ASSESSMENT OF RADIATION DOSE REDUCTION APPROACHES IN PEDIATRIC RADIOGRAPHY

BY

OKHIONKPAMWONYI AISOSA

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SUPERVISOR: MRS OLASUYI KEMISOLA

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CERTIFICATION

This is to certify that the research work for this project and the subsequent write up by Okhionkpamwonyi Aisosa, with matriculation number BMS2001303 were carried out under my supervision.

Mrs Olasuyi Kemisola	………………………
(Supervisor)	(Signature and Date)
Mrs. Fanny Igbenedion	………………………
(Head of Department)	(Signature and Date)
External examiner	………………………
	(Signature and Date)

DEDICATION

I dedicate this research project to my beloved parents, who instilled in me the desire to work hard and excel and supported me morally and financially.

ACKNOWLEDGMENT

All gratitude and appreciation to Almighty God who gave me the wisdom, courage, opportunity, and good health to undergo this study.

I would like to express my heartfelt gratitude to my supervisor, Mrs Olasuyi Kemisola for her guidance, patience, and valuable support throughout the project. Her insights and expertise were important in determining the direction and focus of this study. May God reward her and her family abundantly.

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My heartfelt gratitude goes to my parents, for their care, love, support, prayers, sacrifice, and encouragement. My appreciation also goes to my siblings and relatives. My classmates and friends, I appreciate your support and prayers. Thank you.

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ABSTRACT

Radiography among the pediatrics plays a crucial role in the diagnosis of childhood illnesses, but children are more sensitive to the effects of ionizing radiation, and this aspect makes it necessary that dose should be optimized to reduce the long-term risks. This work determined the level of knowledge, attitudes, and practices of radiographers towards the methods of reducing the dose of radiation in pediatric radiography in Benin Metropolis. Sixty radiographers participated in a descriptive cross-sectional survey using a structured questionnaire and data analysis was done using SPSS version 25. Responses were summarized by descriptive statistics and Chi-square tests were used to determine the relationships with each other at a significance level of 0.05. Awareness about ALARA principle was 100 per cent with only 38.3 per cent being aware about Diagnostic Reference Levels (DRLs). Although the majority of respondents (81.7) cited that they reduced the exposure factors and 80% utilized Automatic Exposure Control (AEC), very few (21.7) used the pediatric-specific exposure charts. There were positive attitudes towards radiation safety but this was not implemented due to lack of immobilizing devices (86.7%), poor calibration of collimators (68.3%), and lack of functional AEC systems (60%). The years of experience were also significantly related to using collimation properly ($p = 0.001$). The study finds that radiographers in Benin Metropolis do not only demonstrate a high level of awareness and positive attitude towards the idea of pediatric dose reduction but also a moderate level of compliance that is attained by infrastructural and procedural barriers. I would recommend strengthening equipment maintenance, applying pediatric imaging guidelines, and improving unremitting professional training as a prevention of safer and more efficient pediatric radiographic practices.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Pediatric imaging is a significant field in the current medical diagnostics because it provides data about the vast spectrum of diseases in children (Talhi et al., 2022). Nearly 300 million pediatric diagnostic radiology studies are conducted annually in the world, and conventional and digital radiography (CR/DR) are the most frequently used ones (Freghali et al., 2021). Ionizing radiation techniques like X-rays, CT, and fluoroscopy are still essential in the diagnosis and treatment of most childhood diseases (Jandan et al., 2022). Nevertheless, the possible dangers of radiation exposure on children have prompted the major advancement in the imaging methods aimed at mitigating the dangers without compromising the high diagnostic accuracy (Talhi et al., 2022). Every imaging process that uses ionizing radiotherapy should be clinically reasonable according to the anticipated diagnostic value. In addition, it must observe strictly the principle of ALARA (As Low As Reasonably Achievable) in order to care of patient safety. Radiation doses should also be regularly assessed and compared with established Diagnostic Reference Levels (DRLs), which should not be exceeded unless clearly justified (Eddy *et al*., 2021). A properly conducted X-ray exam must offer a diagnostic advantage that outweighs the relatively small but real long-term risks, such as an increased likelihood of cancer or potential hereditary effects (David & Lateef, 2017).

Children are particularly vulnerable to radiation. Their smaller body size, rapidly developing organs, and higher rates of cell division make them more sensitive to radiation than adults (Aziz *et al.*, 2024). The increased use of imaging in pediatric care has raised concerns over excessive radiation exposure in this population (Aloufi, 2022). The National Research Council's Committee on the biologicaleEffects of ionizing radiation has reported that children under 10 years old are several times more sensitive to radiation than adults. Furthermore, because they have a longer life expectancy, there is a greater window of time for radiation-induced cancers to develop (Aziz *et al.*, 2024) For example, a typical pediatric CT scan may deliver a dose of about 4 mSv for the brain and up to 1-3 mSv for the chest, abdomen, or pelvis doses that would require hundreds of conventional X-ray projections to match (Garba & Mufutawu 2024; Obara et al., 2017).

The radiographers normally find it difficult to image children. Their smaller size, positioning problems, and higher sensitivity to radiation need specific skills and a perfect awareness of pediatric anatomy, not to mention some psychology (Inah et al., 2022). Kids also tend to be more motile in the process, which means that they are more likely to repeat the imaging, thus exposing them to more radiation (David and Lateef, 2017). Radiation dose reduction strategies are very important to provide safety without reducing the quality of the diagnostic (Jandan et al., 2022). Such measures involve application of quicker imaging screens, reduction in exposure period, and maximization of the distance between the source and the image to reduce motion induced and respiration induced blurring of the image. It is also necessary to focus the

X-ray beam to hit the area of interest only and protect delicate body parts such as the gonads using lead (Inah et al., 2022). Low dose protocols, iterative reconstruction techniques, and sophisticated image processing algorithms have been created in CT imaging to lower the radiation doses. Radiographers too are advised to think of other imaging options such as ultrasound or MRI that do not involve the use of ionizing radiation (Jandan et al., 2022). This paper seeks to discuss the existing strategies in minimizing the radiation dose in radiography among children.

1.2 Statement of research problem

Children below 10 years are multiplied many times more sensitive to radiation compared to adults and have a longer life span making it more dangerous to have radiation-induced cancers (Aziz et al., 2024). In spite of these dangers, research indicates that dose reduction methods are not applied in the imaging of children. It is necessary to evaluate the existing practice, the knowledge of radiographers, and the points of improvement to save patient safety.

1.3 Research Questions

- What radiation dose reduction techniques are currently used in pediatric radiography?
- How knowledgeable are radiographers about pediatric dose optimization principles?
- To what extent are pediatric-specific protocols and technologies utilized?

- What are the barriers to effective radiation dose reduction in pediatric imaging?

1.4 Research hypothesis

Null Hypothesis (H_0): There is no significant association between the application of radiation dose reduction approaches and the reduction of radiation dose received by pediatric patients in radiography.

Alternative Hypothesis (H_1): The application of radiation dose reduction approaches significantly reduces the radiation dose received by pediatric patients in radiography.

1.5 Aim and objectives of the study

- To assess radiation dose reduction approaches in pediatric radiography.
- To identify commonly used dose reduction techniques in pediatric radiography.
- To evaluate radiographers' knowledge and application of pediatric imaging protocols.
- To assess the availability and use of pediatric-specific equipment and protocols.
- To recommend strategies for improving dose optimization practices in pediatric radiography.

