PAEDIATRIC PATIENT DOSIMETRY TOWARDS A PROGRAM TO REDUCE DOSE IN CHEST EXAMINATION IN CUBA

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Abstract

This work presents the results of a survey of Entrance Surface Air Kerma (K_e) values, organ doses, image quality and radiographic exposure parameters in paediatric chest examinations in Cuba, as a part of the activities under IAEA Regional Project RLA/9/067. It included patients from two age groups in three hospitals, one from Havana (west), Santa Clara (centre) and Holguín (East). Exposure parameters and patient information were recorded. Image quality was evaluated by radiologists based on the European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics. K_e values were estimated through the output of the X ray tube and organ doses were calculated using PCXMC-2, a PC-based Monte Carlo program. Results showed that K_e values present a wide dispersion, ranging from 105μGy to 343μGy for newborn patients, and 25μGy to 371μGy for infants. The average organ equivalent doses in PA chest projections of newborn were 0.0092 mSv for thyroid, 0.05 mSv for lungs, 0.016 mSv for bone marrow and 0.049mSv for heart. For infants the organ doses were 0.0035 mSv for thyroid, 0.04 mSv for lungs, 0.013 mSv for bone marrow and 0.019 mSv for heart. This study contributes to determining preliminary reference dose levels for paediatric chest examinations in Cuba.

1. INTRODUCTION

In diagnostic radiology the image should be obtained with the lowest necessary dose to have the largest amount of information in the image. Therefore, periodic dose assessment should be made to encourage the optimization of the radiological procedures. Special attention is necessary for the paediatric X ray examinations, since children have a longer life expectancy than adults and they are more sensitive to ionizing radiation [1]. In fact, it is assumed that children at ages up to 10 years are more radiation sensitive than the average population by a factor of three [1].In particular, in Cuba, newer and older equipment can be found in operation and this fact influences the quality of the service offered to the population. On the other hand, there is no established national reference dose for paediatric chest X ray examinations. For this reason, the aim of this study is to evaluate the Entrance Surface Air Kerma (K_e), the image quality and organ doses for paediatric chest examinations performed in Cuba, to contribute to the establishment of the national reference doses and to contribute to the optimization of radiation protection of the patient. This study is a part of the activities under the IAEA Regional Projects RLA/9/057 and RLA 9/067, whose objective is to optimize the radiological protection of patients in diagnostic and interventional radiology, nuclear medicine and radiotherapy in the Latin America region.

2. METHODOLOGY

This study was carried out in three Cuban hospitals, one being located in Santa Clara City (Institution A), another in Holguín City (institution B), and the third in Havana City (institution C). Institutions A and C have X ray equipment manufactured by Shimatzu with, respectively, nine and seven years of operation, and institution B has a Toshiba X ray equipment that is six years old. The study was performed on two age groups of patients: group 1- newborn up to 1year old, and group II - children with ages from 4 to 6 years old. In each institution, 25 patients were evaluated per examination for each group. For each child, the height, weight, AP diameter, as well as the distance from the centre of the light field to the film were recorded, in addition to the exposure parameters used

for the examination. Entrance Surface Air Kerma (K_e) was estimated using the following equation 1:

$$K_e(kV) = Y_{exam}.Q_{exam}.\left(\frac{1}{FSD}\right)^2.BSF \qquad (1)$$

where:

Y_{exam} is the output of the X ray tube in mGy•mAs^{-1}, at 1 m distance from the focal-spot, for the kVp value used in the examination. This value was obtained by the interpolation from the curve of the output of the X ray tube versus the voltage. The output was previously measured with a calibrated ionization chamber, placed at 100 cm from the X ray focus and at 25 cm from the table top, in order to prevent inaccurate readings caused by backscattering.

Q_{exam} is the product of the current, in mA, and the exposure time, in *s*, used in the examination.

FFD is the focal-spot to film distance, in *m*.

BSF is the backscatter factor. The value 1.35 was adopted for all patients [2].

The image quality was evaluated based on the European Guidelines on Quality Criteria (EGC) for Diagnostic Radiographic Images in Pediatrics [3] and the K_e values corresponding to the images that fulfilled at least 80% of the EGC were used to estimate the value of the reference dose. The organ doses were calculated using the PCXMC software [4]. It is a PC-based Monte Carlo program for calculating patients' organ doses and the effective dose in medical X ray examinations. It uses mathematical phantom models, and can be used to compute the doses in 25 organs of patients of different ages and sizes in freely adjustable X ray projections and other examination conditions of projection radiography and fluoroscopy.

