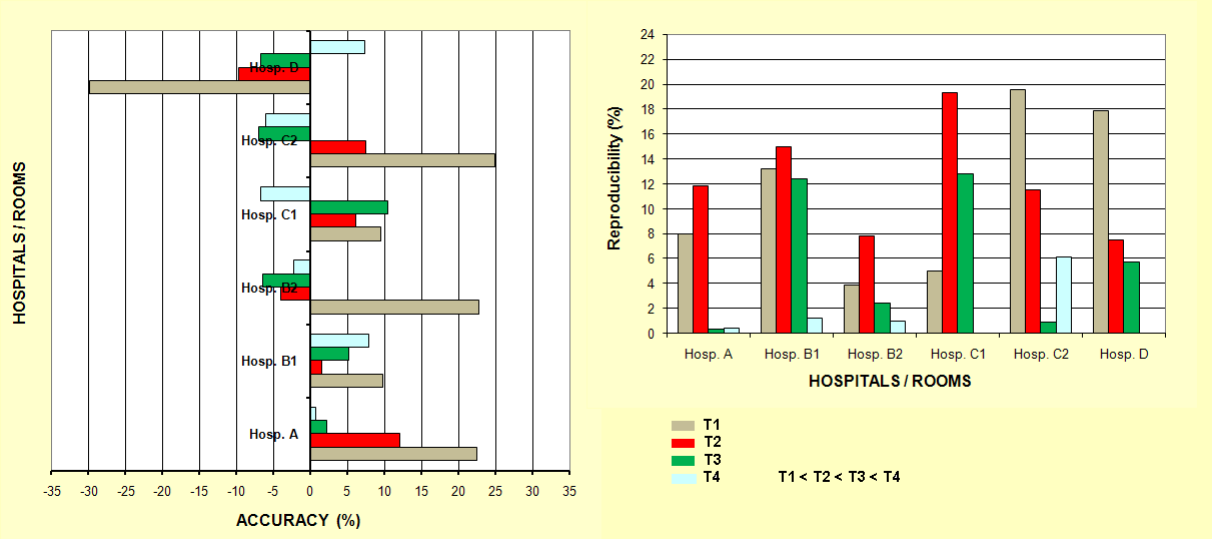

Figure 4. Accuracy and reproducibility of the exposure times. Exposure time values (Ti), covering all range clinically used in each hospital.

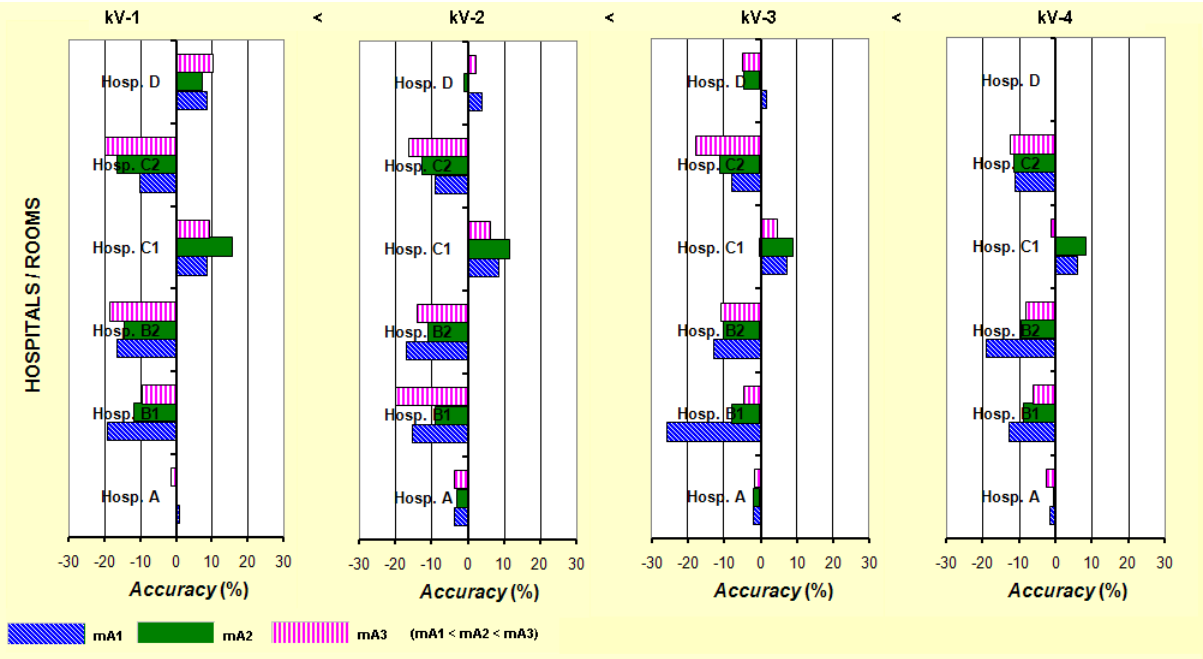

Figure 5. Accuracy of the tube potential. Tube potential values (kV-i) covering all range clinically used in each hospital.