1.6 Significance of the study

The given study will contribute to defining missing links in the modern pediatric dose optimization practice and stimulate the introduction of the standardized and evidence-based protocols. The results will be used in training, the development of policies, and better patient safety results in radiography.

1.7 Scope of the study

The research shall be centered on the radio procedures performed on children in the selected diagnosis imaging centers or hospitals in Benin. It will include routine radiographic tests in children and will include radiographies and imaging department protocols in the period between June up to August 2025.

1.8 Operational terms

1. **ALARA principle:** Acronym for "As Low As Reasonably Achievable," a radiation safety principle focused on minimizing exposure.
2. **Anti-scatter grid:** A device used to reduce scattered radiation reaching the detector, improving image contrast but increasing dose.
3. **Automatic Exposure Control (AEC):** A feature of X-ray machines that automatically adjusts exposure parameters based on patient size and body part thickness.

4. **Collimation:** The restriction of the X-ray beam to the area of interest to limit patient exposure and improve image quality.

5. **Exposure factors:** The technical parameters used in radiography, including kilovoltage peak (kVp), milliampere-seconds (mAs), and source-to-image distance (SID).

6. **Dose:** A general term used when the context is not specific to a particular dosimetric quantity related to the exposure of an individual to ionising radiation.

7. **Dose Area Product (DAP):** The product of the radiation dose and the area irradiated, representing the total amount of radiation energy delivered.

8. **Dose reduction:** Strategies or techniques aimed at minimizing the radiation exposure to the patient while maintaining diagnostic image quality.

9. **Effective dose:** A calculated dose that reflects the risk of radiation exposure, considering the type of radiation and sensitivity of the exposed organs.

10. **Entrance Skin Dose (ESD):** The radiation dose received by the skin where the X-ray beam enters the patient's body.

11. **Filtration:** The process of removing low-energy X-rays from the beam that would contribute to skin dose but not image formation.

12. **Pediatric radiography:** X-ray imaging procedures performed on infants, children, and adolescents for diagnostic purposes.

13. **Radiation dose:** The amount of ionizing radiation energy absorbed by the body during a radiographic procedure.

14. **Radiation protection:** Measures and practices aimed at safeguarding patients and staff from unnecessary radiation exposure.

15. **Repeat imaging:** Taking another X-ray due to poor image quality or motion artifacts, leading to additional radiation exposure.

16. **Shielding:** The use of protective materials (e.g., lead aprons) to block or reduce radiation exposure to non-targeted body parts.

CHAPTER TWO

LITERATURE REVIEW

The literature review is categorized into two parts, the conceptual review, where applicable concepts and theories are explained to give a framework on understanding the subject one is conducting the research, and the empirical review, where findings of other researchers conducted on the topic of research are presented.

2.1 Conceptual review

2.1.1 Radiation risks in children

Children's exposure to ionizing radiation has become a growing concern due to the potential short and long term health risks it poses. These concerns are particularly significant in imaging procedures involving computed tomography (CT) and interventional fluoroscopy, which together account for the majority of radiation doses in pediatric imaging (Aloufi, 2022).

Children are more susceptible to radiation damage than adults for several reasons. First, their tissues and organs are still developing, and they have higher rates of cellular proliferation. Second, with a longer life expectancy, they have more time for radiation-induced conditions, such as cancer, to develop (Aloufi, 2022).

Radiation risks are typically categorized into deterministic and stochastic effects. Deterministic effects occur when a radiation dose exceeds a certain threshold, leading to observable damage such as tissue or organ dysfunction. These effects usually require doses much higher ($\geq$2 Gy) than those used in diagnostic procedures like CT (typically $\leq$50 mGy) (Thakur *et al*., 2013).

Stochastic effects refer to the probability of long-term effects, such as cancer or genetic mutations, and can occur even at lower doses. Evidence from adult epidemiological studies has shown that cancer risks rise with moderate radiation exposure, and children are estimated to face up to ten times higher risk than adults under similar conditions (Aloufi, 2022).

2.1.2 Radiation dose in pediatric imaging

While pediatric imaging can produce highly detailed anatomical images, this often comes at the cost of higher radiation exposure. The unnecessary high dose of radiation can be caused by the use of adult imaging systems on a child, an inability to adjust the scan settings to the patient size, the inability to customize exposures, etc. (Aloufi, 2022). Measurements of radiation dose are in form of:

i. Entrance Skin Dose (ESD): is the dosage at the surface of the skin.

ii. Dose Area Product (DAP): is the amount of energy transmitted over the exposed area.

iii. Effective Dose: is a rough estimate of the total radiation hazard to the whole body.

2.1.3 Dose Justification

Justification is a fundamental concept of radiation protection that makes sure that the projected clinical benefit of any given radiologic procedure exceeds the risks (Foley et al., 2022). Referring clinicians are also important in this process since they are required to comply with the accepted referral guidelines and imaging standards (Garba et al., 2023; Seeram, 2014). Adequate justification results in improved patient safety and also leads to a decrease in the radiation exposure and healthcare expenditure at the population level (Garba & Mufutawu 2024).

The use of the ALARA principle (As Low As Reasonably Achievable) adds additional emphasis on the necessity to reduce exposure with ensuring the diagnostic accuracy (Goo, 2012). Before taking CT scans, justification should be ensured and this is one of the important steps towards upholding this principle.

2.1.4 Dose Optimisation

Dose optimisation is the theory of attaining optimal correlation between image quality and radiation exposure to meet the requirements of multiple and conflicting clinical and technical specifications (Garba & Adebayo, 2024). As pointed out (Strauss et al., 2010) an ideal CT scan must be optimized to suit the clinical requirement besides reducing the radiation dose to both the patient and the population.

Achieving the lowest dose of radiation with a purpose of getting diagnostically useful images is the main aim of dose optimisation (Goo, 2012). Computed tomography (CT) has come up with several measures that can be used to do so namely: Selecting proper scan modes, Noise-reduction image reconstruction methods, Reducing repeat scan, Procedure adaptation to patient size, Tube current modulation (Seeram, 2014).

Recent innovations have brought to the CT imaging the use of artificial intelligence (AI) methods to improve workflow efficiency and image quality and reduce noise and dose. The AI applications are automatic scan range detection, patient placement at the isocenter, and optimization of the reconstruction algorithm (McCollough and Leng, 2020). The further optimization of scan protocols and parameters with the help of further research will help in improving the diagnostic reliability and minimizing radiation dose.

2.1.5 Diagnostic Reference Levels (DRLs)

A DRL is a given radiation dose that is found based on surveys of common practice on standard procedures and population groups. The values are calculated on a reference dose like Dose Length Product (DLP) or Entrance Skin Dose (ESD) which is measured in various plants. DRLs are not applicable to specific patients instead of directing practitioners in assessing and revising protocols once patient doses are regularly above (or below) the recommended levels (ICRP, 2017).

DRLs can be classified by patient size, age or body part, local, national or regional based on gathered dose information. They are not set in stone but rather are expected to promote continuous evaluation of doses and optimisation of doses across institutions.

