Radiation Dose to Pediatric Patients undergoing Chest X-Ray procedures in Rio de Janeiro, Brazil

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Abstract: The aim of this study was to evaluate the distribution of entrance surface air kerma values (ESAK) in pediatric chest X-ray examinations and the image quality. The research was carried out in two X-ray rooms of a pediatric Public Hospital of Rio de Janeiro. The sample of 292 patients (370 radiographs images) was classified by age groups: 0-1 year-old, 1-5 years-old, 5-10 years-old and 10-15 years-old. The ESAK values for chest radiographs were estimated from X-ray tube output rate (mGy/mAs) parameters. The RADCAL dosimetric device was used for the measurements of incident air kerma. The radiologists evaluated the chest image quality in AP/PA projections for 10 patients in each room. The corresponding values of ESAK for AP/PA Projection to the third quartile for Room 1 were approximately 0.08 mGy for 0-5 years-old and 0.11 mGy for 5-15 years-old. In Room 2, the third quartile was 0.05 mGy for 0-10 years and 0.09 for 10-15-years for PA/AP Projections. In the Lateral projection, the values of ESAK were approximately the double of AP/PA projections. The image evaluation showed that all criteria received scores above 80% except the criteria 1 (performed at peak of inspiration) and 2 (reproduction of the chest without rotation and tilting). These results indicate difficulties in the correct positioning of the younger patients, lack of appropriate immobilization devices and the poor experience of the technologist to perform examinations in pediatrics patients. The main reasons for films rejected were overexposure, underexposure, patient motion and positioning. The ESAKs values obtained in this work were the same order of the values reported in literature however the results indicate a large potential of dose reduction and the development of optimization programs.

KEYWORDS: Pediatric Dosimetry, Chest X ray and Optimization

1. Introduction

The Optimisation of radiological procedures requires special attention for pediatric patients, since the risk factors for ionising radiation are greater in children than in adults\textsuperscript{1}. The International Commission on Radiological Protection\textsuperscript{2-4} does not recommend application of dose limits for patients but points out the importance of application of reference levels as a tool in the process of optimisation of protection in medical exposure.

The optimal utilization of ionizing radiation involves three important aspects of the image processing: diagnostic quality of the radiographic images, patient radiation dose and the choice of radiographic technique\textsuperscript{5}.

In pediatric procedures, the correct selection of technical factors (kV and mAs) is difficult because of the great patient size variation (height and weight) for different age groups\textsuperscript{6} and also for the same age groupe, hindering the establishment of standard radiographic exposure tables. The lack of patient cooperation during the examinations and specialized pediatric technologist also affect the quality of radiographic images.

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Studies carried out in several regions in Latin America, and in particular in Brazil, have shown that in general, technologists carried out the pediatrics radiographies without the necessary knowledge in pediatric radiology and especially on the treatment with children in order to obtain their collaboration. Besides, the radiology department don’t have available shielding devices to protect radiosensitive organs of the patient neither immobilization devices. The first consequence is the high level of films rejected.

Simple solutions applied to routine activities may reduce patients dose and improve images quality. However, it is necessary to implement quality assurance programs, including training courses. Continuum evaluation of patient doses correlated with the image quality is an essential part of this program. The development of simple and low cost shielding devices for pediatric patients and the correct utilization during radiological procedures contribute to a better radiological protection.

The objective of this study was to evaluate the distribution of entrance surface air kerma (ESAK) in pediatric patients undergoing Chest X-ray examinations (AP/PA and Lateral), the image quality, the percentage of film rejects and evaluate the conduction of the procedures. The ESAK values were compared with the reference values established by the European Commission.

2. Material and Method

The research was carried out in two X-ray rooms of a pediatric Public Hospital located in Rio de Janeiro. A sample of 292 patients was randomly selected with a total of 370 chest radiographs images. The radiographic data recorded for each examination were: the radiography identification number, the age, height and weight of the patient, radiographic techniques (kV, mAs, focus-film distance) and the utilization or not of devices for shielding protection and immobilization. The sample was classified in four groups: 0-1 year-old, 1-5 years-old, 5-10 years-old and 10-15 years-old.