3. RESULTS AND DISCUSSION

Table 1 presents the results of the average, minimum and maximum values of the exposure parameters used by the three institutions evaluated for paediatric chest X ray examinations. According to the quality criteria of the European Guidelines for newborn chest images, kVp should be between 60 and 65 kVp and the focus-film-distance (FFD) should be between 80 and 100 cm [3].The analyses of the results presented in Table 1 show that kVp values used by the three institutions are comparable to those recommended in the Commission of European Communities (CEC). Concerning the FFD values, institution A uses high FFD values and high mAs, which are outside the recommended CEC values. Institution A uses grid for newborn chest examinations, although this is not recommended for newborn images. This fact explains the high values of mAs used.

The analysis of the exposure parameters used for patients between 4 and 6 years old also show that there is no significant difference in these parameters and those used for newborn patients. The kVp values are near the lowest recommended values in CEC guidelines, that is, 60 to 80kV.

Figures1a and 1b present the Entrance Surface Air Kerma (K_e) values obtained for the chest radiographic examinations of patients from Group I and II, respectively. The data are presented in a box-and-whiskers plot for the first and third quartiles and the median. On the other hand, the results of the radiographic image quality, evaluated by the local radiologist based on the European Guidelines, show that at least 86% of the images performed at the three institutions are in accordance with the standards established by CEC.

TABLE 1. AVERAGE (MINIMUM AND MAXIMUM) VALUES OF THE EXPOSURE PARAMETERS USED BY THE CUBAN INSTITUTIONS FOR CHEST X RAY EXAMINATION IN PA PROJECTION FOR NEWBORN AND 4-6 YEAR OLD PATIENTS.

Institution	Patient Group I Newborn			Patient Group II 4-6 years old		
	Tube potential (kV)	Current-time product (mAs)	FFD (cm)	Tube potential (kV)	Current-time product (mAs)	FFD (cm)
A	62.5 (60-65)	12.5 (14-18)	172 (172)	65.2 (60-70)	14.8 (12-18)	172 (172)
B	60.7 (53-74)	3.7 (2.5-5)	99 (99)	63.4 (55-73)	4.1 (2.8-6.3)	148 (99-197)
C	58.7 (55-60)	3.6 (3-4)	99 (99)	60.9 (56-68)	5.1 (1.0-6.3)	99 (99)

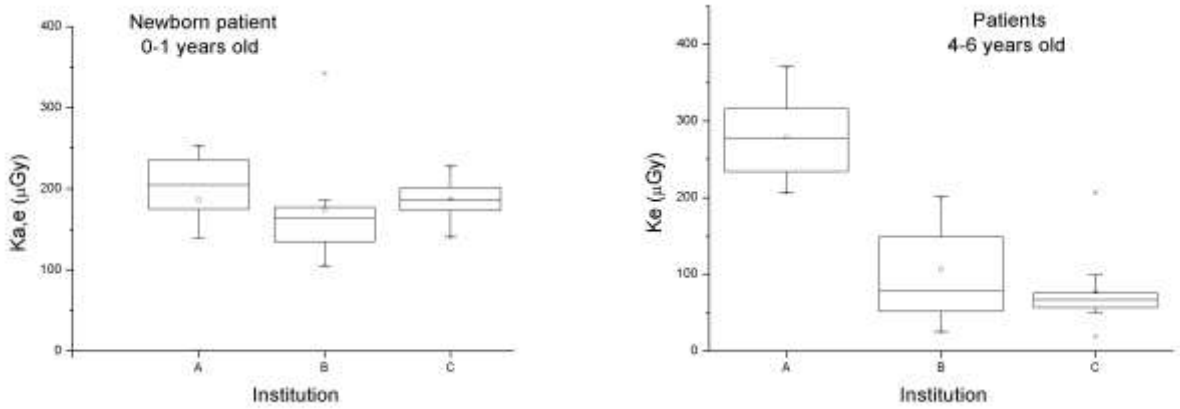

FIG. 1. Distribution of the Entrance Surface Air Kerma (K_e) for chest examinations for each institution for chest examinations in AP projections with patient´s age: a) Group I - 0 to 1 year old, b) Group II - 4-6 years old.

