Entrance Skin Dose Evaluation in Pediatric Patients Undergoing Skull, Pelvis and Abdomen Radiographs

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Abstract. X-rays are widely used in medicine, including pediatrics. In addition to the benefits offered by the diagnosis, its use may also lead to the occurrence of biological effects. In pediatrics some tissues or organs are more radiosensitive. Also, due to the small size of the children, the organs are very close, increasing the radiation dose received by the patients. This study aimed to estimate the radiation dose received by children in the Skull AP, Abdomen AP and Pelvis AP projections. The dose calculation was performed from the x-ray tube output and the values were compared with major international dose reference levels. The results differ slightly from those presented by the adopted reference levels, but still are within the proposed range. The same happens for the radiographic technique used in each exam studied.

Key words. X-ray; dosimetry; pediatrics;

1. Introduction
X-rays have been widely used for medical purposes (diagnosis and therapy) since their discovery in 1895. In the beginning, exposures were much more unsafe, which was the cause of many diseases and deaths due to radiation exposure. For the production of x-rays, three main parameters are taken into account: peak voltage (kVp), current (mA) and exposure time (s). Each radiographic exam has the determination of parameters according to the patient’s size and the projection of the exam.

The pediatric age is the group where radiation exposure is the most worrying. The high growth of cells in this age group makes some tissues and organs more radiosensitive, and the exposure to low doses is a possible cause of the development of biological effects. As children have a longer life expectancy, the occurrence of late biological effects should be considered, mainly due to the number of exposures during this period of physiological and anatomical development. Assessing the amount of radiation dose received by children is relatively complex, as there is a wide variation in their size, weight and height. Therefore, the radiographic parameters also vary greatly.

Taking into account this wide range of radiographic parameters, it is essential to use Dose Reference Levels (DRL), which are used as a reference guide for dose optimization and radiological protection.
Since the exposure of pediatric patients to radiation is a major concern, this study aimed to estimate the dose values received by pediatric patients undergoing conventional skull AP, pelvic AP, and abdomen AP radiographic examinations and to compare these values with International dose reference levels. The study was conducted at Pequeno Príncipe Hospital in Curitiba, Brazil. From the results it was possible to observe before the protocols, some parameters that can be changed, to reduce the radiation dose to a lower level, maintaining the same image quality.

2. Methodology
This work was reviewed and approved by a Research Ethics Committee on Human Beings. Data collection was performed in a large, exclusively pediatric hospital. Dose estimation was performed based on the output of the x-ray tube and the technical parameters recorded during each examination.

Prior to the examination, the consent of the responsible for the child was obtained from the signing of an Informed Consent Form (ICF). At this time the weight, height of the patient and the thickness of the region(s) to be examined were also measured. At the time of the examination, the following data were collected: patient identification, date of birth, gender, age, peak voltage (kVp), product current and time of exposure (mAs), focus-skin distance (FSD), and whether or not there was repetition and indication of the exam. 69 AP Skull, 74 AP Pelvis and 74 AP Abdomen x-ray examinations were followed.

The output of x-ray equipment was determined following the specifications of the Brazilian Health Surveillance Agency (Agência Nacional de Vigilância Sanitária – ANVISA). Entrance skin dose (ESD) calculation was performed as specified in equation 1.

\[
ESD (mGy) = R \cdot \left( \frac{kVp}{80} \right)^2 \cdot \left( \frac{100}{FSD} \right)^2 \cdot mAs
\]

Where, ESD means entrance skin dose (in mGy), R is the x-ray tube output value (in mGy/mA.s.cm²), kVp is the peak voltage value used in the examination, FSD is the distance from the x-ray tube focus to the surface of the anatomical region of the patient (in cm), and mAs the product value between current and time of exposure used in the exam. For the calculation of the dose, the Backscattering factor (BSF) was not taken into account. After the calculation, the mean values obtained were used for comparison and discussion with the DRLs.

3. Results and Discussion
Table 1 presents the mean values of entrance skin dose, obtained with their respective standard deviations (SD) and the technical parameters used for the three incidences, Skull AP, Abdomen AP and Pelvis AP and the comparison with the main international dose reference levels.

| Exam      | Study     | Age (years) | ESD ± SD (mGy) | kVp  | mAs  | FSD (cm) |
|-----------|-----------|-------------|----------------|------|------|----------|
| SKULL AP  | Present Study | 5           | 0.96 ± 0.45    | 67.6 | 28.27| 89.33    |
| EUR16261  | 5         | 1.5         | 65-85*         | <50 ms | 115 (100-150)* |
| NRPB      | 5         | 1.1         | -             | -    | -    | -        |
Analyzing the results obtained by the present work and compared with the adopted dose reference levels, some observations can be made. The ESDs of all incidences had their average values close to the values presented by the intervals of the three reference levels used as guides. The same observation applies to the radiographic technique values. The differences between the values may be due to the radiographic technique variation, considering that mAs is a factor that primarily controls the dose. This may be an explanation for the difference in dose results obtained, as well as the lower FSDs. In addition, patient size may also contribute to different values of ESD. Graphic 1 presents the average thickness values recorded by this study and the National Radiological Protection Board (NRPB)\(^8\) and the relationship with the ESD.

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### Table 1: Comparison of ESD and Thickness Values

| Incidence | Present Study | EUR16261 | NRPB | AUSTRIA |
|-----------|--------------|----------|------|---------|
| **ABDOMEN AP** | 6 | 0.51 ± 0.50 | 0.9 | 0.6 | 0.4 |
| **PELVIS AP** | 5 | 0.34 ± 0.36 | 1 | 0.5 | - |
| **EUR16261** | 5 | 65-85\(^*\) | | | |
| **NRPB** | 5 | | | | |
| **AUSTRIA** | 5 | | | | |

(*\) range presented by the publications

Source: Own Authorship, 2019.
Based on graphic 1, we can correlate patient thickness with radiation dose and peak voltage (kVp). As product between current and exposure time (mAs) is responsible for primarily dose control and the amount of radiation, patients with thicker anatomical regions attenuate more radiation than patients with thinner regions. This is consequently observed in the graph, since the thicker regions present higher ESD values, compatible with the radiographic technique values used in the exams. This may also be one of the reasons for the differences in ESD values found, since thinner anatomical regions require lower values of kVp for the examination and the value of this kVp is determined as a function of the thickness of the patient examined.

Graphic 2 shows the peak voltage (kVp), focus-skin distance (FSD) and ESD ratios obtained in this study and at the European Commission reference level (EUR16261)\(^6\). Relating each parameter we can verify the similar dispersion of the points. The difference between the values in FSD that also controls radiation dose shows that, an optimization may be suggested, further reducing the radiation dose while maintaining the quality of the images.

![Figure 2 – Ratio Between kVp, FSD and ESD](source)

4. Conclusion
Considering the data obtained by this study and the data presented by the international dose reference levels, it can be concluded that the ESD values are within the ranges presented by the DRLs and differ from the values presented for kVp, mAs and FSD. The differences between these values are the possible cause of the difference between the doses obtained by this study. Changes may contribute to the formation of a Brazilian protocol, since there is no recommendation for pediatrics, thus, standardized exams will be even more optimized, with a lower dose and even safer for children.

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