2.1 Image Quality Evaluation

The radiologists of the department evaluated the image quality of the chest images (AP/PA) of 10 patients in each room. This evaluation was based on the eight criteria for diagnostic radiographic images established in the European Guidelines.

2.2 Determination of the entrance surface air kerma (ESAK)

The ESAK values for chest radiographs were estimated from X-ray tube output rate (mGy/mAs) parameters. The ionizing chamber of 6 cm³ connected to the electrometer Radcal 9015 was used for the measurements of incident air kerma. The chamber, positioned on a holder of 20 cm of non-scattered material, was aligned with the center of the radiation field at 100 cm distance from the focus. It was fixed a radiation field approximately 5 cm greater than the sensible volume of the chamber.

The current time product was fixed in 50 mAs. Three readings were carried out for each kilovoltage value (50, 60, 70, 80, 90, 100 kVp). The obtained data led to establish the yield curve in function of the kilovoltage applied to the tube.

The ESAK was obtained from adjustment equation of the radiation output rate (mGy/mAs) and of the technical factors applied to each exam. In the case of a curve adjusted for equation \( y = ax^b \) the estimation was done using the following equation:

\[
K_z = K_0 B = Y P_{ref} \left( \frac{d_{ref}}{d} \right)^2 B = a U^b P_{ref} \left( \frac{d_{ref}}{d} \right)^2 B
\]

(1)

Where:
**K** is the entrance surface air kerma; **K** is the incident air kerma corrected for temperature and pressure; **B** is the backscatter factor (1.36); \(Y = aU^b\) is the radiation output rate, where **a** and **b** are the coefficients obtained in the adjustment of the curve and **U** is the tension applied to the tube during the exam (kVp); **P** is the tube loading (mAs) chosen during the exposition of each patient; **d** is the focus-skin distance.

**2.3 Film Analysis Rejection**

Due to the high number of repetition of the examinations in the department, a study was carried out during one month in order to define the main causes of this problem. The classification was based on the following factors: exposure technique (under or overexposure), processing, positioning and image artifacts.

**3. Results and Discussions**

**3.1 Characteristics of the X rays rooms**

The radiographic parameters employed in Rooms 1 and 2 for Chest examinations for AP/PA and Lateral projections are summarized in Table 1 and 2.

**Table 1. Radiographic parameters for Chest AP/PA projection.**

<table>
<thead>
<tr>
<th>Room</th>
<th>Age group (years)</th>
<th>Number of patients</th>
<th>Thickness (cm)</th>
<th>kVp</th>
<th>mAs</th>
<th>Focus-Film Distance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 1</td>
<td>30</td>
<td>12.2 ± 1.5</td>
<td>58.4 ± 2.3</td>
<td>2.2 ± 0.3</td>
<td>131.0 ± 7.6</td>
</tr>
<tr>
<td></td>
<td>1 - 5</td>
<td>57</td>
<td>15.5 ± 1.9</td>
<td>64.0 ± 10.1</td>
<td>2.3 ± 0.4</td>
<td>138.0 ± 15.8</td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>23</td>
<td>19.5 ± 4.1</td>
<td>73.3 ± 13.9</td>
<td>2.5 ± 0.8</td>
<td>146.6 ± 15</td>
</tr>
<tr>
<td></td>
<td>10 - 15</td>
<td>17</td>
<td>21.9 ± 2.5</td>
<td>81.3 ± 11.4</td>
<td>3.2 ± 0.9</td>
<td>153.5 ± 18.8</td>
</tr>
<tr>
<td>2</td>
<td>0 - 1</td>
<td>30</td>
<td>13.0 ± 1.4</td>
<td>56.0 ± 2.5</td>
<td>1.5 ± 0.4</td>
<td>122.6 ± 23.3</td>
</tr>
<tr>
<td></td>
<td>1 - 5</td>
<td>69</td>
<td>15.6 ± 1.9</td>
<td>58.7 ± 6.5</td>
<td>1.6 ± 0.5</td>
<td>136.3 ± 17.7</td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>48</td>
<td>18.7 ± 2.1</td>
<td>61.2 ± 6.1</td>
<td>1.7 ± 0.4</td>
<td>158.9 ± 27.8</td>
</tr>
<tr>
<td></td>
<td>10 – 15</td>
<td>16</td>
<td>21.8 ± 1.6</td>
<td>73.9 ± 16.6</td>
<td>2.1 ± 0.5</td>
<td>153.6 ± 24.8</td>
</tr>
</tbody>
</table>