2.1.6 Technological Tools for Reducing Radiation Dose in Pediatric Imaging

1. Advancements in Imaging Technology

i. Low-Dose CT Scanners

Currently, state-of-the-art computed tomography (CT) devices include new dose-reduction methods, including iterative reconstructions, like Adaptive Statistical Iterative Reconstruction (ASIR) and Model-Based Iterative Reconstruction (MBIR). The methods enable reduction of radiation dose by as much as 60 percent of the conventional filtered back-projection methods while retaining the quality of the diagnostic images (Kuo et al., 2016).

ii. Digital Radiography (DR)

DR systems have high sensitivity detectors and increased dynamic ranges than the conventional film-screen systems. These aspects allow obtaining high-quality diagnostic images with a very reduced dose, contributing to the improved safety and image quality (Moses et al., 2020).

iii. Fluoroscopy innovations

The new technology of fluoroscopy, including pulsed fluoroscopy and automated dose control systems, has significantly decreased the radiation dose. The pulsed fluoroscopy reduces the continuous exposure duration, whereas automated systems vary dose-output dynamically according to the clinical requirement and the size of the patient (Gondal et al., 2017).

2. Dose Modulation Technologies

i. Automatic Exposure Control (AEC)

AEC systems change the parameters of exposures in real-time, depending on patient anatomy and clinical needs which leads to the reduction of unnecessary radiation. This guarantees the achievement of the highest quality of images and dose efficiency (Gungor et al., 2018).

ii. Size Specific Dose Estimates (SSDE)

SSDE is a more reliable way of measuring radiation exposure since it includes the size of patients, thus dose tracking and optimization becomes more accurate, especially in pediatric imaging (Wang et al., 2019).

iii. Automatic Tube Current Modulation (ATCM)

ATCM guarantees the quality of images by varying the current of tubes at the scanning depending on the anatomy of the patient. It is based on scan projection image (SPI), topogram, or scout view, which estimates patient attenuation in various projections (Agostini et al., 2022). Angular modulation (x, y axis) was reported to decrease the dose of CT of the chest by about 22, and Z -axis modulation could lead to a decrease in dose by 26 (Thakur et al., 2013). The methods enhance the homogeneity of noise and dose optimization without deteriorating the diagnostic applications.

3. Optimization of imaging protocols

i. Pediatric specific protocols

Children are more radiosensitive as compared to adults. Therefore, it is necessary to customize imaging arrangements with respect to age, size, and body part. There should be proper adjustments of exposure parameters like kilovoltage (kVp), milliampere-seconds (mAs), and the distance between a source and an image (SID). Pediatric exposure charts are also becoming more common in helping radiographers to choose the best settings (Goske et al., 2012).

ii. Protocol review and standardization:

Standardization of imaging protocols across different departments and frequent auditing of these protocols promotes consistency and assists in maintaining quality of diagnostic as well as reducing exposure. Setting clear rules and guidelines that rely on clinical signs and patient peculiarities facilitates effective and safe imaging (Baker and Kamboj, 2022).

4. Filtration and collimation

The low-energy X-rays, which do not add any value to the image but add to skin dose are removed by filtration. Collimation allows to limit the X-ray beam to the area of interest, thus protecting tissues adjacent to the area of interest and minimizing the scatter r(Baker & Kamboj, 2022)adiation (Strauss and Kaste, 2006).

5. Quality control and assurance

Phantom Testing:

Frequent testing using phantoms keeps the imaging equipment within the standards of dose and image quality. It helps to predict performance deviation early and enhance equipment calibration and maintenance (Lau et al., 2018).

i. **Image quality monitoring:**

Continuous quality control of the image is to make sure that the dose reduction strategies do not affect the diagnostic abilities. It is also useful in the validation of the effectiveness of instituted dose reduction measures (Baker et al., 2021).
Other imaging modalities.

6. Alternative imaging modalities

i. **Ultrasound**:

Ultrasound is non-ionizing hence the best imaging modality to use in pediatric assessment. It is very efficient in the evaluation of abdominal, musculoskeletal and soft tissue disorders. Nonetheless, it may not be useful in situations that involve an in-depth anatomical assessment or when it comes to air or bone filled organs (Kirkpatrick et al., 2019; Harris et al., 2020).

ii. MRI (Magnetic Resonance Imaging)

MRI is detailed and anionizing radiation image. It can be used especially to assess the brain, spinal cord and the joints. Although it has benefits, it cannot be extensively used in pediatrics due to such issues as increased expenses, inaccessibility, and the necessity to use sedation on uncooperative children (Henson et al., 2020).

7. Motion management and immobilization

Repeated exposure can be avoided by the use of motion control in pediatric imaging. Basic immobilization techniques like foam pads, sandbags, and parental assistance may be used to restrain patient movement and capture an image with the highest level of clarity and retakes (Image Gently, 2019).

8. Diagnostic Reference Levels (DRLs)

DRLs are used as an indicator of the standard imaging dose levels. Although they are not absolute limits, they direct the practitioners on how to optimize the dose and assist in determining outliers or overexposure. DRLs are supposed to be regularly revised and changed to the local practices (Seuri & Rehani, 2012).

9. Dose monitoring and auditing

Dose tracking software is gaining acceptance in hospitals as a means of tracking cumulative radiation exposure on individual patients. They can help healthcare providers to interpret trends, identify anomalies, and modify the protocols to improve safety (ICRP, 2013).

10. Education and training

i. **Radiation safety training**

Constant education about the subject of radiation protection makes radiologic technologists aware of the current best practices and dose reduction strategies (Davis et al., 2021).

ii. **Protocol compliance**

The emphasis of training should be on the adherence to optimized protocols and institutional guidelines that will guarantee consistency between staff and facilities (Gungor et al., 2018).

11. Patient and parental involvement

i. **Informed consent**

Clarity of information enables the parents and patients to make informed decisions and gain trust in the healthcare process by assisting them understand the risks and benefits of imaging in a transparent manner (Wang et al., 2019).

ii. **Shared decision making**

The discussion of alternative imaging and the need to repeat scans promote collaborative decision-making, which eventually leads to benefits of patiently care and safety (Kirkpatrick et al., 2019).

2.2 Empirical review

The articles that have been reviewed in this section were obtained in the Google Scholar, PubMed, and ScienceDirect databases. Articles that are written in English and published since 2013 were considered only. The search keywords that were used in the literature included pediatric radiation dose, pediatrics, and dose reduction. The first screening was done by a thorough review of titles and abstracts to determine relevance, and then full-text review of potentially useful articles was performed. The other relevant studies were found by using reference lists. Data retrieved included author and year, data collection and data analysis methods as well as methods of attaining dose reduction in the pediatric imaging.

Almohiy et al. (2020) examined the knowledge, expertise, and competency of Saudi Arabia radiologists in hospitals on CT radiation dose and related hazards in pediatrics. Sixty-five percent +- 13.5% of the respondents provided good knowledge of carcinogenic risks of CT scans with eight out of ten admitting that they were at high risk of cancer. Nonetheless, the level of awareness about individual radiation hazards differed by type of examination: only 48.5 per cent, 56.5 per cent and 65 per cent were fully aware of the danger in head, chest and abdominal CT of children. The research proposed that regular and specialized training would be a good idea in improving basic knowledge of radiologists and physicians on CT radiations safety.

