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Optimization of Radiation Protection for Companions in Pediatric Chest Radiography

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study is to optimize the positioning of the companion during pediatric chest radiographic exams by analyzing the scattered radiation dose measured with an ionization chamber.

Place and Duration of Study: The experimental study was conducted between February 2024 and April 2024, in the radiodiagnosis laboratory belonging to the Medical Physics

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and Radiology Technology courses at the Franciscan University (UFN) in the city of Santa Maria, Rio Grande do Sul.

Methodology: A fixed conventional X-ray device and a phantom (simulating object) filled with 15 cm of water to represent a pediatric chest were used. The parameters of voltage (kV) and the product of current and time (mA.s) were kept constant. Measurements of the air KERMA (K_{AIR}) were performed by positioning the dosimetric system at four points around the phantom (0º, 90º, 180º, and 270º), simulating the exposure conditions of the companion.

Results: The results showed that the lowest radiation dose received by the companion at the gonadal level occurred at 90º around the table (cathode side), while the lowest dose at the lens level was at 270º (anode side). The highest dose at the gonadal level was observed at 180º, and the highest dose at the lens level was at 90º.

Conclusion: It was concluded that the companion should position themselves on the anode side (270º), as the lens does not have lead protection, while protection is available for the rest of the body. This recommendation aims to optimize radiological safety for the companion.

Keywords: X-rays; incident radiation; scattered radiation; radiological protection.

1. INTRODUCTION

Chest radiographic exams are essential for diagnosing respiratory conditions such as pneumonia, bronchitis and pleural diseases like pleural effusion and pneumothorax. However, exposure to ionizing radiation is a concern, especially in children due to their higher biological sensitivity and risk of cellular damage, as well as the exposure of companions during pediatric exams [1].

Proper immobilization of children often involves other people (88.9%), a practice that, while reducing child stress, contradicts the ALARA principle (As Low As Reasonably Achievable), which aims to minimize radiation exposure [2]. Proper immobilization during the procedure should ensure quality images and reduce the need for repeat exams [3].

According to the World Health Organization (WHO), approximately 50% of pediatric radiological exams are chest X-rays, with a central concern about the scattered radiation generated by the interaction of X-rays with the patients' tissues.

The measurement of scattered radiation dose, such as air KERMA (K_{AIR}), in pediatric chest exams stands out as an important tool for evaluating radiation dose for patients and companions, following the ALARA principles to protect long-term health [4]. This includes careful selection of exposure parameters, the use of modern equipment with dose reduction technologies, and considering imaging alternatives that do not involve radiation when appropriate [3].

The radiological protection system has evolved through decades of study, adapting to advances in scientific understanding of radiation effects. It is founded on two primary goals: first, to keep doses to organs and tissues below thresholds to prevent harmful tissue reactions (deterministic effects), and second, to manage effective dose to limit the probability of stochastic effects. The system's design inherently reflects the relationship between dose and health risk, specifically in terms of the correlation between the severity of effects and doses exceeding thresholds for tissue reactions, and the association between the probability of stochastic effects and doses, given that there is no threshold for these effects [5].

Positioning for a pediatric chest exam, according to Bontrager & Lampignano [6], involves determining the film size and maintaining the cassette transversely. The child should be in a dorsal decubitus position with arms extended and scapulas out of the lung fields, supported by sandbags. Correct positioning includes keeping the shoulders below the upper margin of the detector, with the central ray perpendicular to the film centered on the midsagittal plane (MSP), as shown in detail in Fig. 1.

For dose restriction in the case of caregivers and companions of patients, the National Nuclear Energy Commission (CNEN) from Brazil has established a reference value of 5 mSv per diagnostic or therapeutic procedure. Pregnant companions and those under 18 years of age should be avoided; if such exposure occurs, CNEN has set a dose restriction value of 1 mSv per episode for children and 1 mSv per episode for the embryo or fetus [7].