**Table 2. Radiographic parameters for Chest Lateral projection.**

<table>
<thead>
<tr>
<th>Room</th>
<th>Age group (years)</th>
<th>Number of patients</th>
<th>Thickness (cm)</th>
<th>kVp</th>
<th>mAs</th>
<th>Focus-Film Distance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 1</td>
<td>11</td>
<td>9.5 ± 1.1</td>
<td>67.0 ± 4.4</td>
<td>2.5 ± 0.4</td>
<td>133.9 ± 7.6</td>
</tr>
<tr>
<td></td>
<td>1 - 5</td>
<td>20</td>
<td>12.2 ± 2.0</td>
<td>80.9 ± 13.3</td>
<td>3.0 ± 0.5</td>
<td>145.7 ± 18.1</td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>7</td>
<td>14.9 ± 5.1</td>
<td>89.7 ± 18.3</td>
<td>5.1 ± 2.7</td>
<td>152.1 ± 20.2</td>
</tr>
<tr>
<td></td>
<td>10 – 15</td>
<td>4</td>
<td>17.5 ± 4.0</td>
<td>106.0 ± 9.1</td>
<td>4.7 ± 0.6</td>
<td><strong>174.0 ± 9.1</strong></td>
</tr>
<tr>
<td>2</td>
<td>0 - 1</td>
<td>6</td>
<td>10.2 ± 1.7</td>
<td>63.0 ± 6.2</td>
<td>1.9 ± 0.8</td>
<td>129.2 ± 1.0</td>
</tr>
<tr>
<td></td>
<td>1 - 5</td>
<td>17</td>
<td>12.1 ± 1.5</td>
<td>64.0 ± 8.7</td>
<td>1.7 ± 0.5</td>
<td>129.2 ± 5.9</td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>13</td>
<td>13.8 ± 3.6</td>
<td>69.1 ± 7.8</td>
<td>2.2 ± 0.8</td>
<td>159.1 ± 30.8</td>
</tr>
<tr>
<td></td>
<td>10 – 15</td>
<td>5</td>
<td>15.2 ± 1.9</td>
<td>87.6 ± 21.6</td>
<td>4.3 ± 0.6</td>
<td>157.8 ± 21.2</td>
</tr>
</tbody>
</table>
Comparison of the radiographic parameters with the European Guidelines\(^5\) (60 – 80 kV and 100 – 150 kV with grid for older children), it can be observed that the kVp values for both Rooms in Chest AP/PA were lower and inadequate for good radiographic technique recommendations. The same results can be verified for Lateral Projection. In general, the use of low kV values lead to a select higher mAs in order to produce an acceptable film density. In the focus-film distance (FFD), all age groups were within the recommended level (100-150 cm), except for aged group 10-15 /Lateral Projection.

During this survey was verify that the frequency of chest examination was greater for the 1-5 years old group (45%).

It is important to point out that during the radiological procedure more than 90% of the examinations were carried out without anti-scatter grid for any age range. The shielding devices are not available so anatomic parts of the patient were unnecessarily irradiated. The X-ray equipment did not allow selecting and/or changing the additional filtration that is essential in pediatric procedures.