Since 162 radiographers were interviewed, AL-Rammah (2016) discovered that only 15% of them were familiar with the ALARA (As Low As reasonably Achievable) principle. Over fifty four percent (54 percent) of them falsely thought multi-slice CT produces low radiation and 62% of them did not know that radiation is categorized as a carcinogen by the U.S Food and Drug Administration. It is worth noting that only 68% of them were trained on radiation formally. In general, 83% of them estimated the dose of CT underestimated and 70% of them mistakenly believed that MRI uses ionizing radiation.

A survey of the knowledge of radiation protection and Diagnostic Reference Levels (DRLs) in Saudi Arabia was performed by Bawazeer (2022) through a cross-sectional survey of CT radiographers. More than 80 percent were familiar with CT dose display and correct dosimetric units, whereas 60.6 percent could not define dose optimization. It was found that there was a significant relationship between years of experience and the lack of understanding dose optimization. There was poor knowledge of DRA with more than 65 percent failing to identify the purpose or the role of DRA correctly. Over fifty percent did not receive any training on national DRLs, which is why specific education programs are necessary.

Aziz et al. (2024) touched upon the issues regarding the minimization of the radiation provided during pediatric CT scanning in emergency care without harming the quality of the diagnostic results. Their literature review identified the increased radiosensitivity of pediatric tissues and proposed three approaches to it: optimizing scan parameters according to patient size, following the guidelines, including ALARA and PECARN, and using other imaging modalities where suitable. The research emphasized innovations in the future, the collaboration between departments, and the standard of the protocols as the key to making pediatric imaging safer.

David and Lateef (2017) assessed Entrance Surface Dose (ESD) of pediatric chest X-rays of three Nigerian hospitals located in Southwest Nigeria with 100 randomly chosen patients. ESD values were 38-150 mGy (0-1 year), 43.34-194 mGy (1-5 years), 74-223 mGy (5-10 years) and 87.60-292 mGy (10-15 years). Mean ESDs were also lower than certain past studies in Nigeria, but still above recommended reference ranges and therefore dose optimization was possible.

Eddy et al. (2021) used three medical centers to study the CT dose index of 320 cranial CT scans in children to determine the relationship between the dose index and the CT dose index in children. They found that dose indices (CTDIvol and DLP) were higher than Diagnostic Reference Levels in France by up to 47.7 percent in the various age categories of the children. The research identified the necessity of modifying the protocols and improving the compliance with the radiation protection principles to decrease excessive doses of CT in children.

Emmanuel (2022) calculated mean ESDs of pediatric chest AP radiographs in three hospitals in Cameroon with vastly different dose in hospitals and age groups. Doses in most cases were higher than the reference levels in National Radiological Protection

Board (NRPB) 2000 and indicate the need to optimise and standardise the dose in paediatric radiography.

Feghali et al. (2021) experimented with a new post-processing and denoising algorithm to dose-reduction in pediatric digital radiography without denoising the quality of images. Images of 174 patients aged 6 months to 9 years had 50, 32 and 12.5 percent simulated dose reductions. The 50 percent dose minimization was the only dose that preserved non-inferior quality of diagnostic image in all anatomical areas. The inter-rater reliability depended on the region and weight category but was most often moderate or very good, which indicated the possibility of post-processing methods in dose-reducing.

Garba and Mufutawu (2024) conducted a survey involving 101 radiography students in Nigeria in an attempt to determine their level of knowledge on CT dose parameters and dose optimization. The percentage of respondents who were aware of the CT dose indicators was 91.1 with the majority of those who were able to name the dose indicators correctly, but 84.2 did not know the most informative dose indicator showing moderate knowledge levels and the necessity of more educational intervention.

Lee et al. (2020) compared Monte Carlo (MC) simulation to thermoluminescent dosimetry (TLD) in estimating the effective dose during panoramic radiography in children. MC simulation provided similar results on dose estimates compared to TLD whereby the beam height was established to be the most critical factor in dose reduction. It was found that radiation dose among pediatric patients can be reduced successfully by using shorter beam heights.

Although a gap in understanding of safe dose protocols of radiography in children existed, Moolman et al. (2020) confirmed the gap in knowledge among radiographers in South Africa, Gauteng. They identified only 57% of them confident in their understanding of pediatric radiation dose using a questionnaire, which demonstrates that better education and awareness are necessary to raise the rates of safe operation of imaging procedures.he need for improved training and awareness to ensure safe imaging practices.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research setting

The research was conducted at the radiology departments and private centers where diagnostic imaging for pedriatrics is being performed.

3.2 Study design

A descriptive cross-sectional study design was used to assess radiographers approaches for dose reduction during pedriatric imaging at radiology departments and centers in Benin metropolis.

3.3 Target population

All radiographers and imaging protocols from selected hospitals who perform pediatric radiographic examinations.

3.4 Sampling technique/ Sample size

Purposive sampling technique was employed, all licensed radiographers currently practicing at selected the radiology departments were included in the study. Thirty one radiographers were from federal hospital, 12 from state hospitals and 17 from private centers in Benin City.

3.5 Instrument for Data Collection

A structured, self-administered questionnaire was used for data collection. The questionnaire was divided into five sections: demographic information, knowledge of dose reduction techniques, attitudes toward pediatric radiation safety, practice of dose optimization, and challenges in implementing pediatric dose reduction. It comprises a mix of Likert scale, Yes/No, frequency scales, and open-ended questions. The questionnaire was pre tested to ensure clarity, validity, and reliability. The questionnaire is attached as appendix I.

3.6 Validity of instrument

Reviews of the literature were part of the judgmental approach to establishing content validity, which was followed by expert evaluations.(Taherdoost, 2016). Content validity was ensured by subjecting the questionnaire to expert review by my project supervisor.

3.7 Reliability of instrument

Before the commencement of data collection, a pilot test was conducted among five radiographers at another hospital to assess reliability. The data from the pilot study were analyzed using Cronbach's alpha, yielding a reliability coefficient of 0.76 indicating good internal consistency.

3.8 Method of data collection

Printed questionnaires was given to complete and returned within 2 days.

3.9 Method of data analysis

Data was analyzed using the Statistical package for social sciences (SPSS) version 25. Descriptive statistics including frequencies, percentages were used to summarise responses. Chi square tests, t- tests were used to assess association between variables. Correlation analysis was done to explore the relationships and determinants of radiation dose approaches. A p-value of < 0.05 was considered statistically significant.

3.10 Ethical Considerations

Ethical approval was obtained from the Health Research Ethics Committee of . University of Benin Teaching Hospital (UBTH). Informed consent was obtained from all participants before data collection. Ethical approval request is attached as appendix II.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results obtained from the analysis of data collected for the study The analysis was conducted using SPSS version 25, and findings are presented using frequency tables, percentages, and inferential statistics. Discussions are integrated with relevant empirical studies to provide contextual understanding.

4.2 PRESENTATION

DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

The majority of the respondents were males (71.7%) whose ages ranged between 25-34 years (91.7%), with a majority of them having a B.Sc degree (81.7%). The percentage of interns was very high (41.7), and it was only 18.3% that possessed more than six years of experience in pediatric radiography. Thirty one (51.7%) radiographers were from federal hospital, 12 (20.8%) from state hospitals and 17 (28.3%) from private centers.