Table 2 presents the mean value, minimum, and maximum of K_e and the percentage of the chest examinations performed for newborn and infant patients that meet the CEC criteria. The table also shows the values of the 3rd quartile for the K_e distribution in each hospital. The results show that in the three hospitals and for new born patients the 3rd quartile of K_e exceeds the reference dose value for newborn chest examination given in the European Guidelines, that is, 80µGy. In the case of infant patients, institution C presents the 3rd quartile value for K_e lower than 100µGy, that is, the European reference value for 5-year old patients [3].

When compared to similar studies, the K_e values found in this study are higher than those reported by Azevedo et al [5] and Lacerda et al [6] in Brazil, and similar to those reported by Kumaresan et al in India [6]. In order to estimate reference dose levels (RDL) for chest paediatric examinations for Cuba, we calculated the value of the third quartile of the K_e values of the three institutions that correspond to the images that fulfilled at least 80% of the CEC. The results showed a reference dose value of 200µGy for newborn patients and 130 µGy for the infant patients between 4 and 6 years old. The RDL for newborn chest examination are higher than RDLs obtained in previous studies performed in Brazil, Costa Rica and Ecuador, where the value was 135µGy. For infant patients, the RDL obtained in the current study is lower than 180µGy, the RDL value obtained in Brazil, Costa Rica and Ecuador. On the other hand, the Cuban reference dose value obtained in this study is 2.5 times higher than the value established by the CEC for newborn patients, and is 30%

higher than the value established by the CEC for 5-year old patients. Reduction of the doses can be obtained by increasing the tube potential and reducing the mAs values and, in the case of newborns, performing the examinations without using the grids.

TABLE 2. PERCENTAGE OF THE IMAGES THAT REACHED THE QUALITY CRITERIA AND THE K_E VALUES FOR EXAMINATIONS OF NEWBORN PATIENTS AND THOSE BETWEEN 4 AND 6 YEARS OF AGE.

Institution	Newborn patients				Patients between 4 and 6 years of age			
	Percentage of images fulfilling ≥80% of the quality criteria	Entrance surface air kerma (μGy)			Percentage of images fulfilling ≥80% of the quality criteria	Entrance surface air kerma (μGy)		
		Min-Max	Average	3rd quartile		Min-Max	Average	3rd quartile
A	100%	139-253	205	224	100%	206-371	279	310
B	95%	105-343	176	180	85%	25-201	103	150
C	87%	154-251	207	238	86%	19-207	77	78

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The average organ doses values for the main organs, calculated using PCXMC-2, are shown in Figure 2. The results show that for newborn patients the thyroid dose is higher than for infant patients, indicating that the collimation of the X ray field is not optimized.

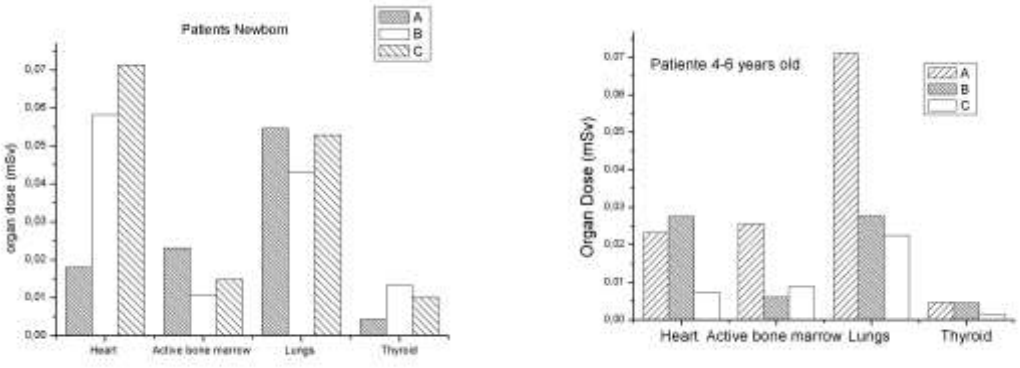

FIG. 2. Average organ doses values for the main organs.

4. CONCLUSIONS

This study has shown that the preliminary value for reference dose for paediatric chest examination in Cuba is higher than the values established by the CEC, due to low kV, high mAs and the use of grids for newborn examinations in some institutions. The results obtained are useful in the establishment of a baseline for the Cuban radiation protection program for paediatric radiology.

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