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Evaluation of Radiation Dose for Pediatric Patients on Brain CT Scans as A Function of Protocol Used and Type of CT Device in The Palestinian Governmental Hospitals

Student

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Evaluation of Radiation Dose for Pediatric Patients on Brain CT Scans as A Function of Protocol Used and Type of CT Device in The Palestinian Governmental Hospitals

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This Thesis is submitted in partial fulfillment of requirements for the degree of Master of Medical Imaging Technology Faculty of Graduate Studies - Al-Quds University

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Dedication

This dissertation is dedicated to those whose unwavering support and encouragement were the driving force behind this academic journey, and to my family, for their boundless love, understanding, and sacrifices. their belief in me has been my greatest motivation, to my mentors and advisors, whose guidance has shaped my intellectual growth and inspired me to push the boundaries of knowledge, to my friends, who provided moments of respite and laughter during the challenging times, reminding me that balance is the key to success and, above all, to my husband, whose constant faith in my abilities and endless encouragement fueled my determination to reach this milestone.

This work stands as a tribute to each of you, reflecting the collective effort that made this journey possible.

Asala Khalil

Declaration

This thesis was submitted in partial fulfillment of the requirement for the master’s degree in medical Imaging Technology.

I declare that the content of this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed:

Date: 6/1/2024

Acknowledgment

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Abstract

Medical imaging, specifically computed tomography scans, plays a vital role in diagnosing and treating various medical conditions, such as brain tumors, lesions, and strokes. This is particularly beneficial in pediatric cases where it can aid in diagnosis and potentially save lives. However, its use also raises concerns about unnecessary radiation exposure. The purpose of this study is to evaluate the existence of local Diagnostic reference levels in Palestine, and to contribute to national efforts in building national DRLs. A multi-center retrospective cross-sectional analytical design was carefully chosen for achieving the study's objectives. A suitable protocol data and dose reports contain information from Picture Archiving and Communication System (PACS) and Hospital Information System (HIS) were used to collect data in different hospitals of Palestine. A Microsoft Excel spreadsheet was used to analyze the collected data. Regarding the effect of types of protocols on the amount of patient dose, the results showed that all protocols were affected with the amount of patient dose but insignificant at the Dose Length Product. While regarding the effect of Equipment on the amount of patient dose, the results showed that all equipment models were insignificant with the amount of patient Computed Tomography Dose Index, Dose Length Product, (mAs and KVP). The findings showed that CT Dose Index vol and Dose Length Product values in the governmental hospitals were much higher than European Dose Length Product values, which proves that the governmental hospitals do not use a standardized pediatric brain CT protocol.

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List of Abbreviations

ALARA: As Low as Reasonably Achievable

BEIR: Biological Effects of Ionizing Radiation

CT: Computed Tomography

CTA: Computed Tomography Angiography

CTDIvol: CT dose index volume

DRL: Diagnostic Reference Level

DLP: Dose-Length Product

IAEA: International Atomic Energy Agency

IBSS: International Basic Safety Standards

ICRP: The International Commission on Radiological Protection

LNT: Linear No-Threshold

MoH: Ministry of Health

MDCT: Multi-Detector CT

mGy: milligray

mSv: millisieverts

SSDE: Size-Specific Dose Estimate

cSL: Slice Collimation

Terminology

Pediatric computed tomography: is a brief, painless examination that provides cross sectional images enabling the visualization of internal organs, bones, soft tissues, and blood vessels. It may be used to aid in the diagnosis of any unexplained discomfort or to assess injuries resulting trauma.

Diagnostic reference levels: are techniques for optimizing ionizing radiation-based medical imaging processes.

Chapter 1: Introduction

1.1 **Background of the Study**

Medical imaging is a critical task in the diagnosis and treatment procedure. In radiology, several procedures and protocols are utilized to convey information from the inside of the human body. A computed tomography (CT) scan of the brain may be performed to assess the brain for tumors and other lesions, injuries, intracranial bleeding, and structural anomalies (e.g., hydrocephalus , infections, brain function or other conditions), particularly when another type of examination (e.g., X-rays or a physical exam) are inconclusive. A brain CT may also be used to evaluate the effects of treatment on brain tumors and to detect clots in the brain that may be responsible for strokes. Another use of brain CT is to provide guidance for brain surgery or biopsies of brain tissue (Hussain et al., 2022).