This population is representative of a relatively young and early-career population of radiographers, as was also the case with the study by Moolman et al. (2020), who also found that low levels of professional experience add to the dispersion in the knowledge and practice of pediatric radiography.

Table 4.1: Demographic Information of Respondents

Variable	Category	Frequency(n=46)¤	Pacentage'(%)¤
	Below 25	2	3.3
Age(years)	25-34	55	91.7
	35-44	1	1.7
	45 and above	2	3.3
Gender	Male	43	71.7
	Female	17	28.3
Highest-qualification	B.Sc	49	81.7
	PGD	9	15.0
	M.Sc	2	3.3
Job title/position	Intern Radiographer	25	41.7
	Chief Radiographer	20	33.3

KNOWLEDGE OF DOSE REDUCTION TECHNIQUES

The percentage of respondents who knew about the ALARA principle was 100 and all of them admitted that children are radiosensitive compared to adults. Nevertheless, only 38.3% of them were aware of Diagnostic Reference Levels (DRLs), and only 15% of them were aware of the accepted range of 10-15 mrem of maximal entrance skin dose (ESD) when taking pediatric chest radiographs.

This partial awareness is the reflection of the findings obtained by Bawazeer (2022), who found that the CT radiographers, in general, knew little about DRLs, with more than 65 percent of them being unable to name the purpose of them. Likewise, Garba and Mufutawu (2024) established that though most students at radiography knew about dose indicators, only 10.9% could name them properly, which is not enough to demonstrate that a particular technical depth of dose optimization knowledge was acquired.

Conversely, Almohiy et al. (2020) found that Saudi Arabia radiologists had more knowledge (65% good understanding), which is why the continuous education program can potentially enhance awareness in low-resource areas. The existing result highlights the importance of specific training among Nigerian radiographers as a way of closing the knowledge-to-practice gap in the field of optimization of pediatric doses.

Table 4.2: Respondents' Knowledge of Pediatric Dose Reduction Techniques

Variable	Yes (%)	No (%)

Aware of ALARA principle	100.0	0.0
Familiar with Diagnostic Reference Levels (DRLs)	38.3	61.7
Trained in selecting pediatric-specific exposure parameters	100.0	0.0
Know average ESD range for pediatric chest radiographs	15.0	85.0
Believe children are more radiosensitive than adults	100.0	0.0

Recognized Pediatric Dose Reduction Strategies

Most of the respondents identified the decrease of exposure factors (81.7%), utilization of AEC (80%), and collimation (75%) as key dose reduction measures. Such results are consistent with those of Aziz et al. (2024), who instructed the importance of parameter modification and the compliance with ALARA and PECARN guidelines as the central aspect of safe pediatric imaging.

On the same note, Lee et al. (2020) showed that the beam height reduced radiation dose in pediatric panoramic radiography, which supports the role of collimation in the current research. The present results reveal that the radiographers in Nigeria are mostly familiar with the general dosage reduction methods, but their regular use is doubtful.

Table 4.3: Recognized Dose Reduction Strategies

Strategy	Yes (%)	No (%)
Proper collimation	75.0	25.0
Lowering mAs and kVp	81.7	18.3

Automatic exposure control (AEC)	80.0	20.0
Image post-processing only	0.0	100.0

Attitude Toward Pediatric Radiation Safety

Radiographers exhibited a high positive attitude towards radiation safety among children with more than 70 percent of them being in agreement with the idea that protection against radiation is a high priority and that children imaging requires more attention. It is consistent with Moolman et al. (2020), who discovered that 57% of South African radiographers were confident in their knowledge of pediatric doses, but they still needed additional education. The great supporting attitude toward training (65%) also coincides with recommendations on Bawazeer (2022) and Al-Rammah (2016) who revealed the significance of continuous professional development to preserve the standards of safety. The positive attitudes, which are reported in this research, indicate willingness to improve in case structural and training opportunities are availed.

Table 4.4: Respondents' Attitude Toward Pediatric Radiation Safety

Statement	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree/Strongly Disagree (%)
Radiation protection for children is a top priority	76.7	6.7	6.7	10.0
Confident in minimizing dose while maintaining image quality	73.3	5.0	10.0	11.7
Pediatric X-rays should always be justified	71.7	8.3	11.7	8.3
Shielding is necessary in all pediatric radiographs	70.0	8.3	6.7	15.0
Optimization training should be mandatory	65.0	5.0	13.3	16.7
Pediatric radiography requires more attention than adult	61.7	8.3	11.7	18.3

procedures

Practice of Dose Optimization Techniques

Two-thirds (70) of those always used collimation and three-quarters of the respondents (75) varied exposure based on patient size, yet only a quarter (21.7) of the respondents used pediatric exposure charts. This weakness in practice reflects Eddy et al. (2021) and David and Lateef (2017), who reported radiation levels of more than the reference levels because of the inconsistent adherence to the protocols.

The success of the training (66.7) indicates that there is increasing awareness, which is consistent with Almohiy et al. (2020), who offered frequent training to ensure safety of radiations in pediatrics. However, the lack of access to protocols aimed at children is one of the main issues.

Table 4.5: Practice of Pediatric Dose Optimization

Practice Variable	Most Frequent Response	Percentage (%)
Collimation use	Always	70.0
Adjust exposure based on child size	Often	75.0
Provide shielding	Sometimes	61.7
Use pediatric exposure charts	No	78.3
Equipped with digital	Yes	75.0

system		
Received training in last 2 years	Yes	66.7
Repeat exams common	No	68.3

Challenges in Implementing Dose Reduction

The major impediments were equipment failure and absence of immobilization equipment. Only 33.3% of radiographers indicated that they used a functional AEC, which is in line with Emmanuel (2022) and David and Lateef (2017), who documented high ESDs in the facilities where the best equipment was not employed. Such constraints of infrastructure and resources make it difficult to adhere to ALARA, which helps to justify the arguments of Aziz et al. (2024) and Eddy et al. (2021) to standardize the protocol and modernize imaging equipment.

Table 4.6: Challenges Reported by Respondents

Challenge Statement	Agree (%)	Strongly Agree (%)
Non-functional or poorly calibrated collimators	68.3	13.3
Lack of immobilization devices causes repeats	76.7	10.0
Absence of functional AEC limits optimization	30.0	30.0

Malfunctioning exposure knobs hinder selection	10.0	35.0

Reliability Analysis

Internal consistency and reliability were strong with Cronbach's Alpha for attitude and practice items at 0.83.

Hypothesis Testing

There was no meaningful correlation between years of experience and familiarity with DRL ($p>0.05$). There was, however, a statistically significant correlation between years of experience and proper use of collimation ($p=0.001$). This is in alignment with Bawazeer (2022), whose research set up a strong association between years of experience and dose optimization misinterpretation. More experienced radiographers showed better collimation use, affirming professional exposure's role in skill development.

Table 4.7: Chi-square Tests of Association

Variable Relationship	χ^2	df	p-value	Remark
Years of experience × Knowledge of DRLs	3.029	3	0.387	Not Significant
Years of experience × Use of Collimation	16.150	3	0.001	Significant

4.3 DISCUSSION

This section summarizes the significant research results of the research based on empirical literature. The discussion is structured in terms of five themes that include: knowledge, attitude, practice, challenges, and experience in the optimization of dose in pediatric radiography. The analysis is a synthesis of the statistical findings and the overall implication of the findings in practice.

