

## ASSESSMENT OF ENTRANCE SURFACE DOSES FOR NEWBORN BABIES WITHIN AN INTENSIVE CARE UNIT\*

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*Abstract.* Newborn babies with health conditions or those who have been born premature frequently require treatment in the neo-natal intensive care unit (ICU). The exposure to ionizing radiations in childhood increase two or three times the risk of cancer induction compared to the case of adults. The study describes the distribution, frequency of radiological examinations and estimates the ESD for the most important radiological procedures. The statistical process has been carried out by comparing the average values of the ESD with the reference levels by the “t” test. The average of ESD for the chest examination compared to the reference levels are high statistic significance ( $p < 0.001$ ). Irrespective of a child’s weight, the kilo-voltage, used has been below the values, recommended for all radiological procedures. Worrying, in the case of this group of children, is not the ESD for one single exposure, but the repeated examinations during the child’s hospitalization period, leading to cumulative doses, to which it is likely that many other may be added during childhood. The incorrect use of the low kilo-voltage technique as a consequence of the small volume and weight of these babies, causes the increase of the dose.

*Key words:* radiological examinations, entrance surface doses, reference levels, risk.

### 1. INTRODUCTION

The X-ray examination with image-receptor (film) represents the first method of radiological investigation for more than one century. The radiation doses received by patients during such investigations have been very poorly taken into consideration during the first years of using this method. In time, with the increase of the radiological investigations and the new approach regarding the risk of cancer development in the long term, following the exposure to ionizing radiations, a much greater attention has been paid to maintaining the doses received by patients at a low level. The rather small probability of inducing fatal cancer to a patient due to a single radiological examination depends on the patient’s age and the type of

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examination. The exposure to ionizing radiations in childhood causes an increase between two and three times for the risk of radiation - induced cancer comparative with the adults. Therefore it is highly important that the radiation doses received by children through medical exposure shall be minimized. The International Commission on Radiological Protection – (ICRP 60, 1991) [1]. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has established that, due to the high mitotic capacity of the children's cells, the risk of exposure to ionizing radiations is strongly dependent on the child's age and the time of exposure [2]. Nowadays, from the stochastic point of view, there is no evidence of the existence of any threshold from radiation. This means that any radiation dose, regardless of the small size, may have a potentially damaging effect. The probability, but not the severity, of the stochastic effects grows up in parallel with the increase of the exposure (ICRP 60, 1991) [3]. The choice of the treatment in the case of newborn babies requiring intensive high care depends on the radiological diagnosis. The child's weight at birth, the gestational age and the breathing problems are likely to lead to a large number of radiological examinations. Children's radiological examinations, beginning with the first day of life, require a much greater interest, due to the fact that at this age the probability of radiation – induced cancer increases, as a result of the relatively great life expectancy [4]. On the other hand, the small dimensions of newborn babies sometimes make all organs be in the beam fascicle, resulting in an exposure of the entire body during an X-ray examination [5]. The anatomic, physiological and pathological particularities of newborn babies also represent a significant risk factor exposure to ionizing radiations [6]. The risk / benefit ratio of each X-ray examination is significant and should be treated very carefully due to the fact that the effects of ionizing radiations are cumulative [7]. If the number of radiological investigations of each newborn baby showing health problems or in case of a premature born baby is strictly necessary, if the examination techniques are the recommended ones and if the doses received during such radiological procedures are under periodical observation, then the risk of exposure to ionizing radiations shall be minimum compared to the diagnosis – related benefit.

## 2. MATERIAL AND METHOD

Each year a number of approximately 300 children in the neonatology department of a pediatric clinic are treated within the Intensive Care Unit (ICU) and in this number are also included the newborns showing health problems and the premature newborn babies, before 37 weeks. A study has been carried out for a period of three years, related to the number of radiological examinations performed to each of these children and with reference to the type of procedures. The data have been obtained out of the information registered in the Radiology and

Neonatology Departments. The radiological examinations have been performed with a mobile X-ray device, with a total filtration of the beam fascicle of 3.4 mmAl, at a distance focus – 100 cm image receptor (film), the children being placed directly on the cassette with the radiological film in the incubator. Given the fact that it is well known the existing relation between the weight of the examined subject and the technical parameters of the X-ray device, we have divided the children, in three groups related to their body weight: 0.7–1.5 kg; 1.5–2.5 kg; more than 2.5 kg.

