Dose Calculation in Pediatric Population Undergoing Chest X-Ray at a Tertiary Healthcare Setting in Ghaziabad

Ritu Shishodia[1], Dr Ashish Kumar Shukla[2], Abhishek Kaushik[3], Rohini gupta[4], Arif Hussain Malla[5]
[1,2,3,4,5] Santosh deemed to be university

Abstract- This study comprehensively evaluates radiation dose estimation and optimization strategies in pediatric patients undergoing chest radiography within a tertiary healthcare setting in Ghaziabad, India. Pediatric radiography, though vital for diagnostic accuracy, poses significant concerns regarding radiation exposure due to the increased radiosensitivity of children. The study aimed to calculate entrance surface dose (ESD), dose-area product (DAP), and effective dose (ED), and identify technical, anatomical, and procedural factors affecting dose variations. A prospective approach was employed, including 178 pediatric patients aged 0–10 years undergoing routine chest X-rays. Exposure parameters such as kilovoltage peak (kVp), milliampere-seconds (mAs), and source-to-image distance (SID) were recorded. Data analysis revealed that radiation dose levels correlated strongly with patient age, body mass, and exposure factors, while optimization using ALARA principles significantly reduced radiation burden by up to 30%. Establishing localized diagnostic reference levels (DRLs) was recommended to improve consistency in pediatric imaging practices. The findings emphasize continuous education, equipment calibration, and adherence to standardized pediatric imaging protocols to ensure patient safety and diagnostic efficacy.

Keywords- Pediatric radiography, Radiation dose, ALARA, Diagnostic reference levels, Radiation safety, Chest X-ray, Dose optimization

I.INTRODUCTION

Medical imaging has revolutionized healthcare by enabling non-invasive visualization of internal anatomy and pathology. Among these modalities, chest radiography remains one of the most frequently used diagnostic procedures, particularly in pediatrics. It assists in detecting respiratory disorders, congenital anomalies, infections, and cardiac abnormalities. However, ionizing radiation, which is inherent to X-ray imaging, carries a potential risk of inducing stochastic biological effects such as cancer, especially in pediatric patients whose tissues are more radiosensitive and who have a longer life expectancy during which radiation effects may manifest. Consequently, radiation protection and dose optimization have become paramount in pediatric imaging. International guidelines including those from the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) emphasize the ALARA (As Low As Reasonably Achievable) principle to minimize radiation exposure.
Children differ significantly from adults in their anatomy, physiology, and radiosensitivity. Factors such as smaller body size, rapidly dividing cells, and developing organs contribute to a heightened risk from ionizing radiation. Moreover, pediatric imaging often requires repeated examinations, further increasing cumulative exposure. Studies across multiple countries have highlighted that pediatric X-ray doses can vary considerably between institutions, mainly due to inconsistent protocols, differences in equipment calibration, and inadequate operator training. In developing nations, including India, the lack of standardized pediatric diagnostic reference levels (DRLs) contributes to this variability.

This study focuses on quantifying and optimizing radiation doses in pediatric chest X-rays performed at a tertiary healthcare institution in Ghaziabad. It seeks to establish baseline dose values, analyze correlations between patient parameters and exposure settings, and propose practical recommendations for dose optimization. Through systematic assessment and adherence to radiation protection standards, this research aims to enhance diagnostic safety and efficiency in pediatric radiology.

II.MATERIALS AND METHODS

A prospective observational study design was used, encompassing 178 pediatric patients aged 0–10 years undergoing chest radiography (anteroposterior, posteroanterior, or lateral projections) at a tertiary hospital in Ghaziabad. Patients above 10 years and cases lacking complete exposure records were excluded. All examinations were performed using a digital radiography (DR) system, ensuring consistent exposure control. Ethical approval was obtained from the institutional ethics committee, and data confidentiality was maintained throughout the study.

Exposure parameters including tube voltage (kVp), tube current-time product (mAs), source-to-image distance (SID), and focus-to-skin distance (FSD) were recorded for each examination. The Entrance Surface

Dose (ESD) was estimated using the formula:

$$ESD = Output \times (mAs / 100) \times (1 / (FSD)^2) \times \text{Backscatter factor}$$

where the machine output was determined through calibration and expressed in mGy/mAs at a reference distance of 100 cm. The Dose-Area Product (DAP) was derived from ESD by incorporating the exposed field size, while the Effective Dose (ED) was calculated using conversion coefficients from ICRP Publication 103. Data were analyzed using descriptive statistics, correlation analyses, and dose comparisons across age and weight groups.