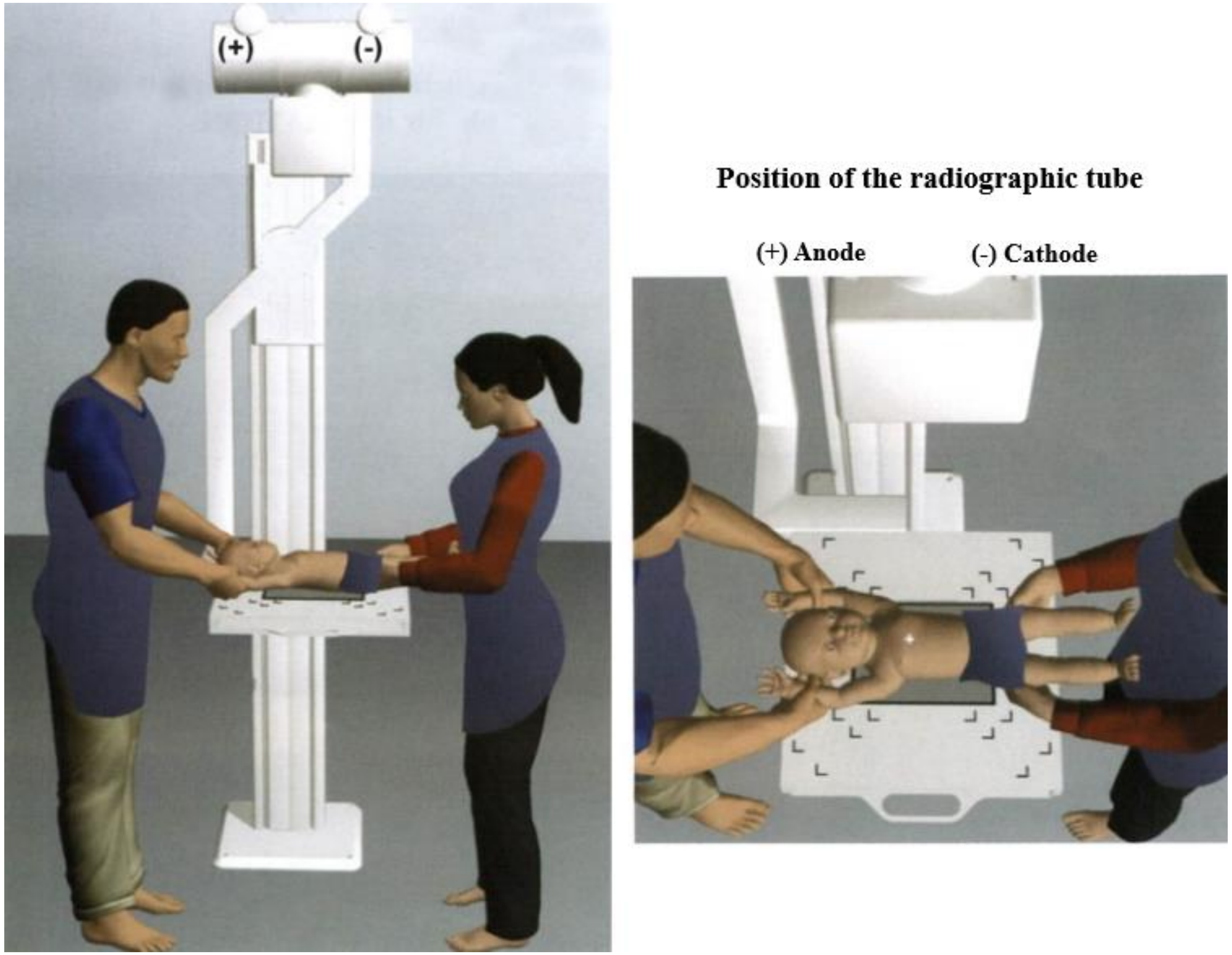

Fig. 1. Positioning for Pediatric Chest AP
Adapted from [8]

Radiology professionals have the responsibility to inform both parents and other companions about the risks associated with radiation exposure and to ensure that all safety measures are followed during the exam [4]. To mitigate the risks, it is recommended to use lead aprons and to ensure proper positioning of the companions, minimizing their exposure [1]. Therefore, the objective of this study is to optimize the positioning for the companion during pediatric chest radiographic exams.

