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Article

A comparison of age-dependent entrance skin doses in pediatric chest exams with diagnostic reference levels for the Antioquia region of Colombia

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ABSTRACT **In pediatric radiology, radiological protection is of vital importance due to the great radio-sensitivity of body tissues in childhood, which can come to present stochastic effects as children have a longer life expectancy. The objective of this research is to establish diagnostic reference levels in chest exam pediatric patients. The study, carried out in one of the largest pediatric centers of the city of Medellin, the capital of the Department of Antioquia, consisted of the calculation of the Entrance Skin Dose (ESD) for a sample of 814 chest radiographic studies in the anteroposterior (AP) and left lateral (L LAT) projections, and it was compared with the doses obtained with the computational program PCXMC 2.0. For the estimate of the Entrance Skin Dose, data were collected from the exams, including the size of the radiation field, mAs and kVp. The ESD in chest exams for 5-year-old children was the only one that exceeded the international reference levels, giving evidence of the need to optimize the techniques used in this type of study in the institution under evaluation.**

Keywords: pediatric / X-ray imaging / dose reference level / radiography / radiation dose

Introduction

The medical condition of a patient in many cases can be established by the images produced by X-ray. In the field of radiology, patients are exposed to different quantities of radiation depending on the type of exam. This radiation can affect the quality of the image, which is very important for the radiologist's diagnosis. It has been demonstrated through radiobiology research papers that radiation can produce other genetic effects; these effects are known as *stochastic*, and are characterized by the fact that their probability increases with the dose (UNSCEAR, 2000). The objective of *radiological protection* (in the context of diagnostic radiology) is to minimize the probability of stochastic effects. The diagnostic reference levels (DRLs) are intimately related to the concept of the optimization

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of radiological protection, and they try to harmonize the techniques utilized in the different hospital centers, on regional and national levels, to thereby avoid the dose variability which was found in the study (IAEA, 2004) due to the different radio-diagnostic practices used.

Childhood diagnostic X-ray exams require special care due to the fact that children have a longer life expectancy and therefore, they have greater propensity for the stochastic effect of radiation (BEIR, 2006). Chest radiography is carried out with more frequency in pediatric hospitals, therefore implying a greater significance in the radiological risk to children.

Some international publications (EC, 1996; NRPB-R289, 1996) have reported reference levels for distinct types of exams and projections with which we can contrast our outcomes and thereby be able to make decisions on the technique used or on the quality control of the equipment utilized.

A quantity which in a trustworthy manner correlates the risk with medical exposure is the effective dose (ICRP, 1991). This quantity is not easy to measure in a routine exam because it is necessary to resort to indirect measures such as the Entrance Skin Dose (ESD). This research is the start of establishing a methodology which will allow establishing the pediatric reference dose in the Antioquean Region in Colombia.

Methodology

The pediatric X-ray unit of the *Fundación Hospitalaria San Vicente de Paúl* in the city of Medellin was chosen for this study due to the fact that it receives a considerable quantity of pediatric patients from the Antioquean Region. From the data collected in the hospital, a sample of 471 patients between the ages of 0 and 13 years old was obtained, corresponding to 814 radiographic studies for the AP and L LAT projections in chest exams.

The X-ray equipment employed in this study is a G.E. PROTEUS XR/a, which possesses an X VARIAN RAD 14 X-ray tube with 0.6 and 1.2 mm focal spots and with a total filtration of 2.6 mm of Al. To verify the physical conditions of the X-ray machine, a quality control check was carried out. From the sample collected from technical data used in the radiographic studies, it was found that the institution handles a range of kilovoltages between 55 and 110 kVp and times of exposure which go from 10 to 32 ms. Measurements of the nominal values of these parameters were carried out, and the outcomes of the evaluation showed a deviation of 3.7% for the average kVp, and a 4% deviation for the time of average exposure, giving evidence of good conditions for the operation of the machine. In order to verify the output of voltage from the equipment, the Ripple percentage was calculated, as it is an influential factor in patient dose. This is why measurements of kilovoltage were carried out with a PTW DIAVOLT UNIVERSAL X-ray meter (http://www.ptw.de/). Afterwards, the data was transferred to a computer by means of DiaControl software. The percentage of the Ripple obtained was 0.12. This value corresponds to a high-frequency generator which is the one recommended internationally for use in pediatric radiography. The institution has a CR 35-X computerized radiographic system from AFGA.

