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Research Article

# Assessment of Pediatric Exposure to Ionizing Radiation in Diagnostic Radiography: A Study at Diamniadio Children's Hospital

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## Abstract

Radiography, widely used for diagnostic purposes, represents a major source of exposure to ionizing radiation in children, a population particularly sensitive to the biological effects of radiation. Despite its widespread use, no study has previously assessed pediatric exposure to ionizing radiation in Senegal. This study was therefore conducted to measure and analyze exposure levels during routine radiographic examinations at the Diamniadio Children's Hospital. A retrospective descriptive and analytical study was carried out from January 1 to June 30, 2022, within the radiology and medical biology departments. Demographic data and anatomical regions examined were collected from radiology registers. Data were entered using Microsoft Excel 2016 and analyzed with RStudio version 4.1.2. A total of 2820 children were included, with a median age of 4.35 years and a male-to-female ratio of 1.58. The [0-5 years [and [5-10 years [age groups were the most represented, accounting for 53.2% and 30.5% of cases, respectively. Chest and lower limb radiographs were the most frequently performed examinations across all age groups, with a higher exposure frequency observed in boys. These findings indicate that children undergo a substantial number of radiographic examinations, which may increase stochastic radiation effects. Therefore, strict application of radiological protection principles by radiologists and referring physicians is essential.

## Keywords

X-ray, Radiography, Pediatrics, Exposure, Radiation Protection, Senegal

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# 1. Introduction

Radiography is a widely used medical imaging technique for diagnostic purposes. Although the dose of ionizing radiation (IR) delivered during a radiographic examination is generally considered low, its high frequency of use makes it one of the main sources of exposure to ionizing radiation in medical imaging [1].

Long-term epidemiological studies, particularly those conducted among survivors of the atomic bombings of Hiroshima and Nagasaki, as well as among occupationally exposed radiation workers, have established an association between exposure to ionizing radiation and an increased risk of carcinogenesis, as well as the occurrence of fetal malformations [2, 3].

In 2006, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported that the lifetime risk of solid cancer following exposure during childhood is estimated to be two to three times higher than that observed in the general population [4]. This increased vulnerability of the pediatric population is mainly related to the radiosensitivity of developing tissues and to a longer life expectancy.

According to the World Health Organization (WHO), approximately 3.6 billion diagnostic imaging examinations are performed worldwide each year, of which nearly 350 million involve children under the age of 15 [5]. These data highlight the importance of pediatric radiation protection in the context of healthcare delivery.

Despite the major clinical benefits of radiography, concerns remain regarding the potential health risks associated with repeated exposure to ionizing radiation, particularly in children. To date, no study has evaluated pediatric exposure levels in diagnostic radiography in Senegal. Therefore, the present study aims to measure and analyze ionizing radiation exposure levels in pediatric patients undergoing radiographic examinations at the Diamniadio Children's Hospital.

# 2. Patients and Methods

This study was conducted in the radiology department of the Diamniadio Children's Hospital. It was a retrospective, descriptive, and analytical study carried out over a six-month period. The study population included all children aged 0 to 15 years who attended the radiology department with a request for an X-ray examination. Children with missing age or sex information, as well as those who underwent more than one radiological projection, were excluded from the study.

Data were collected from patient registers and entered into a computerized database. Data entry was performed using Microsoft Excel 2016, and statistical analyses were conducted using RStudio software.

# 3. Results

## 3.1. Age and Sex Distribution

A total of 2820 children aged between 0 and 15 years were included at the time of the radiological examination. Among them, 53.20% were exposed to X-rays before the age of 5 years. The male-to-female ratio was 1.58, with a predominance of males, who accounted for 61.31% of the study population (Table 1).