2. MATERIALS AND METHODS

The study was conducted in the radiodiagnosis laboratory of the Universidade Franciscana (UFN) in Santa Maria - RS, as part of the research for the Radiodiagnosis and Radiological Procedures III course. An Intecal radiographic equipment, model MAAF, and a RADCAL dosimetry system, model 9015, with a DE 180 cm³ survey probe were used to evaluate scattered radiation. To simulate a pediatric chest radiographic exam, a phantom object consisting of a plastic box measuring 39 x 26 x 22 cm³, filled with water up to a thickness of 15 cm, was used. The dosimetric measurements were performed with a voltage of 70kV, current of 200mA, and a current-time product of 5 mA.s, with a radiation field of 25 x 25 cm. The dosimetric chamber was positioned at 100 cm perpendicular to the primary beam projection. Fig. 2 illustrates 8 measurement positions: 4 at the gonad region (90 cm) [Fig. 2(a-d)] and 4 at the lens region (150 cm) [Fig. 2(e-h)]. Three readings were recorded for each companion position. In each stage, configurations of three readings for each companion position at the table ends were recorded.

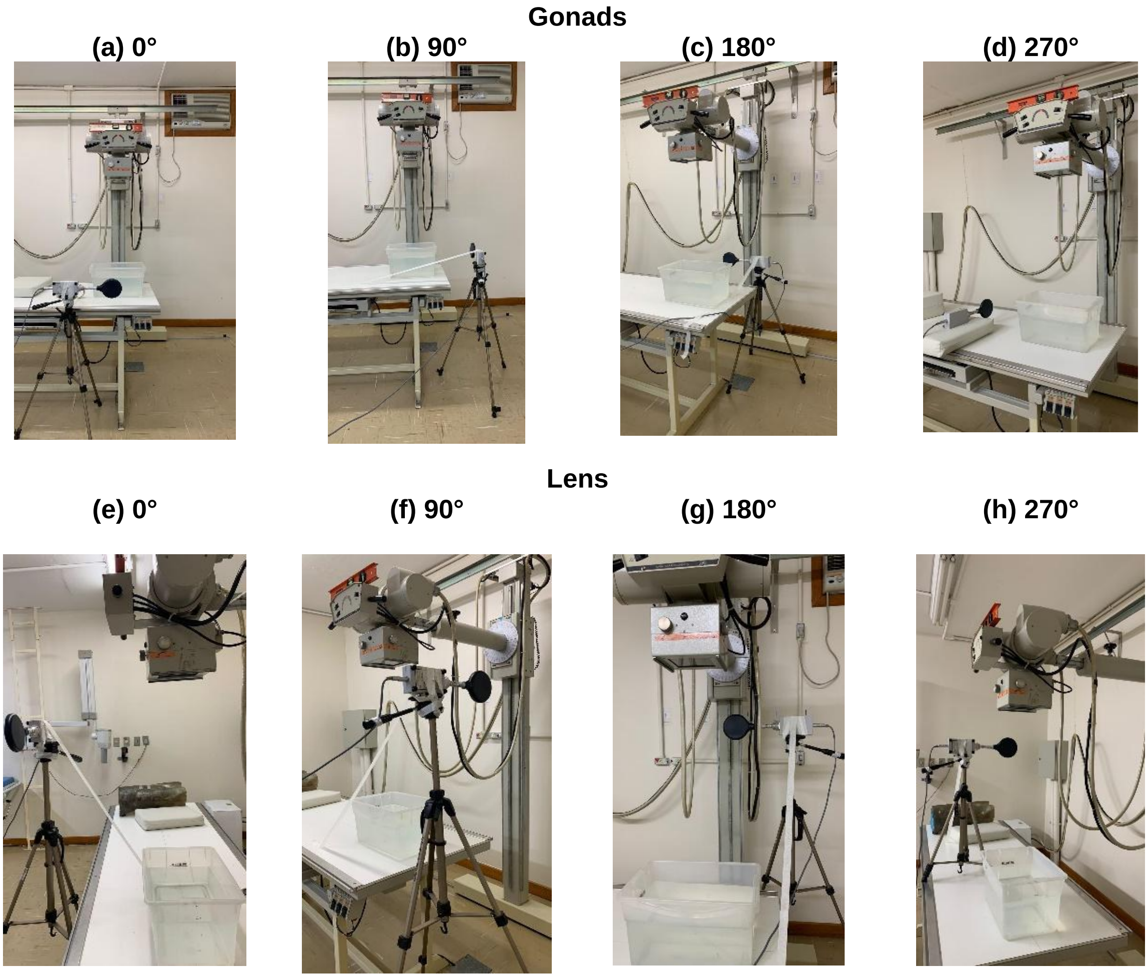

Fig. 2. Demonstration of positions and heights for K_{AIR} measurement

3. RESULTS AND DISCUSSION

The values obtained for K_{AIR} for each of the measurements made from the geometry in Fig. 2 and their average values are presented in Table 1, identified according to the angle of disposition.

Table 1, therefore, presents the measured K_{AIR} values at different angles of disposition for the positions at the height of the gonads and the lens of the eye, allowing for the analysis of the information regarding the distribution of the radiation dose as a function of body orientation.

Considering the height of the gonads, the K_{AIR} values vary according to the angle of disposition, with the lowest values measured at 90° (0.560 mSv) and the highest at 180° (1.117 mSv). This variation can be attributed to the different exposure of the gonads depending on the body's position relative to the radiation source. The 90° position consistently presents the lowest K_{AIR} values, indicating lower exposure in this orientation. Conversely, the 180° position shows the highest average values, suggesting that this position offers the highest radiation exposure.