Quality assurance procedures were followed to verify equipment performance, including kVp accuracy, filtration, and collimation checks. Operator training focused on applying optimized parameters according to patient size, reducing unnecessary repeats, and ensuring proper beam collimation and shielding. The ALARA principle guided all exposure decisions, ensuring diagnostic adequacy at minimal dose.

III.RESULTS

The study analyzed 178 pediatric patients, including 92 males and 86 females. Patients were categorized into three groups based on age: Group I (0–1 year), Group II (2–5 years), and Group III (6–10 years). The mean ESD values for PA chest radiographs were 0.05 mGy in Group I, 0.09 mGy in Group II, and 0.18 mGy in Group III. For AP projections, values ranged from 0.07 to 0.21 mGy. The mean effective dose (ED) across all groups was 0.05 mSv. These values are consistent with reported international diagnostic reference levels (DRLs) for pediatric chest radiography.

Statistical analysis revealed a strong correlation ($r = 0.78$, $p < 0.01$) between patient weight and ESD. Similarly, mAs showed a direct linear relationship with radiation dose, while increasing SID inversely affected exposure levels. Optimization trials indicated that reducing mAs by 20% and using appropriate beam collimation could lower ESD by approximately 30% without perceptible degradation in image quality. Age-based dose variations reflected physiological differences in body mass and chest thickness, necessitating patient-specific exposure charts.

Operator technique and adherence to exposure protocols were found to be major determinants of dose variability. Radiographs acquired by trained technologists consistently demonstrated lower ESD values compared to those obtained by less experienced operators, highlighting the impact of skill and awareness on patient safety.

IV.DISCUSSION

The findings of this study reaffirm the variability in pediatric radiation doses across different age groups and highlight the need for protocol standardization. Children’s increased radiosensitivity necessitates meticulous control of exposure parameters. Comparison with international data shows that the recorded doses in this study align with the IAEA PiDRL (2018) guidelines, though inter-operator variation remains a significant challenge. Dose optimization strategies such as the use of automatic exposure control (AEC), beam filtration, and proper positioning can contribute significantly to dose reduction.

The results are consistent with studies by Ma et al. (2024) and Weiss et al. (2024), which also reported progressive dose increments with patient age and body size. Findings by Polito et al. (2021) and Lahham et al. (2021) emphasized that simple protocol modifications—like collimation, shielding, and mAs reduction—yield substantial dose savings. Similarly, Karami and colleagues (2016) demonstrated that thyroid shielding can effectively minimize organ-specific dose. These correlations underscore the necessity of individualized imaging approaches rather than a one-size-fits-all protocol.

Another critical aspect of dose management lies in continuous equipment calibration and staff training. Outdated radiographic systems with inconsistent tube output are a common problem in developing regions. Standardizing imaging parameters and implementing real-time dose monitoring tools can mitigate these discrepancies. Furthermore, introducing local DRLs, as proposed by Gilley et al. (2023) and Célier et al. (2020), enables institutions to benchmark their performance and identify areas requiring optimization.

While this study demonstrated encouraging outcomes, it also revealed the lack of uniform awareness among radiologic technologists regarding pediatric dose sensitivity. Regular workshops, audits, and incorporation of radiation protection modules into academic curricula could address this gap. Additionally, parental awareness campaigns regarding radiation risks and safety measures may further promote informed consent and ethical imaging practices.

V.CONCLUSION

This study concludes that pediatric patients undergoing chest radiography in tertiary healthcare facilities are subject to varying radiation doses influenced by technical parameters, patient characteristics, and operator practices. Adhering to the ALARA principle, optimizing exposure parameters, and implementing pediatric-specific diagnostic reference levels can significantly reduce unnecessary exposure while maintaining diagnostic integrity. The establishment of institutional DRLs, periodic equipment calibration, and operator training programs are imperative for consistent radiation safety. Future research should focus on longitudinal monitoring of pediatric radiation exposure and development of automated dose-tracking systems to enhance quality assurance.

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