There have been carried out a number of measurements of the entrance surface doses (ESD) by using the technical parameters of the radiological installation for the three groups and for two types of procedures: chest-abdomen and chest, these being the most frequent ones. Measurements have been carried out with a multifunctional instrument for testing the quality of the radiological systems. The values resulted from the measurements have been compared to the doses reference levels from the Order no. 285/79/2002 of the Ministry of Health and Family and of the president of the National Committee for the Nuclear Activities Control regarding the people radioprotection in the event of the medical exposures to ionizing radiations. We make the mention that, now, there are doses reference values to the entrance surface doses only for one month – old children and only for the chest examinations. Student test „t” was used for statistical analysis.

### 3. RESULTS

In the newborn department of the pediatric section within the County Emergency Hospital of Craiova, between 2005–2007, 97% of radiological investigations were those of chest and chest plus abdomen, the others being of skull and extremities.

*Table 1*

The frequency of radiological examinations and the distribution per types of procedures

| Type of examination | 2005 | 2006 | 2007 |
|---------------------|------|------|------|
| Chest and abdomen   | 284  | 289  | 270  |
| Chest               | 13   | 18   | 11   |

Just as it comes out of Table 1, the radiological procedures, that are most frequently performed, have been the chest examination and the abdomen as a consequence of the breathing and digestive problems of the newborns and the premature babies. In 2007 it was noticed a slight decrease of the number of radiological investigations although the number of newborns was kept on growing.

The decrease in the number of radiological examinations in 2007 might be explained by the fact that both the neonatology physician and the radiologist have tried to get, as much as possible, as many diagnosis related information or as many medical records that are relevant for the planned exposure so as to avoid useless exposures. When the neonatology physician has any doubts whatsoever as related to several conditions, it is preferable to choose a chest-abdomen investigation, than to perform two separate X-rays for each of the two anatomical regions. This shall lead to the decrease of the doses received by the children [8, 9].

Table 2

The number of radiological investigations, reported to the number of newborns

|                          | 2005 | 2006 | 2007 | Total |
|--------------------------|------|------|------|-------|
| Number of newborns       | 2930 | 2881 | 2974 | 8785  |
| Number of investigations | 297  | 307  | 281  | 885   |

During these three years of study, 8 785 children have been born, and the percentage of those who underwent at least one such X-ray examination was 10.07%. A special attention should be paid to the justification and optimization of the radiological examinations, taking into account the specific objectives of the exposure and also the characteristics of the staff involved in such procedures.

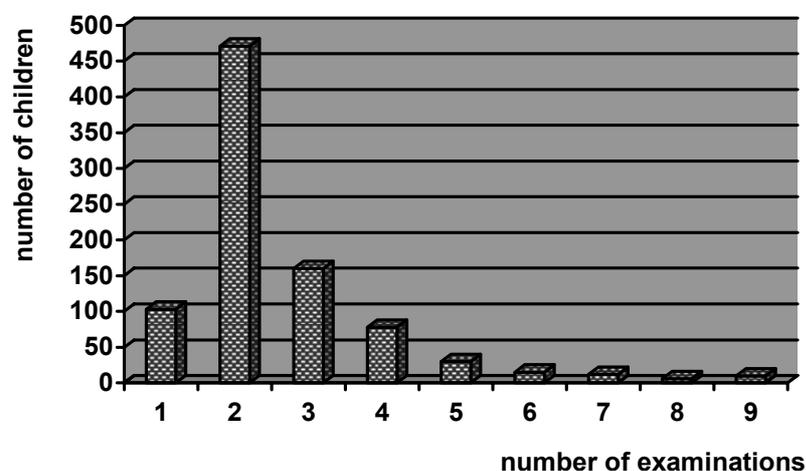


Fig. 1 – The distribution of the X-rays examinations performed per child.

The longest hospitalization periods in the Intensive Care Unit (maximum 67 days) have been for the premature newborns, the highest number of radiological examinations being performed in the latter's case. From the total number of

children radiological examined, only 101 (11.64 %) have undergone to one single examination, the biggest number of children incurring two X-ray examinations. The maximum number of X-ray examinations/child in this present study is significantly low nine compared to 17 or even 36 X-ray examinations/child as resulted in other studies (12). The highest number of X-rays examinations has been carried out in the case of the children from the first group of weight.