These findings imply that the orientation of the companion during radiological procedures can significantly influence the dose received by the gonads. This variation in exposure based on orientation underscores the importance of proper positioning in radiological procedures. It suggests that careful consideration and adjustment of the companion's position can substantially reduce the radiation dose received by the gonads. This is particularly crucial in optimizing radiological protection, as reducing exposure to sensitive areas such as the gonads can significantly lower the risk of radiation-induced damage.

In the case of the lens of the eye, the K_{AIR} values also vary, but less markedly compared to the gonads. The average values obtained were higher at 90° (1.108 mSv) and 180° (1.083 mSv), while the lowest average was observed at 270° (0.474 mSv). The relative consistency in measurements for the angles of 0°, 90°, and 180° (with averages of 1.084 mSv, 1.108 mSv, and 1.083 mSv, respectively) suggests that the lens of the eye is exposed relatively uniformly in these positions. However, the significant reduction in dose observed at the 270° position highlights the role of body orientation in radiological protection. This position, in particular, appears to offer better protection for the lens of the eye compared to other orientations. In radiological procedures, where minimizing exposure to the lens is essential to prevent radiation-induced cataracts, adopting this orientation could be a vital protective measure. This finding emphasizes the need for detailed guidelines on optimal body positioning during radiological procedures.

These results emphasize the importance of body position in the distribution of the radiation dose for both the gonads and the lens of the eye. The variations in K_{AIR} values indicate that optimizing the patient's position during radiological procedures can significantly reduce radiation exposure. Radiological protection strategies should, therefore, consider these variations to minimize exposure risks for both reproductive organs and sensitive areas such as the eyes.