***Table 1.*** *Distribution of patients by age group and sex.*

| Age group (years) | Male | Female | Total |
|---|---|---|---|
| [0-5] | 917 | 583 | 1500 |
| [5-10] | 528 | 332 | 860 |
| [10-15] | 284 | 176 | 460 |
| Total | 1729 | 1091 | 2820 |

## 3.2. Distribution of Radiological Examinations by Age Group and Sex

The figures below present the distribution of radiological examinations according to age group and sex. The number of examinations was not uniformly distributed across age groups and, to a lesser extent, between sexes. The [0-5 years [age group was the most exposed to X-rays in both sexes, including 3.33% during the neonatal period (0-28 days), followed by the [5-10 years [age group (30.49%). Overall, boys were more frequently exposed to X-rays than girls across all age groups.

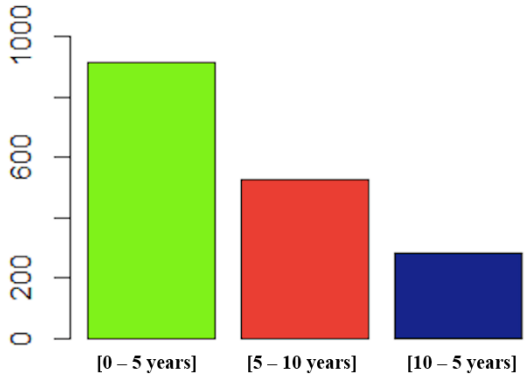


***Figure 1.*** *Distribution of radiological procedures by age in boys.*

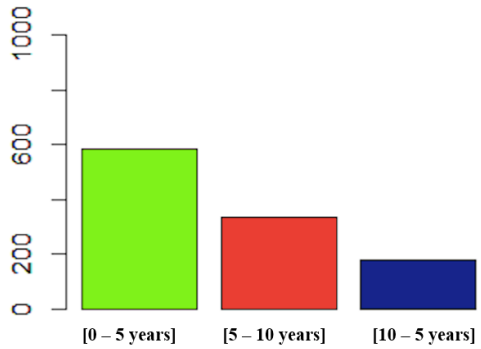


*Figure 2. Distribution of radiological procedures by age in girls.*

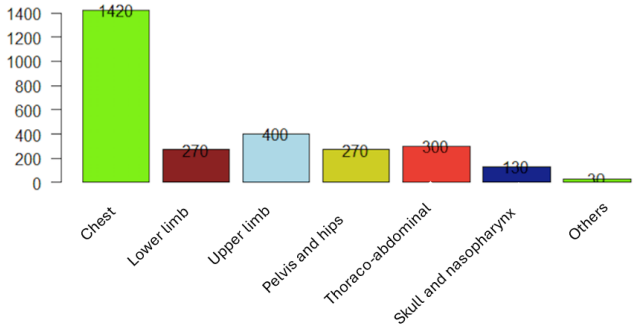


*Figure 4. Distribution of Radiological Examinations According to Anatomical Region Examined.*

## 3.3. Distribution by Department

The distribution of radiology requests by department was as follows: General Surgery (38.30%), Outpatient Clinic (31.56%), Emergency Department (24.46%), Pediatric Ward (3.55%), Neonatology (1.78%), and ENT (0.35%).

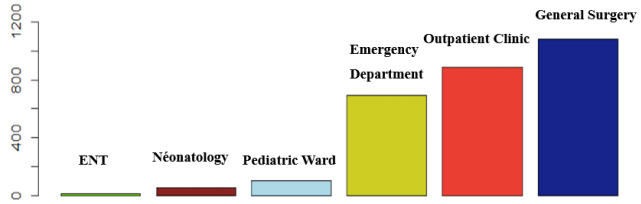


*Figure 3. Distribution of radiology requests by department.*

## 3.4. Distribution of Diagnostic Imaging Procedures by Explored Anatomical Region

The distribution of radiographic examinations by explored anatomical region is shown in Figure 4. The number of procedures is indicated for each anatomical region. Chest radiography was the most frequently performed examination, accounting for 50.35% of all X-ray procedures. The remaining examinations represented 49.65% of the total.