As a result of the analysis of information at the Radiology Department, it came out that the radiological history of some of the children under observation (18%), does not justify all the radiological examinations. The examinations were performed before an already prescribed treatment had made its effect or out of fear of the neonatology physician related to the child's life. The cooperation deficiency and the functional particularities (faster heart beats, faster breathing, incapacity of holding his breath when ordered, increase of intestinal gases), are also such other reasons which may deteriorate the image quality, leading to X-ray examinations being repeated [10].

Table 3

Comparing the exposure factors used with the recommended ones

| Chest   | kV    |             | ms    |              | Speed of the film |             |
|---------|-------|-------------|-------|--------------|-------------------|-------------|
|         | used  | recommended | used  | recommended  | used              | recommended |
|         | 52-57 | 60-65       | 12-14 | More than 4  | 200-400           | 200-400     |
| Abdomen | 53-58 | 65-80       | 14-18 | Less than 20 | 200-400           | 600-800     |

Out of Table 3 it comes out that chest X-rays have been carried out with smaller tube potentials than the recommended ones. Choosing the optimum potential of the X-ray tube is very important since this depends on the part of the body that needs to be visualized, on the size of the patient, the type of requested clinical information and the response of the image receptor (the radiological film) [11]. In this study it has been found the tendency of using a low kilo voltage related to both types of examinations. Using a higher potential may lead to a decrease with 16–36% of the entrance surface doses for the X-rays of newborns without any impediment related to the image quality from the diagnosis point of view.

The body image forming involves the interaction of several factors. In order to get a correct balance between the patient's doses and the image quality, it is necessary to understand the way of formation of the radiological image and to know the factors that are influencing the quality of the image, as well as the radiation doses received by the patient, so that the most adequate options shall be chosen.

Another extremely significant factor to decrease the doses and to visualize certain details with clinical interest is represented by the screen / film combination. The screen / film combination used during the first two years of study has a sensitivity class of 200, in 2007 being 400 for both types of procedures, although for the abdomen it is highly recommended to be between 600 and 800.

Because till now, for newborns, there are no reference levels of ESD on weight groups and on different types of investigations, I have compared the average value of ESD for the three groups with the reference dose level according to Order no. 285/79/2002 of the Ministry of Health and Family and of the president of the National Committee for the Nuclear Activities (Table 4).

Table 4

The average of entrance surface doses (ESD)

| Type of examination | ESD ( $\mu\text{Gy}$ ) |                 |                        |         | Recommended<br>Order no.<br>285/79/2002 |
|---------------------|------------------------|-----------------|------------------------|---------|---|
|                     | 0.7 – 1.5 kg           | 1.5 – 2.5 kg    | more than<br>de 2.5 kg | average |   |
| Chest               | 87.2 $\pm$ 0.25        | 89.9 $\pm$ 0.22 | 92.1 $\pm$ 0.17        | 89.7    | 80                                      |
| Chest and abdomen   | 89.7 $\pm$ 0.21        | 92.2 $\pm$ 0.19 | 99.9 $\pm$ 0.11        | 93.9    | -                                       |

Table 4 emphasizes a statistical significant difference ( $p < 0.001$ ) between the average value of ESD in this study and the recommended one.

One may find the fact that for the first type of examination, the average value of the entrance surface doses is higher compared to the common chest X-ray. Even if the ESD for the exposure of abdomen plus lung is bigger than the ESD for lung, it is obvious that for the babies who needed both examinations as a result of the diagnostic, this option has been a benefit. They received in this situation a much smaller dose compared to what they would have received from two separate exposures. This is due to a broader field of exposure and that is why the collimation of the X-rays fascicle is so important in the decrease of children doses. In the case of the chest X-ray, the average of the measured doses is slightly below or over the recommended value, as shown in Table 4. The positioning of young and very young children is pretty difficult. They become even more difficult when the radiological examination is due to the children in incubator. A wrong positioning with 1–2 cm may lead to the increase of organ doses, as it is shown in Fig. 2.



Fig. 2 – Examples of incorrect positioning and collimation in the case of a lung and abdomen radiography.

The difference between the ESD values in the case of chest X-ray for the three groups of babies isn't too big because the mAs product used isn't modified from one group to another, only the tube potential being modified with two to 5 kV. But, there are significant differences in comparison to other studies where estimations of ESD were made for the same population of babies and for the same weights.

