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Dose evaluation in paediatric patients undergoing chest X-ray examinations

F. Piantini[a], H.R. Schelin[a,*], V. Denyak[a,b], A.P. Bunick[a], A. Legnani[a], J.A. Ledesma[a], D. Filipov[c], S.A. Paschuk[c]

[a] Pelé Pequeno Príncipe Research Institute, Av. Silva Jardim, 1632, Curitiba, PR 80250-060, Brazil
[b] National Science Center 'Kharkov Institute of Physics and Technology', Akademicheskaya 1, Kharkiv 61108, Ukraine
[c] Federal University of Technology, Av. Sete de Setembro, 3165, Curitiba, PR 80230-90, Brazil

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ABSTRACT

This study aimed to estimate the incident air kerma in chest X-ray examinations, for lateral (LAT) and anterior–posterior (AP) (together with posterior–anterior (PA)) projections, in one of the largest paediatric hospitals in Brazil, and to compare these with the results obtained in a general hospital of the same city. The dosimetric results were analysed along with the patient characteristics and radiographer strategies. The examinations of 225 (119 male and 106 female) patients were studied and 389 X-ray scans (200 AP/PA projections and 189 LAT projections) of paediatric patients were acquired. For analysis of the results, the patients were divided into the following age groups: 0–1 y, 1–5 y, 5–10 y, and 10–15 y. Patient's thickness can be determined from age, height or weight with an uncertainty of 20–30%. In different hospitals, the difference in patient's thicknesses between the same age groups can reach 25–55%. A minimal correlation between the patient dose and thickness was observed, with a 4-fold difference in the dose for patients of the same thickness. By standardizing radiological protocols, it should be possible to keep the dose within intervals of 50–100 µGy for LAT projection and 40–80 µGy for AP/PA projection.

1. Introduction

The radiation dose to which children are exposed from diagnostic radiology examinations has become of great concern over the past three decades, mostly because of its growing contribution to overall radiation exposure, and also because X-ray equipment is not optimized for paediatrics use. Other essential factors with an impact on such investigations are the longer life expectancy of children, relative to adults, which increases the associated radiation risk, and the elevated radiosensitivity. Another new risk factor is the digital nature of modern image receptors, which has significantly increased the upper limit of the detector and, consequently, possible patient exposure.

In the late 1980s, intensive studies led to the creation of European diagnostic reference levels (DRLs) and a number of national DRLs (UNSCEAR, 2013; IAEA, 2013). In Brazil, such investigations started in the early 2000s (Khoury, 2001; Mohamadain, 2003), and have been performed in a few hospitals to date. Considering the fact that DRLs are subject to change as radiographic equipment and technique improve, achievement in dose-reduction is of constant interest, particularly in paediatric hospitals.

Chest radiography is the most frequently used paediatric X-ray examination. The aim of this study was to estimate the incident air kerma (K_i) in chest X-ray examinations, in lateral (LAT) and anterior–posterior (AP) (together with posterior–anterior (PA)) projections, in one of the largest paediatric hospitals in Brazil and to compare these findings with the results obtained in the general hospital of the same city (Porto et al., 2014). The dosimetric results are discussed along with a detailed analysis of the patient characteristics and radiographer strategies.

2. Materials and methods

The study was performed at the Pequeno Príncipe Hospital, one of the largest paediatric hospitals in Brazil. The project was approved by the ethics committee of the hospital that is linked to the Brazilian Federal Government. All patients' parents received information and approved the survey.

The examinations of 225 (119 male and 106 female) patients were studied. In 94% of these examinations, the LAT projection was requested together with the AP/PA projection. The indications for the examinations were cough, fever, and suspicion of bronchitis or pneumonia.

In this study, 389 X-ray examinations (200 AP/PA projections and 189 LAT projections) of paediatric patients were acquired. Only the

* Corresponding author.
E-mail address: schelin2@gmail.com (H.R. Schelin).

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examinations that resulted in diagnostically acceptable radiographs were included in the study. For analysis of the results, the patients were divided into the following age groups: 0–1 y, 1–5 y, 5–10 y, and 10–15 y. The number of AP/PA (LAT) examinations analysed was: 59 (53) in the 0–1 y group, 72 (72) in the 1–5 y group, 48 (43) in the 5–10 y group, and 21 (21) in the 10–15 y group.

For each examination, the patient's weight, height, age, and lateral and frontal thicknesses were noted, together with the tube voltage (kVp), current-time product (mAs), and focus-surface distance (FSD).

The X-ray equipment used was a Siemens Polymat Plus S (2011), high-frequency three-phase model, with a 2.5-mm Al total beam filtration. A Potter–Bucky grid was used in 70 examinations (with 20 examinations in the group 5–10 y and 41 examinations in children above 10 years of age).