Knowledge of radiation dose reduction approaches

The current research found that the entire respondent population (60; 100%), was conversant with the ALARA concept of minimizing radiation exposure As Low As Reasonably Achievable. In the same manner, all (60; 100%) agreed that children are radiosensitive than adults. Only 23 participants (38.3%), though, were conversant with Diagnostic Reference Levels (DRLs) of pediatric imaging, and only 9 (15.0%) were conversant with the accepted acceptable range of Entrance Skin Dose (ESD) in pediatric chest radiographs.

It is a disturbing lack of understanding between the technical dose quantification parameter understanding and the general radiation protection understanding. The ALARA awareness presupposes being exposed to theoretical aspects of radiation protection but being unaware of the DRLs and ESDs means that radiographers might not be empowered to practice the theoretical principles in practice.

The results of this research are in line with the findings of Bawazeer (2022) who concluded that over 80% of CT radiographers were familiar with CT dose indicators and with the appropriate dosimetric units, but over 65% of them were unable to define dose optimization and even name the role of DRLs. On the same note, Garba and Mufutawu (2024) remarked that although 91.1 percent of the students that attended radiography majors were familiar with the indicators of the CT doses, 84.2 percent of them were not aware of the most informative one.

Comparatively, Almohiy et al. (2020) determined that larger cohorts of Saudi radiologists had a better grasp of the concept of radiation risks and 65 percent +- 13.5 percent had a good grasp of the carcinogenic risk of CT scans. The variation can be explained by the varying degrees of continuing medical education and institutional support. The high systems like the health system of Saudi Arabia normally offer continuous radiation protection education, and lack of access to such in Nigeria might be one of the factors that led to the reduced awareness of DRL recorded.

This lack of some technical skills is a challenge to the optimization of pediatric doses. Moolman et al. (2020) also highlighted such shortcomings in South African radiographers assuring confidence in the understanding of pediatric radiation dose regimens, which was 57% only. The combination of the results indicates the necessity of specific training, especially on the interpretation and use of the DRLs and ESDs, which are essential in the quantification and minimization of patient dose.

Pediatric radiation safety attitudes.

The attitude plays an important role in the compliance with radiation protection standards. In the research 46 (76.7) of the individuals involved strongly felt that children radiation protection was a priority and 44 (73.3) had confidence that they would get dose reduction without affecting image quality. Further, 43(71.7) respondents responded that all pediatric X-ray tests must be justified upfront and 39 (65.0) respondents thought that under-training on dose optimization must be obligatory to all radiographers.

These findings depicted a very positive perception of pediatric radiation protection among the Nigerian radiographers. All of them displayed professional responsibility of minimizing exposure according to the international level. This is also in agreement with Moolman et al. (2020) who demonstrated that 57 per cent of South African radiographers were confident in their pediatric radiation practice and knowledge but the majority of them needed to be retrained.

Mandatory training is based on the report by Al-Rammah (2016) who found out that only 68 percent of Saudi radiographers received any training in radiation safety in the first training. The author focused on the fact that poor education was responsible as to the persistent misconceptions, including the 70 percent of the participants who were of the opinion that MRI uses ionizing radiations.

In addition, most respondents who chose justification and dose reduction is also aligned to the recommendation of Aziz et al. (2024), in which the focus was placed on adherence to ALARA and PECARN guidelines in enhancing radiation safety in pediatric imaging.

Agreement with international literature of such results supports a trend of increased radiographic practice on the side of being more safety-conscious. Positive attitudes on the other hand must be converted to routine under the right institutional arrangements, training, and working resources, which are further discussed in this discussion.

Exercise in Dose Optimization Techniques.

The researchers concluded that 49 (81.7) per cent of the respondents usually reduced exposure factors (mAs and kVp), 48 (80.0) and 45 (75.0) frequently used Automatic Exposure Control (AEC) and collimation respectively. Nevertheless, 13 (21.7) responses used child only exposure charts, and 40 (66.7) respondents had been taught pediatric dose optimization in the last two years.

The findings indicate that there are appropriate adherence with general radiation safety measures but there is a lack of standardization of technique exposure. The exposure charts used provide reproducibility, and help in dose reproducibility - lack thereof implies that most radiographers rely on subjective judgment.

The results are in line with Aziz et al. (2024), who underlined the need to find balance between exposure parameters and patient size and the principles of ALARA. On the same note, Lee et al. (2020) also suggested that effective dose in pediatric panoramic radiography is significantly limited by a low beam height. Feghali et al. (2021) also indicated that they could reduce up to 50 per cent of the time spent on the post-processing software without negatively affecting the image quality, highlighting the technological opportunities of the modern world to streamline the work.

The use of pediatric exposure charts is limited, however, according to Eddy et al. (2021), the pediatric dose of CT was 47.7 times more than the DRLs in France, and David and Lateef (2017), the highest pediatric chest ESDs were 38-292 mGy, which is higher than the recommended exposure. In both reports, excessive doses were because of absence of standardized protocols- a case that was present in this study.

In such a way, even though the Nigerian radiographers indicate satisfactory effort in the alteration of technical parameters, the standardization process of the institutional settings and the assistance of technology is scarce, preventing full optimization.

Problems with Pediatric Dose Reduction.

The respondents identified the non-functional or maladjusted collimators that lock out the effective beams as barriers to dose optimization, 52 (86.7%) of the radiographers confirmed that there were no such immobilization devices like sandbags and straps, and 27 (45.0) respondents confirmed that there were malfunctioning exposure knobs that prevented the appropriate selection of exposure factors applicable in pediatrics.

All these problems are consistent with the results provided by Emmanuel (2022), who mentioned amplified ESDs in the chest X-rays of children in three Cameroonian hospitals because equipments were not calibrated and standardized. High ESDs in the Nigerian hospitals were also related to the use of outdated equipment and absence of dose audit mechanisms as described by David and Lateef (2017).

Again, in pediatric age groups, Eddy et al. (2021) found higher CTDIvol and DLP (up to 47.7% higher than French DRLs), which was again associated with high radiation exposure and improper equipment calibration and adherence to updated imaging guidelines.

Likewise, the authors Aziz et al. (2024) and Bawazeer (2022) also focused on the fact that infrastructural and educational constraints negatively affect the implementation of maximum dose reduction in the developing world. The problems that were revealed in this research, therefore, have a reflection in a problem that is common in the African and Middle Eastern settings interoperability of qualified professionals and less than satisfactory equipment.

Such problems must thus be addressed by institutional investment to equip themselves with state-of-the-art equipment, regular calibration of equipment and constant monitoring by quality assurance measures.

Effects of Professional Practice on Practice.

Chi-square test showed that there is a significant relationship between experience and use of appropriate collimations (kh2 = 16.150; df = 3; p = 0.001) and no relationship between experience and DRL awareness (kh2 = 3.029; p = 0.387). Radiographers who had over six years of experience were more likely to make consistent use of collimation than those with under one years of experience who either were interns or radiographers (11; 18.3%).