Table 5

ESD for the chest X-rays examination in our study and in Cook *et al.* study (1998)

| Weight (kg)   | ESD ( $\mu\text{Gy}$ )  |                      |
|---------------|-------------------------|----------------------|
|               | Present study (average) | Cook study (average) |
| 0.7 – 1.5     | 87.2                    | 10                   |
| 1.5 – 2.5     | 89.9                    | 20                   |
| More than 2.5 | 92.1                    | 30                   |

Table 5 shows ESD for chest X-ray exam in our study are three to eight times higher comparing to the results of Cook *et al.* study.

**Comparison with previously published data.** Our results may be compared with previously published data to attempt to delineate mechanisms for dose reduction. Table 6 summarize a comparison between examination techniques and mean ESD per radiograph in this study and in the others.

Table 6

Comparison of entrance surface dose (ESD) with previously published data

| Reference               | Type of examination | kV/mAs    | Mean ESD per radiograph ( $\mu\text{Gy}$ ) |
|-------------------------|---------------------|-----------|--|
| <b>This work</b>        | Chest               | 52-57/2.5 | 90   |
|                         | Chest and abdomen   | 52-58/2.5 | 94   |
| <b>Smith et al</b>      | Chest               | 60-70/1.0 | 44   |
| <b>Fletcher et al</b>   | Chest and abdomen   | 50/0.4    | 70   |
| <b>Faulkner et al</b>   | Chest and abdomen   | 46/2      | 39   |
| <b>Mc Parland et al</b> | AP Chest            | 52-60/0.8 | 20   |

The high values of ESD in this study are explained as a result of low kilovoltage but especially because of the mAs used which is much higher than in the four studies [12, 13, 14, 15]. It must be remembered that the effective radiographic voltage depends on the type and age of the generator. Not all generators allow the short exposure times that are required for higher kV technique. In addition, on most radiographic units it is not possible to set small increments of kV and mAs.

#### 4. DISCUSSIONS

In the case of newborn babies with health problems and in the case of those children who were born premature, it is no worry about the doses resulted per type of procedure, but it is for the number of X-ray examination/ hospitalized child, all these leading to cumulative doses, to which it is likely that several others shall add during childhood.

The cooperation deficiency and the functional differences (faster heart beats, faster breathing, incapacity of holding his breath when ordered, increase of intestinal gases), are reasons which may alter the image quality.

The incorrect collimation of the beam fascicle in case of children with the smallest dimensions makes the internal organs be almost entirely in the radiation fascicle, which leads to the increase of the effective doses. It is a wish that all radiological operators have pediatric and pathological knowledge in order to provide an appropriate limitation of the exposure field.

The image quality shall be good enough, if not the best. This means that each such radiological examination shall be individualized, based upon the patient's data and on the indications given by the specialized physician.

It is highly important to work fast and gently when dealing with X-rays carried out for a newborn baby, the additional noises, an incubator window left open or a brutal move may cause the health state of the infant get worse, as well as a pain for the baby and an extension of the hospitalization period. As a consequence of these radiological requirements, physicians shall be well trained in order to perform single radiological examinations.

## 5. CONCLUSIONS

Knowing the tendencies of the received doses by the newborns during radiological examinations may stand for a guidebook with respect to the optimization of the radioprotection which would consequently lead to the minimization of the risk of exposure to ionizing radiations.

Medical practitioners tend to use low kilo-voltage and high products mAs as a result of reduced dimensions of the babies, but also to reduce the noise of X-rays that can create difficulties in interpretation.

Each and every clinician shall understand their responsibilities and the collective responsibility in providing the medical act. All these could lead to a decrease in the number of unjustified investigations and to a decrease of the doses per patient. One shall also take into consideration an appropriate training of the medical team both in terms of specialization issues and in terms of radioprotection, so that the highest radiological protection standards shall be adopted.

The periodical analysis of the causes leading to the repetition of the X-rays examination following a poor quality of the radiological image may lead to the decrease of the degree of repetitiveness.

It is necessary to point out the medical staff awareness on the means and methods of patient's protection, on the levels of irradiation to which a child may be exposed, and on those risks which occur by repeating such exposures.

The development of certain working protocols at the hospital level would represent an opportunity to improve the clinical system and the working procedures in the way to increase the care received by the patients.

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