## 3.5. Distribution of Conventional Radiology Procedures by Anatomical Region According to Age and Sex

The distribution of conventional radiology procedures varies markedly with the child's age. Chest radiographs were the most frequent in children under 4 years, accounting for over 52% of procedures. Their frequency decreased with age, representing 29.5% in children aged 5-9 years and 27.6% in those aged 10-15 years. In contrast, limb radiographs were rare in children under 5 years but became increasingly common in older children, with upper and lower limb examinations together comprising the majority of procedures from age 6 onwards.

Pelvic and hip examinations were performed at relatively consistent rates across age groups, except in children over 9 years, for whom this region ranked as the second most frequently examined (≈18%). Abdominal and cranial radiographs were less common but consistently observed across all ages. Overall, chest radiography demand was highest in children under 5 years.

Sex-specific analysis indicated that the predominance of chest radiographs in boys was most pronounced in the under-5 age group, while in girls, the most commonly examined regions were, in descending order, chest, upper limbs, abdomen, and pelvis/hips.

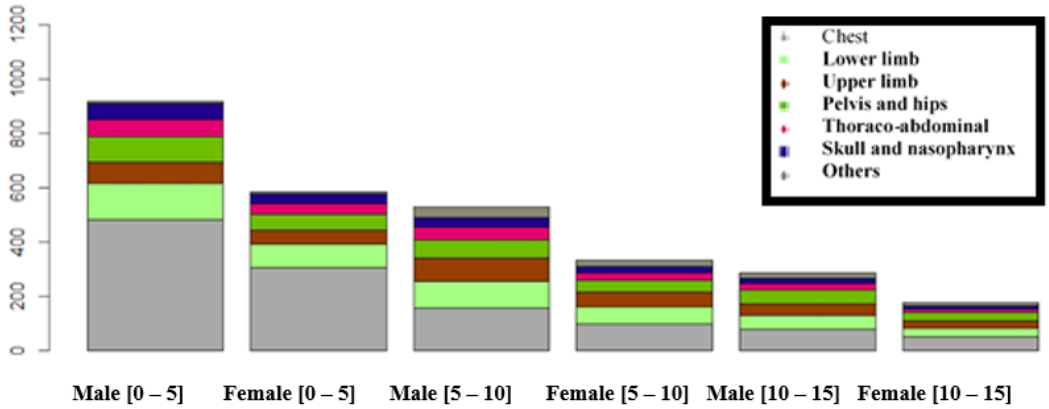


*Figure 5. Distribution of Conventional Radiology Examinations by Anatomical Region According to Age and Sex of the Child.*

## 4. Discussion

A total of 2820 radiological procedures were performed during the study period on children under 16 years of age attending the radiology department. When compared with the 22100 children who visited the hospital during the same period (January-June 2022), this corresponds to a rate of 13.30 radiological procedures per 1000 children. This average could be extrapolated to the broader pediatric hospital population in Senegal and serve as a useful indicator of children's exposure to medical ionizing radiation (excluding therapeutic use).

Fetuses and children are more sensitive to ionizing radiation (X-rays) than adults. In their growing bodies, the high number of mitotic cells increases radiosensitivity. Due to their small body size, critical organs are often within the primary beam or significantly affected by scattered radiation. Furthermore, their long life expectancy allows sufficient time for the lengthy carcinogenesis process to manifest [6]. Indeed, this latency period ranges from seven to ten years for the development of radiation-induced leukemia or solid tumors [7].

In our study population, 61% of patients were boys, resulting in a male-to-female sex ratio of 1.58. This is higher than the ratio reported by N'dakena et al. [8], which was 1.12. The mean age of our patients was 4.35 years, ranging from day 1 of life to 15 years. The most represented age group was 0-5 years, accounting for 53.2% of patients. Our results are not directly comparable to many studies on exposure levels in conventional radiography conducted in the sub-region, which reported 32% [9] and 39% [10], respectively. This difference can be explained by the larger sample size (2,840 patients) and younger age range (0-5 years) in our study compared with those of Sawadogo and Mbo [9-10]. This relatively young age underscores the need for heightened vigilance, as numerous epidemiological studies have shown that cancer risk is inversely proportional to age at the time of exposure to ionizing radiation [11].