### 3.2 Image Quality Evaluation

The image evaluation over clinical aspects (Table 3) shows the frequency of acceptability for each quality criterion analyzed for AP Projection in Room 1 and Room 2.

In Room 1 it was observed that the criteria 1 (performed at peak of inspiration) and 2 (reproduction of the chest without rotation and without tilting) show an range of acceptability between 90 to 100% for the groups: 0-1 year old and 1-5 years old.

The age group 5-10 years presented an acceptability of 100% in all quality criteria and the group 10-15 years for the criteria 1, 6 and 7 almost 90% of the images were in accordance with the requirements and the score for criteria 3 was 80%. The non-fulfillment of those criteria indicates difficulties in the correct positioning of the younger patients. A similar result was observed in Room 2.

So, the image quality criteria for each film were in general acceptable.

**Table 3. Frequency of acceptability of each criteria of image quality for both rooms**

<table>
<thead>
<tr>
<th>Image Criteria</th>
<th>Room 1</th>
<th>Room 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-1</td>
<td>1-5</td>
</tr>
<tr>
<td>1.Performed at peak of inspiration, except for foreign body aspiration</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>2. Reproduction of the thorax without rotation and without tilting</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>3. Reproduction of the chest must extend from just above the apices of the lungs to T12/L1</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>4. Reproduction of the vascular pattern in central 2/3 of the lungs</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>5. Reproduction of the trachea and the proximal bronchi</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>6. Visually sharp the diaphragm reproduction of and costo-phrenic angles</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>7. Reproduction of the spine and paraspinal structures</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>8. Visualisation of the retrocardiac lung and the mediastinum</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
3.3 Evaluation of the entrance surface air kerma (ESAK)

The distribution of values of the entrance surface air kerma for the four age groups (0-1, 1-5, 5-10 and 10-15 years-old) for different projections (AP/PA and Lateral), can be observed in Table 4 and 5.

3.3.1 Distribution of ESAK Chest AP/PA and Lateral Projections

In Room 1, it can be observed for AP/PA Projection (Table 4) that the ESAK values vary from approximately 0.05 to 0.13 mGy, with a mean value equal to (0.07 ± 0.02) mGy for age group 0-1 year old. For ages groups of 1-5, 5-10 e 10-15 years-old, the ESAK values found were (0.08 ± 0.03) mGy, (0.11 ± 0.09) mGy and (0.14 ± 0.06) mGy, respectively. The values obtained in this work are of the same order of those ones reported in the literature\(^7\).\(^{13}\).

Table 4. Distribution of the ESAK (maximum, mean and minimum) value for both rooms in Chest AP/PA Projection.

<table>
<thead>
<tr>
<th>Room</th>
<th>Age group (years)</th>
<th>Entrance Surface Air Kerma (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean value*</td>
</tr>
<tr>
<td>1</td>
<td>0 - 1</td>
<td>0.07 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>1 - 5</td>
<td>0.08 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>0.11 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>10 - 15</td>
<td>0.14 ± 0.06</td>
</tr>
<tr>
<td>2</td>
<td>0 - 1</td>
<td>0.04 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>1 - 5</td>
<td>0.05 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>0.04 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>10 - 15</td>
<td>0.07 ± 0.04</td>
</tr>
</tbody>
</table>

* mean value ± s.d (standard deviation)

In relation to the minimum and maximum values, a greater variation of ESAK was in the 5-10 years group, where values varied from 0.03 to 0.52 mGy. This result may be due to the great variation of the selected technical parameters (kVp settings and mAs) that results in a non-standardize pediatric procedures.

In Room 2, it can be observed for AP/PA Projection (Table 4), that the ESAK values vary from approximately 0.03 to 0.12 mGy, with a mean value equal to (0.04 ± 0.02) mGy for age group 0-1 year, presenting a greater variation in the age of 10-15 years (0.03 e 0.17 mGy).

It was also observed that the ESAK values in Room 1 were superior to the Room 2 for all ages range. This may be due to the use of higher kilovoltage values.