Table 1. List of measured K_{AIR} readings at the gonads and lens heights, along with the average value and their positions

		Gonads		
	0º	**90º**	**180º**	**270º**
Measured values (mSv)	1.052	0.564	1.326	1.003
	1.052	0.534	1.043	0.972
	1.065	0.571	1.007	1.003
	1.065	0.569	1.093	1.015
Average	1.059	0.560	1.117	0.998
		Lens		
	0º	**90º**	**180º**	**270º**
Measured values (mSv)	1.103	1.097	1.106	0.471
	1.085	1.116	1.088	0.474
	1.066	1.110	1.057	0.471
	1.081	1.110	1.082	0.478
Average	1.084	1.108	1.083	0.474

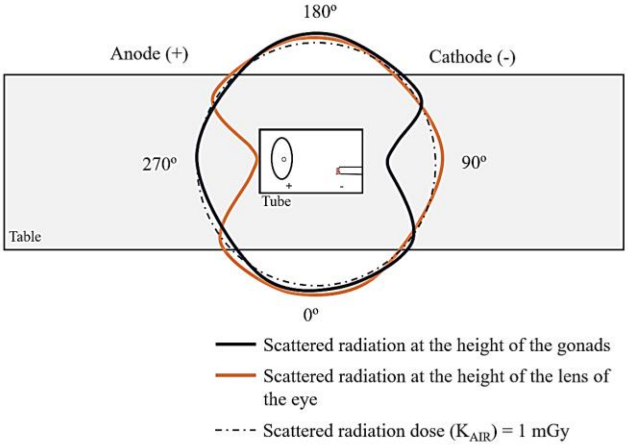

Fig. 3. K_{AIR} curve for gonad and lens heights

Considering the results obtained from the measurements, there is an agreement with the anode heel effect. The anode heel effect results in a reduction of X-ray intensity on the anode side of the useful beam, caused by absorption in the thicker part of the target, and consequently, the radiation intensity on the cathode side in the irradiated area is higher [9].

Fig. 3 was constructed from the data in Table 1, showing the curves of scattered radiation dose in relation to the position of the companion around the radiographic equipment for both measured heights.

From a more dynamic perspective, Fig. 3 shows that, to minimize exposure to the gonads during pediatric chest radiographic exams, the ideal positioning of the companion is at 90°, which presented the lowest average radiation dose. In this position, the companion is lateral to the patient, significantly reducing direct exposure to the gonads. In contrast, the highest exposure was recorded at the 180° position, where the companion is facing the X-ray beam, resulting in a higher radiation dose. However, to minimize exposure to the lens of the eye, the ideal position is 270°, providing more effective protection. The highest radiation dose to the lens was recorded at the 90° position, where the companion is lateral to the X-ray beam, resulting in greater exposure.

A study by Duandini, Hidayanto and Budi [10], showed that the dose calculation results using the Klein-Nishina equation for the pediatric patients' companion during thoracic examination ranged from 0.39×10^{-5} mSv to 4.64×10^{-5} mSv, which is significantly below the admissible dose. However, our study demonstrated values that were still well below the stringent limits set by CNEN in Brazil, which is 5 mSv per diagnostic or therapeutic procedure. This underscores the effectiveness of current radiological protection measures and the significant margin of safety maintained in pediatric radiological practices.

4. CONCLUSION

Pediatric chest exams conducted with investigative criteria are crucial for diagnosing various medical conditions, but it is essential to balance the diagnostic benefits with the risks associated with ionizing radiation exposure. Appropriate radiological protection measures must be implemented to minimize exposure to primary radiation for the child and scattered radiation for the companions.

The results of this experimental research identified the ideal points for the companion's positioning, highlighting the locations with the lowest radiation doses. Considering that the dose received varies with height and that lead body protection is available, the most suitable position for the companion is one that minimizes exposure to the lens, which is not protected by lead. Therefore, to achieve this goal, the companion should position themselves at 270° in relation to the radiographic equipment, that is, on the anode side.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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