In children, the risk of radiation-induced cancer is approximately four times higher than in adults and varies with age at exposure. Leukemia risk is highest before age 10, thyroid cancer before age 20, and breast cancer between ages 10 and 19. Several studies have documented increased incidence of thyroid cancer following childhood thyroid irradiation [12].

Our study also showed that children aged 0-5 years were the most frequently exposed to ionizing radiation, with exposure rates more than three times higher than those of children aged 10-15 years. This difference may be explained by the vulnerability of children in this age group to infectious, skeletal, nutritional, and other conditions (including ingestion of toxic substances or foreign bodies) as well as the diagnosis of genetic diseases. These conditions represent major indications for radiological examinations for diagnosis, follow-up, and detection of complications.

Boys were generally more exposed than girls, particularly in the 0-5-year age group. This sex difference in very young children is likely related to higher neonatal mortality in boys compared with girls in developing countries. Several authors, including Cantagrel [13], Koura [14], and Ndour et al. [15], have observed similar patterns without establishing a direct link between sex and mortality. It is reasonable to assume that the higher incidence of neonatal pathologies in boys results in a greater number of imaging procedures.

The high number of radiological procedures in very young children carries significant radiobiological risks. Children are much more sensitive to ionizing radiation than adults. Studies of atomic bomb survivors showed that the risk of leukemia per unit dose was 5-10 times higher for exposures before age 5, with excess risk persisting over several decades. The latency for solid tumors is also shorter for exposures occurring during childhood compared with later life exposures [16]. Children's long life expectancy further increases the likelihood of developing cancer.

Additionally, for a given procedure, the absorbed dose is higher in children than adults due to smaller body size and closer proximity of organs [17]. These characteristics justify prioritizing consideration of long-term risks of cancer and leukemia following medical exposure to ionizing radiation during childhood.

In this study, chest radiographs represented the main source of exposure in girls. Cohort studies of individuals undergoing multiple childhood radiographs for tuberculosis or scoliosis follow-up have demonstrated a dose-dependent increased risk of breast cancer in adulthood [18]. Children, young adults, and females are more susceptible to stochastic effects than males, as shown in Japanese cohorts [19].

Stochastic effects result from chromosomal DNA alterations compatible with cell survival and vary according to cell type: carcinogenesis in somatic cells or heritable genetic alterations in germ cells [20]. Cancer risk is higher in females due to the radiosensitivity of breast tissue, which is included in the exposure field during chest X-rays and CT scans. Specific protective measures should be applied to these populations [21].

## 5. Conclusion

Advances in medical imaging, including the implementation of digital detectors and improved radiation protection, have helped reduce the doses delivered during radiological examinations. Nevertheless, overall exposure remains high due to the increasing number of procedures, particularly in children and neonates. Our study conducted at the National Children's Hospital of Diamniadio demonstrated that pediatric radiology procedures are frequent and highlight the increased radiobiological risk in children.

Based on these findings, the implementation of radiation protection measures recommended by the ICRP and the IAEA should be accompanied by ongoing training and awareness programs for all healthcare professionals. Prescribing physi-

cians should limit the routine ordering of radiographic examinations in order to minimize exposure of radiosensitive regions in children.

## Abbreviations

| | |
|---|---|
| ENT | Ear, Nose and Throat |
| DNA | DeoxyriboNucleic Acid |
| CT | Computed Tomography |
| ICRP | International Commission on Radiological Protection |
| IAEA | International Atomic Energy Agency |

## Conflicts of Interest

The authors declare no conflict of interest.

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