In the Lateral projection (Table 5), the values of ESAK were approximately the double of AP/PA projections. The age groups that presented a greater variation were the 1-5 years with 0.06 to 0.31 mGy for Room 1 and 0.08 to 0.36 mGy for age 10-15 years in Room 2.
Table 5. Distribution of the ESAK (maximum, mean and minimum) value for both rooms in Lateral Projection.

<table>
<thead>
<tr>
<th>Room</th>
<th>Age group (years)</th>
<th>Entrance Surface Air Kerma (mGy)</th>
<th>Mean value*</th>
<th>Maximum value</th>
<th>Minimum value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 1</td>
<td>0,10 ± 0,02</td>
<td>0,15</td>
<td>0,07</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1 - 5</td>
<td>0,16 ± 0,06</td>
<td>0,31</td>
<td>0,06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>0,21 ± 0,05</td>
<td>0,29</td>
<td>0,15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 - 15</td>
<td>0,26 ± 0,03</td>
<td>0,28</td>
<td>0,22</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0 - 1</td>
<td>0,07 ± 0,02</td>
<td>0,09</td>
<td>0,04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 - 5</td>
<td>0,08 ± 0,04</td>
<td>0,23</td>
<td>0,02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 - 10</td>
<td>0,08 ± 0,04</td>
<td>0,19</td>
<td>0,03</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 - 15</td>
<td>0,19 ± 0,10</td>
<td>0,36</td>
<td>0,08</td>
<td></td>
</tr>
</tbody>
</table>

* mean value ± s.d (standard deviation)

3.3.2 Establishment of the third Quartile for the Public Hospital

The corresponding mean values of ESAK to the third quartile for both rooms can be observed in Fig. 1. In AP/PA Projection, the third quartile ESAK values were equal to 0.07 mGy for 0-1 year old, 0.08 mGy for 1-5 years, 0.11 for 5-10 years and equal to 0.11 mGy for 10-15 years in Room 1. In Room 2, the third quartile was 0.05 mGy for age group between 0-10 years and 0.09 for 10-15-years. In the Lateral projection, the values of ESAK were approximately the double of AP/PA projections.

Figure 1. Distribution of the third quartile ESAK mean value for AP/PA (a) and Lateral (b) Projection.

Comparing the third quartile with the value obtained in the literature, it was verified in this study that (Fig. 1 (a)) the infants and 5 years old patients were below the value presented as reference for both projections. However, it can be observed in Room2 that the ESAK values were the same for patients aged between 0 to 10 years-old. In fact, they use the same technical factors for any age.

In Lateral Projection (Fig. 1 (b)), it can observed the third quartile ESAK mean value of age 10-15 years was approximately 50% higher when comparing with AP/PA.
3.4 Repeated analysis

During one month was carried on the evaluation of repeated analysis of films, in order to identify the number and the causes of rejected radiographies (Fig. 2). The sample include 277 images that were rejected.

Figure 2. Distribution of the causes in rejected films.

The majority of them were due to the incorrect selection of technical parameters resulting in overexposure and underexposure. Other main contributions for the rejection were patient motion and positioning. Its demonstrates difficulties in the correct positioning of the younger patients and the poor experience of the technologist with pediatrics patients.

4. Conclusion

It can be concluded that ESAK values are within the values recommended in international publications\textsuperscript{5,7-13}. Although, the third quartile ESAK mean value were the same for different age groups. The main image quality criteria that had a low acceptability were criterion 1 (performed at peak of inspiration) and 2 (reproduction of the thorax without rotation and without tilting). It was also concluded that 90% of the examinations were carried out without grids and more than 50% of exam repetition is due to the inadequate choice of the technical factors. It was also observed that it was not used protective shielding during the examinations. These results show the necessity of developing optimization programs in the pediatric radiology department with special emphasis in specific training for the technicians in pediatric procedures.

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REFERENCES