The ESD for each study was obtained from the Kerma incident in air at the distance of reference multiplied by an adequate retrodispersion factor, equation (1). The air Kerma was estimated from the measurements of output $Y(d)$ of the X-ray machine from a distance of one meter in a range of voltages and mAs used in the radiographic techniques employed in the institution. These measurements were corrected by a distance factor to the entrance of the patient and were multiplied by the product of the current and the time employed in each exam, as is shown in equation (2):

$$ESD = K_{ai} BSF, \tag{1}$$

$$k_{ai} = Y(d) \frac{d^2}{d^2{}_{FSD}} mAs. \tag{2}$$

The air Kerma measurements and quality control of the X-ray equipment were carried out with a flat ionization camera of 30 cm^3 PTW calibrated in the range of energy of the diagnostic radiology.

The value of the backscatter factor (BSF) used in the dosimetric calculations of the ESD for children between 1 and 13 years of age was taken from the literature (Petoussi-Henss *et al.*, 1998); a value of 1.3 was adopted, which is an average value chosen for the exam conditions for pediatric X-rays.

The half value layer of the equipment was calculated at 70 kVp, a field of 100 cm^2, and a distance for the tube focal spot to detector of 100 cm. The value obtained was 2.7 mm of Al.

The backscatter factor employed for the calculations of the dose in neonates was measured experimentally with a simulator and a value of 1.16 was obtained, which agrees with other research (Lacerda *et al.*, 2008). Additionally, the ESD for 0-, 1-, 5- and 10-year-old patients was calculated in AP projection with the computational program PCXMC 2.0 (Tapiovaara *et al.*, 2008). First, the parameters of the exam were adjusted, including the focal-spot/patient distance, the size of the field and the kVp. The median values used in the statistical sample were taken from the institution being studied. Afterwards, the Monte Carlo simulation was carried out with a number of $2e^5$ photons, and finally, the calculation of the dose was carried out, obtaining the incident air Kerma value. This value was multiplied by the retrodispersion factors previously chosen.

Results

The dose distribution (third quartile) for the AP and L LAT projections centered on age is shown in Figure 1.

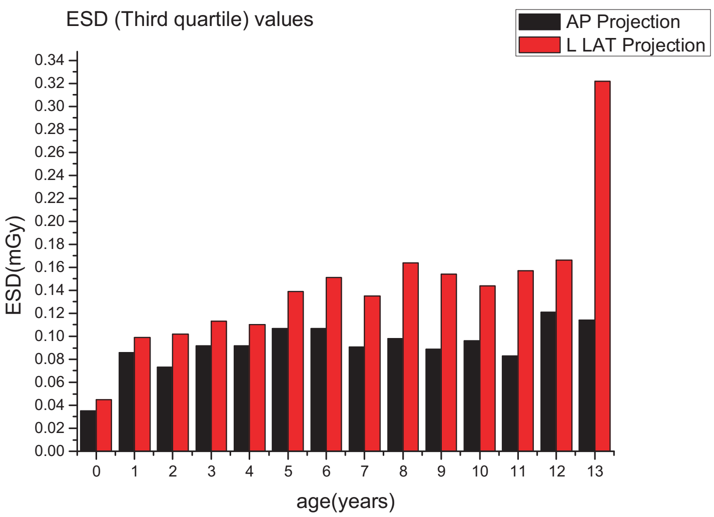

Figure 1 – ***Distribution of ESD (third quartile).***

The dose reported in the 0-6 range was estimated for non-cooperative patients, that is, patients who were positioned horizontally on the equipment table, while the dose estimated in children between 7 and 13 years of age was obtained for cooperative patients positioned vertically on the bucky. The ESD (third quartile) values obtained for those between 0 and 5 years of age in AP projection are higher than those obtained in those between 6 and 13 years of age due to the great difference in the focal point/patient distance used among these two types of projection. Contrasting with this situation, the entrance doses for the left lateral projection are higher in the 6- to 13-year-old range, due to the use of elevated kVp and mAs in the studies. The dose with the highest value presents itself in children from 12 and 13 years of age. This is due to the elevated parameters of kVp and mAs employed in the studies. Furthermore, the sample of radiographic data is quite small compared with that for other ages. The exposition parameters and the number of projections for each age are presented in Table I and Figure 2, respectively. The radiographic study sample was collected from September 3, 2010 until July 18, 2011.

TABLE I

Mean values of parameters in AP projections for X-ray chest examination.

Patient age (years)	kVp	mAs	d_{FSD} (cm)
0	55.7	1.0	92
1	62.8	1.5	87.2
2	62	1.3	86.4
3	63.6	1.4	86
4	63.8	1.5	85.6
5	64	1.4	84.4
6	63.1	1.4	84.6
7	74.4	2.8	160.2
8	78.2	3.0	160
9	78.4	2.8	159.4
10	73.5	3.3	158.8
11	72.1	2.4	158.1
12	74.4	3.9	157.5
13	75.3	2.8	156.4

d_{FSD}: Focus surface distance.