The finding is consistent with that of Bawazeer (2022), who concluded that years of experience had a significant impact on dose optimization awareness. Moreover, Almohiy et al. (2020) observed that the senior radiologists had knowledge of the carcinogenic effects of radiations among children. The agreement in the results of the studies proves that experience improves practical judgement, compliance with protocols, and safe modification of techniques.

Implications of the Findings.

Overall, the awareness of radiographers on pediatric radiation safety was high (100%), and the attitude to the topic was positive (>70%), yet no compliance with standardized protocols (only 21.7% used pediatric exposure charts). The overall infrastructural weaknesses (60%-86.7) also diminish the overall effectiveness of professional awareness on outcomes.

This positive attitude with an imbalanced practice is familiar with the international results of Moolman et al. (2020) and Bawazeer (2022), who both came to the same conclusion that knowledge, technology, and the institutional culture contribute to the success of dose optimization as much as the former two factors.

Thus, long-term success of the improvement of the radiation safety of pediatrics in Nigeria will rely on professional educational continuation, the modernization of equipment, and the imposition of the policy of regulatory professional organizations. Enhancing of these pillars will enhance the fact that radiographers not only have knowledge of what to do, but that they are also in a good position to do it regularly

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

The research evaluated methods of radiation dose reduction when performing pediatric radiography among 60 radiographers.

Key findings include:

1. All of the respondents knew about ALARA, yet only 38.3% knew about DRLs.
2. Dose reduction strategies that were widely used were mAs/kVp reduction (81.7%), AEC (80%), and collimation (75%).
3. The positive attitudes were portrayed on the issue of pediatric safety and justification of X-ray procedures.
4. The level of pediatric exposure chart was also minimal (21.7%), although 66.7% were recently trained.
5. Absence of immobilization devices, non-functional AECs, and badly-calibrated equipment were major challenges.
6. Use of collimation was found to be closely related to experience ($p=0.001$).

5.2 CONCLUSION

The paper concludes that the awareness of radiographers about the principles of radiation safety and positive attitudes to pediatric dose optimization are commendable. Nevertheless, great inconsistencies exist in practice, especially when it comes to standardized procedures and the availability of working equipment. The results are consistent with those provided by Moolman et al. (2020) and Bawazeer (2022), as they highlight the need to promote pediatric imaging safety through ongoing professional training and equipment upkeep.

5.3 RECOMMENDATIONS

1. It is preferable that all radiographers should be obliged to undergo continuous professional training to enhance their competence in dose optimization and DRL usage in pediatrics.
2. Hospital management should ensure regular equipment calibration and provision of immobilization devices.
3. Standardized pediatric exposure charts should be developed and implemented nationwide.
4. Professional associations such as the ARN and RRBN should sponsor regular workshops focused on pediatric dose reduction.
5. Periodic dose audits should be institutionalized to track compliance with ALARA and DRL guidelines.

5.4 AREAS FOR FURTHER RESEARCH

Future research should include:

- Larger, multi-center studies across Nigeria.
- Quantitative measurement of patient doses (ESD, DAP, CTDIvol) in pediatric radiography.
- Evaluation of digital and AI-assisted imaging tools for pediatric dose reduction.

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APPENDIX I: QUESTIONNAIRE FORM

My name is Okhionkpamwonyi Aisosa with matriculation number BMS2001303, a student in the Department of Radiography, School of Basic Medical Science, University of Benin conducting a research study on "Assessment of radiation dose reduction approaches in pediatric radiography'', under the supervision of my lecturer Mrs Olasuyi Kemisola. Kindly help complete this questionnaire.

Please select appropriate options

SECTION A: Demographic Information

Gender ☐ Male ☐ Female

Age ☐ Below 25yrs ☐ 25-34yrs ☐ 35-44yrs ☐ 45yrs and above

Qualification ☐ B.Sc ☐ PGD ☐ M.Sc

Job title ☐ Intern Radiographer ☐ Chief Radiographer ☐Senior Radiographer

Hospital/ center ☐ Federal ☐ Sttate ☐ Private

Years of experience in pediatric radiography?

☐ Less than 1 year ☐ 1-3 years ☐ 4-6 years ☐ Above 6 years

SECTION B: Knowledge of dose reduction techniques

1. Are you aware of the ALARA principle? ☐ Yes ☐ No

2. What does ALARA stand for?

a. ☐ As Low As Reasonably Achievable

b. ☐ Allow Limited Access to Radiated Areas

c. ☐ None of the above

3. Are you familiar with Diagnostic Reference Levels (DRLs) for pediatric imaging?

   ☐ Yes ☐ No

4. Which of the following are recognized pediatric dose reduction strategies? (You can select more than one)

   ☐ Use of proper collimation

   ☐ Lowering mAs and kVp

   ☐ Automatic exposure control

   ☐ Image post-processing only

5. Do you think children are more radiosensitive than adults?

   ☐ Yes ☐ No

6. Are you trained in selecting pediatric-specific exposure parameters?

   ☐ Yes ☐ No

7. Do you know the average entrance skin dose (ESD) range acceptable for pediatric chest radiographs?

   ☐ Yes ☐ No

SECTION C: Attitudes toward radiation safety in pediatrics

8. Radiation protection for children is a top priority in radiographic procedures.

   ☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree

   ☐Strongly Disagree

9. I believe I am confident in my ability to minimize dose while maintaining image quality in pediatric imaging.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

10. Radiographers should always justify pediatric X-ray procedures before performing them. ☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

11. Shielding (e.g., gonadal or thyroid) is necessary in all pediatric radiographs.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

12. Radiation dose optimization training should be mandatory for all radiographers.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

13. Pediatric radiography requires more attention and care than adult procedures.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

SECTION D: Practice of dose optimization techniques

14. How often do you use collimation when performing pediatric X-rays?

☐ Always ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

15. Do you use age- or weight-specific exposure charts or protocols in your facility? ☐ Yes ☐ No

16. Do you adjust exposure parameters based on the child's size or clinical indication?

☐ Always☐ Often ☐ Sometimes ☐ Rarely ☐ Never

17. How often do you provide shielding for pediatric patients during X-ray exams?

☐ Always ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

18. Are repeat examinations common in your facility due to improper positioning or exposure in pediatric patients? ☐ Yes ☐ No

19. Is your department equipped with digital radiography systems that support dose optimization? ☐ Yes ☐ No ☐

20. Have you received any formal training/workshop on pediatric dose reduction in the past 2 years? ☐ Yes ☐ No

21. What strategies do you use for dose optimization in pediatric imaging?____

SECTION E: Challenges in implementing pediatric dose reduction

22. Non functional or poorly calibrated collimators make it difficult to restrict xray beam to the area of interest.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

23. Unavailablity of immobilization devices such as straps, sandbags, leads to repeat exposes.

24. The absence of functional automatic exposure control (AEC) limits my ability to optimize exposures in children.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

25. Malfuctioning exposure parameter knobs for adjusting Kvp and mAs reduce my ability to select appropriate pediatric exposure factors.

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

26. Does your X-ray equipment have automatic exposure control (AEC)?

☐ Yes ☐ No

27. If yes, is it functional and used regularly?. ☐ Yes ☐ No

APPENDIX II: ETHICAL APPROVAL REQUEST

Department of Radiography,

School of Basic Medical Sciences,

University of Benin,

Edo State.

June 2025.