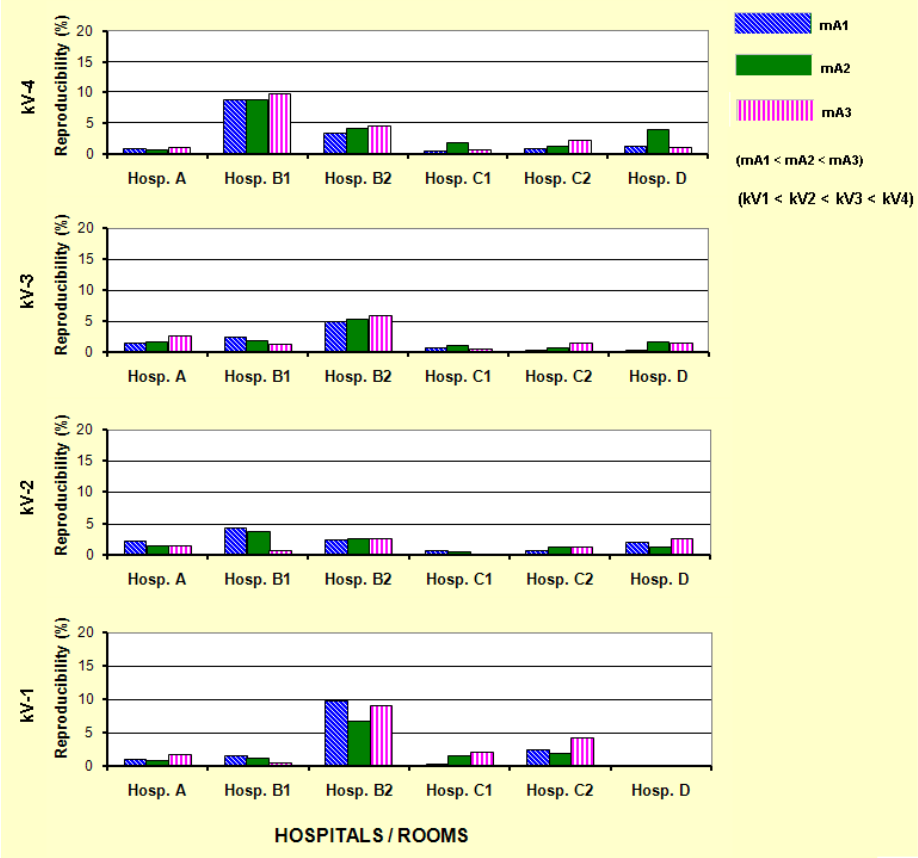

Figure 6. Reproducibility of the tube potential. Tube potential values (kV-i) covering all range clinically used in each hospital.

Table 2. HVL values for the equipments of the hospitals studied and the exposure parameters used for the measurements.

Hospital / Room	**Tube Potential** (kV)	**Current** (mA)	**Time** (ms)	**HVL** (mm Al)
Hosp. A				
	81	160	125	3.40 ± 3%
Hosp. B				
Room 1	80	200	100	3.56 ± 6%
Room 2	80	300	100	3.61 ± 2%
Hosp. C				
Room 1	80	200	100	3.00 ± 4%
Room 2	81	160	125	3.12 ± 5%
Hosp. D				
	70	200	100	1.70 ± 5%

Table 3. X-ray / light beam alignment and accuracy of the X-ray field indicator for the equipments of the hospitals studied.

HOSPITAL / ROOM	**ACCURACY** (%)	**ALIGNMENT** (^{o})
Hospital A		
	< 1.0	< 1.5
Hospital B		
Room 1	< 1.5	< 1.5
Room 2	< 1.0	< 1.5
Hospital C		
Room 1	< 1.0	< 1.5
Room 2	< 1.0	< 3.0
Hospital D		
	< 1.5	< 1.5

The X-ray tube output at 80 kV for the equipments of the hospitals were lower than acceptance range recommended by Brazilian standard (2.4 to 4.8 mGy . m^2 . mA^{-1} . min^{-1} for single-phase units and 4.8 to 6.4 mGy . m^2 . mA^{-1} . min^{-1} for three-phase units). However, the recent protocol published by the regulatory authority [4] only recommends that radiation output measured should be considered as a base line for future tests, if the remaining constancy tests present satisfactory results.

The Fig. 2 shows that only two equipments (Hosp. C - room 2 and Hosp. D) of two hospitals presented unsatisfactory results of linearity (> 20%). The Fig. 3 shows that the equipments of Hospital A and room 2 of the Hospital B, presented reproducibility lower than 10% (as the Brazilian standard recommends) for the current settings tested. The equipments of the Hospital C and D and room 1 of the hospital B presented satisfactory results of reproducibility only for some current settings.

Fig. 4 shows that for low time settings the accuracy of the exposure time was generally greater than 10% (the standard acceptance limit). For some time-current settings the equipments showed satisfactory results. It is important to mention that it is recommended the use of time exposures lower than 10 ms in X-ray examinations of children [1]. The only equipment that complies with this requirement is that from the Hospital A. For the parameter reproducibility of the exposure time we can see that only the equipment of the Hospital B room-2 presented satisfactory results (lower than 10%) for all current-time settings tested. We can see an improvement of the reproducibility with the increment of the time.

Fig. 5 and 6 show that only two hospitals (A and D) presented accuracy and reproducibility within the acceptance limits (10%); some equipments showed acceptable accuracy and reproducibility for some current-kV settings.

Tab. 2 shows that only the equipment of the Hospital D presented unsatisfactory HVL value (2.1 mm Al for 70 kV / single-phase unit). For the remaining equipments, the HVL values were greater than 2.6 mm Al (minimum value recommended for 80 kV / three-phase units). The high values of HVL for single-phase equipments can contribute to the low X-ray tube output, increasing the time exposure setting necessary to provide a good quality radiographic image.

Tab. 3 shows that alignments of the X-ray / light beam for all equipments were below the acceptance limit (< 3^o). In the same way, the accuracy of the X-ray / light field indicator was below the limits (< 2%).

4. CONCLUSION

It was observed that only one hospital had the suitable equipment for X-ray examinations of children. Results showed that all six equipments of the four hospitals presented unsatisfactory performance in some quality control tests. Only for some combinations of the exposure parameters, generally employed in pediatric X-ray examinations, some equipments complied with the authority requirements.

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