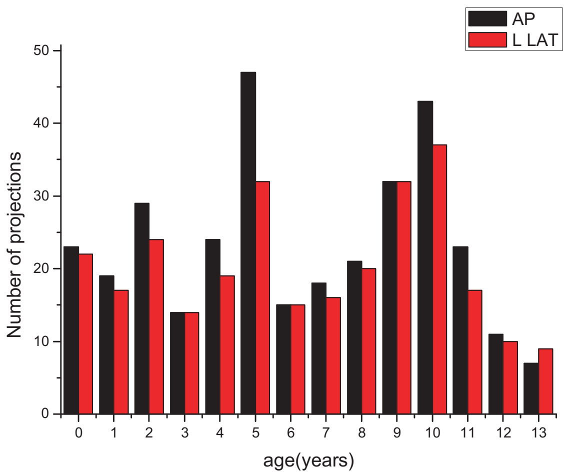

Figure 2 – ***Number of projections collected in the institution used in the dose calculations.***

TABLE II

Comparison of third quartile ESD (μGy) values for examination of the chest with international DRLs.

		ESD (μGy)		
Age of patient (years)	Projection	This work	EC	NRPB
0	AP	34.8	80	50
1		86.2	135	50
5		107.5	100	70
10		96	****	120
0	L LAT	45.1	****	****
1		99.3	****	****
5		139.5	200	****
10		144.2	****	****

NRPB: National Radiological Protection Board. EC: European Commission. **** Unreported data.

Table II presents the comparison of the surface entrance dose (third quartile) in chest exams for the AP and L LAT projections in 0-, 1-, 5- and 10-year-old children with reference levels reported by the European Commission (EC) and the National Radiological Protection Board (NRPB). The doses for 0-, 1- and 10-year-old children are below the international reference levels, while the dose for 5-year-old children goes beyond them. This is due to the fact that various studies of the sample show high radiographic techniques, such as, for example, exposure times which were greater than those internationally recommended (10 ms) for this type of projection.

It is important to point out that these DRLs were obtained before the generalized introduction of systems of Computerized Radiography (CR) and Digital Radiography (DR) in many parts of the world, and that they need to be broadened and reevaluated (ICRP, 2004) in order to keep the most recent developments in mind.

Table III presents the comparison of the Entrance Skin Dose of the patients in the AP projection obtained by two different methods. The ESD values obtained with the PCXMC 2.0 program show good agreement with the mean value of the ESD estimated from the output of the X-ray equipment and the technical parameters for each study.

Table IV presents the comparison of the mean value of the ESD obtained for the radiographic research in this paper for neonate patients, with other research. In spite of using longer times than those recommended by the European Commission in chest exams in the AP projection in these patients (< 4 ms), the mean value of

TABLE III

Comparison of mean ESD values for AP projection in this study.

Age of patient (year)	Kvp	mAs	d_{FSD}(cm)	ESD (mGy)	
				Ionization chamber	PCXMC 2.0
0	56	1.0	92	0.033	0.036
1	62.8	1.5	87.2	0.087	0.086
5	64	1.4	84.4	0.090	0.088
10	74	3.3	158.8	0.078	0.078

TABLE IV

Comparison of ESD mean values for examination with other studies.

Study	ESD (mGy)
This work	0.033
Lacerda *et al.* (2008)	0.075
Armpilia *et al.* (2002)	0.036
Jones *et al.* (2001)	0.057
Dougeni *et al.* (2007)	0.034

ESD obtained is less than in other research due to the good conditions of the X-ray equipment and the techniques employed by the technicians in the institution.

The uncertainties associated with the measurements are reported with a basis in the methodology used in the OIEA professional practice code (IAEA, 2007).

Conclusions

Some reference levels for the surface entrance dose in patients from 0 to 13 years of age are established for AP and L LAT projections in chest exams, which will help to guarantee the good professional practice of these radiographic studies in agreement with the optimization of the radiological protection of the Department of Antioquia.

The study showed a great variability of the dose, but it is precisely this fact which brought us to establish the reference levels to harmonize the different techniques in X-ray services which allow for good diagnostic images at reasonable doses (ALARA).

The experimental results used to obtain the entrance dose of the patient in pediatric chest exams were validated with those obtained by the PCXMC program, showing the precision of the computational programs based on theoretical models for the calculation of dose.

According to the recommendations of the European Guides, the practice of L LAT projections in children's diagnostic chest exams should only be carried out when the reading of the AP and PA projections do not give the desired information. From the sample of studies collected in the FHSVP, we were able to observe a great demand for L LAT projections in pediatric patients, which is why the collective dose in the childhood population in the region increases greatly.

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