To determine the incident air kerma (K_i) values, the radiation outputs of the X-ray tube for different tube voltages (Y(kVp)) were measured using an ionization chamber (Model 10×5–6, Radcal Corp.) with a 6-cm^3 sensitive volume. The ionization chamber, connected to an electrometer, was placed 25 cm from the table top to prevent the influence of backscatter and at a distance d =100 cm from the X-ray focus. The exposures were acquired and the output was recorded for 10 mAs in a tube potential range of 50–90 kVp, at 10 kVp increments.

The K_i values for kVp, mAs and FSD used in the examinations were calculated with the formula:

$$K_i = Y(kVp)\cdot\left(\frac{d}{FSD}\right)^2\cdot mAs$$

with an overall uncertainty less than 15%.

3. Results and discussion

3.1. Patient characteristics

The patient's thickness is the most important characteristic when choosing the radiological protocol, first of all, when choosing kVp. Other patient characteristics, such as age, weight, and height correlate with thickness and can be used for its evaluation.

3.1.1. Thickness

Table 1 shows the parameters of the thickness distributions of the patients. The thickness distributions are symmetrical. Their dispersions are almost equal for children up to the age of 10 years, with a two-fold increase for the 10–15 y age group.

A comparison with the results of our previous study (Porto et al., 2014), which was performed at the general hospital in the same city, showed that, on average, the thickness was 4.5 cm lesser in patients in the paediatric hospital. For patients with a thickness of 10–20 cm, such a difference is significant when deciding on exposure techniques. Thus, age group is not an appropriate parameter for comparison of exposure techniques and doses in different hospitals, and thickness measurements should be used in such studies.

The correlation (Fig. 1) between the frontal and lateral thicknesses of the patients shows that the lateral thickness is approximately equal to the frontal thickness plus 5 cm. The more correct formula, which was obtained by fitting a straight line to the data points, as shown in Fig. 1, determines this relationship with an error of 20–30%.

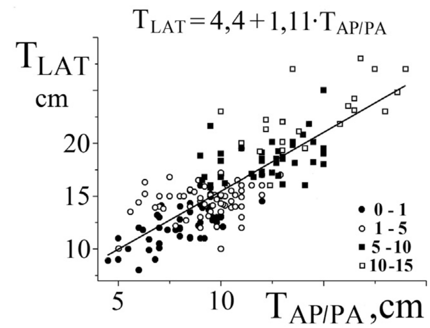

Fig. 1. Correlation between the frontal and lateral thicknesses of patients. The points indicate the measurements. The straight line and the formula demonstrate the results of fitting.

Fig. 1 shows that the thicknesses of the neighbouring age groups overlap significantly. Thus, the sizes of the previously mentioned age groups should be revised to establish a single radiological protocol for each group.

3.1.2. Age

The correlation between the patient's age and thickness is presented in Fig. 2. The dependence is linear, and the thickness can be calculated with an error of 20–30%, which practically does not depend on age. Thus, patient's age can substitute patient's thickness when establishing radiological protocols.

In practice, a more convenient method is to establish age groups with fixed radiological protocols within the group. The thickness dispersion for each age sets the lower limit for the group size. With the increase in the dispersion and decrease in the straight line angle (Fig. 2), the lower limit increases. In the extreme case of an angle equal to zero, only 1 age group exists and a single protocol can be used.

The equality between the thickness dispersion and the change in its mean value within the age group can be chosen as a criterion for evaluating group size. A dispersion value equal to 2 standard deviations can be used. The change in the mean thickness value within the age group and the group size are linked via the fitting curve formula.

In the case of correlation between the patient's age and thickness, the standard deviation was equal to 1.65 cm for the LAT thicknesses as well as for the AP/PA thicknesses. The calculated group size was 3.8 years for LAT projection and 6.0 years for AP/PA projection. For practical purposes, the age groups 0–5 y, 5–10 y, 10–15 y can be suggested for AP/PA projection and 0–3 y, 3–6 y, 6–9 y, 9–12 y, 12–15 y for LAT projection.

3.1.3. Height

Fig. 3 shows the correlation between the patient's height and thickness. As in the case of age, there is a linear relationship, and the

Table 1
Parameters of the thickness distributions (cm).

Project	Age group	Mean	Median	Stand. dev.	Min.	Max.	1st quartile	3rd quartile
LAT	0–1	12.1+/−0.2	12.1	1.6	8.0	16.0	11.1	13.0
	1–5	14.6+/−0.2	15.0	1.6	10.0	19.5	13.9	15.5
	5–10	18.5+/−0.3	18.4	1.8	15.8	25.0	17.1	19.5
	10–15	22.5+/−0.7	22.2	3.1	16.0	28.0	20.1	24.2
AP/PA	0–1	8.1+/−0.2	8.0	1.6	4.5	12.0	7.0	9.3
	1–5	9.3+/−0.2	9.5	1.6	5.0	12.9	8.4	10.3
	5–10	12.1+/−0.3	12.0	1.8	9.0	15.0	10.8	13.5
	10–15	14.5+/−0.6	13.8	2.6	10.0	19.0	12.4	16.5