The Chairman,

Health Research and Ethics Committee

University of Benin Teaching Hospital,

Edo State.

Dear Sir/ma,

APPLICATION FOR ETHICAL APPROVAL TO CONDUCT A RESEARCH STUDY

I Okhionkpamwonyi Aisosa with matriculation number BMS2001303, hereby apply for the above subject. I am an undergraduate student from the Department of

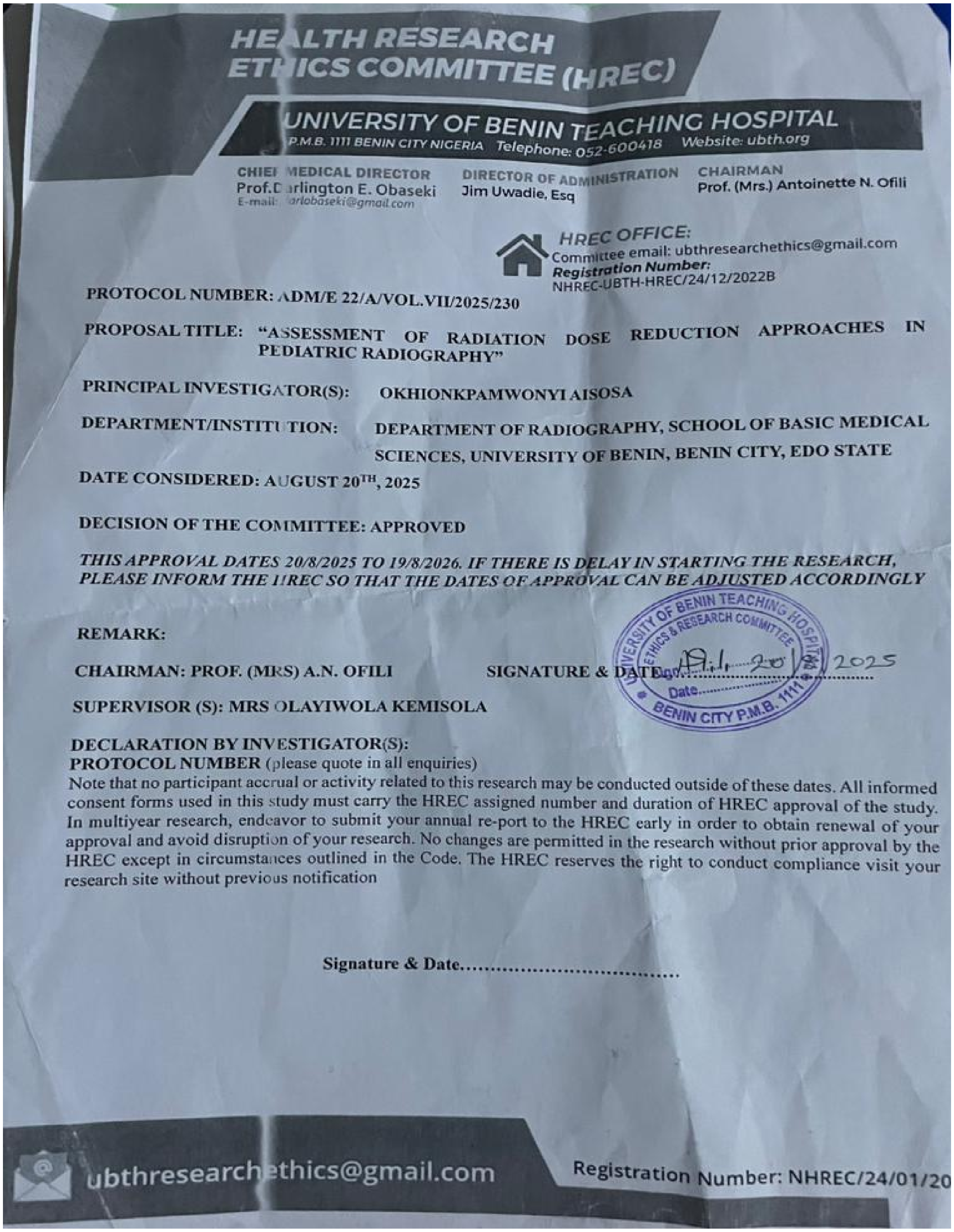
Radiography, School of Basic Medical Science, University of Benin. I kindly request for ethics approval to conduct a research project on the topic titled "Assessment of radiation dose reduction approaches in pediatric radiography" in partial fulfillment of the requirements for the award of a Bachelor of Science degree in Radiography. Attached is a copy of my research project proposal. I hope my request will be considered.

Yours Faithfully,

Okhionkpamwonyi Aisosa

Phone number: 08151696525

APPENDIX III: ETHICAL APPROVAL LETTER



HEALTH RESEARCH ETHICS COMMITTEE (HREC)

UNIVERSITY OF BENIN TEACHING HOSPITAL

P.M.B. 1111 BENIN CITY NIGERIA Telephone: 052-600418 Website: ubth.org

CHIEF MEDICAL DIRECTOR
Prof. Darlington E. Obaseki
E-mail: darlobaseki@gmail.com

DIRECTOR OF ADMINISTRATION
Jim Uwadie, Esq

CHAIRMAN
Prof. (Mrs.) Antoinette N. Ofili

HREC OFFICE:
Committee email: ubthresearchethics@gmail.com
Registration Number:
NHREC-UBTH-HREC/24/12/2022B

PROTOCOL NUMBER: ADM/E 22/A/VOL.VII/2025/230

PROPOSAL TITLE: "ASSESSMENT OF RADIATION DOSE REDUCTION APPROACHES IN PEDIATRIC RADIOGRAPHY"

PRINCIPAL INVESTIGATOR(S): OKHIONKPAMWONYI AISOSA

DEPARTMENT/INSTITUTION: DEPARTMENT OF RADIOGRAPHY, SCHOOL OF BASIC MEDICAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE

DATE CONSIDERED: AUGUST 20TH, 2025

DECISION OF THE COMMITTEE: APPROVED

THIS APPROVAL DATES 20/8/2025 TO 19/8/2026. IF THERE IS DELAY IN STARTING THE RESEARCH, PLEASE INFORM THE HREC SO THAT THE DATES OF APPROVAL CAN BE ADJUSTED ACCORDINGLY

REMARK:

CHAIRMAN: PROF. (MRS) A.N. OFILI **SIGNATURE & DATE** 21, 20/8/2025

UNIVERSITY OF BENIN TEACHING HOSPITAL ETHICS & RESEARCH COMMITTEE Date BENIN CITY P.M.B. 1111

SUPERVISOR (S): MRS OLAYIWOLA KEMISOLA

DECLARATION BY INVESTIGATOR(S):

PROTOCOL NUMBER (please quote in all enquiries)

Note that no participant accrual or activity related to this research may be conducted outside of these dates. All informed consent forms used in this study must carry the HREC assigned number and duration of HREC approval of the study. In multiyear research, endeavor to submit your annual re-port to the HREC early in order to obtain renewal of your approval and avoid disruption of your research. No changes are permitted in the research without prior approval by the HREC except in circumstances outlined in the Code. The HREC reserves the right to conduct compliance visit your research site without previous notification

Signature & Date.....................................

ubthresearchethics@gmail.com Registration Number: NHREC/24/01/20