Nonetheless, due to the high organs' sensitivity in underage patients especially children and infants, the exposure to ionizing radiation is considered a risk and might affect them biologically. Several worldwide guidelines have promoted radiation dose optimization in medical exposure throughout the last two decades, particularly in CT scans. The International Atomic Energy Agency (IAEA), International Basic Safety Standards (BSS), European Basic Safety Standards, and the International Commission on Radiological Protection are among them (Hussain et al., 2022).

Wilhelm Conrad Röntgen discovered X-rays in late 1895. They are utilized in computed tomography (CT) scanners, which have ionizing energies between 40 and 140 Kev, which is high adequate to penetrate a patient's body and provide diagnostic images not including the need for invasive or interventional treatments (Ledenius, 2011).

Godfrey Hounsfield and Allen Cormack invented the CT scanner, which allowed them to successfully create a cross-sectional picture of the brain in 1972. A unique method known as slip-ring with single-row detector, which is based on bringing the patient into the scanner as the tube/detector array gantry rotates continuously to obtain a single image per rotation, was utilized with the first helical CT scanners in the early 1990s. Several rows of detectors and an appropriate workstation that could output numerous pictures in a single helical rotation helped to overcome this disadvantage in the 1990s. The improvements included longer body part scanning, better Z-axis resolution, and shorter scan times. The quick development CT scanner is made up of: The CT scanner with a 4-row detector was created in 2000. After that, in 2001, 8-row scanners represented the state of the art. Sixteen row scanners were in use by 2003. These days, 32- and 40-row scanners as well as 64-, 128-, and 256-row detector scanners are finally available (Ministry of Health, 2022).

In Palestine, CT scanners started with 16 slides and developed to 32, 64, and then 128 slides in the government sector. Knowing that in some centers in the private sector there are 256 slides. The devices are available in all governorates of the West Bank in Palestine, due to the successive health and political conditions affecting the country. The mentioned widespread devices rely on company protocols, and there are no fixed protocols inside Palestine (Ministry of Health, 2022).

CT technology is a precise medical imaging procedure that combines the use of x-rays with digital technology. This increasingly sophisticated imaging system has expanded the scope of clinical diagnosis and considerably improved patient care, leading to dramatic increases in the use of diagnostic imaging worldwide in recent decades, including in pediatric cases. Pediatric CT can provide quick and precise results, thus aiding diagnosis and potentially saving lives and indicating the need for more-intrusive procedures. However, its inappropriate use can expose young people to unneeded and avoidable radiation hazards (Sulieman et al., 2023)

Because the X-ray beam ionizes the exposed cells, any mistakes made in the repair process might result in DNA damage and mutations, which could eventually develop into tumors. As a result, the absorbed dosage that arises from CT scans became a worldwide health concern (Strauss et al., 2019).

The guidelines main purpose is to decrease the risk associated with radiation exposure while ensuring that the appropriate diagnostic information is acquired. To reduce radiation exposure in pediatric patients, proper imaging methods and dose-reduction strategies must be used (Puttagunta & Ravi, 2021).

The European Commission initiated a project concerning pediatric Dose Resolution Levels which resulted in guidelines and European pediatric diagnostic reference levels (EDRLs). The guidelines address the different issues when deriving typical doses as well as DRLs (local, national, or regional). The issue of coping with the different body sizes is addressed and groups based on body weight are recommended. Age is also presented as an additional grouping parameter for the purpose of comparing weight-based DRLs with age-based DRLs. The guidelines define EDRLs for several types of examination. However, at the time of publication, published NDRLs were rare. The current EDRLs are therefore based on a limited number of NDRLs (Almen et al., 2022).

The European Guidelines on Diagnostic Reference Levels for Pediatric Imaging provides age-based DRLs for head CT for 0–3 months (CTDIvol 24 mGy; DLP 300 mGy cm), >3–12 months (28 mGy; 385 mGy cm), 1–<6 years (40 mGy; 505 mGy cm), and >6-year-old (50 mGy; 650 mGy cm) children (Kharita et al., 2020).

This research is one of several attempts in the region to synthesize the findings of a pediatric brain CT survey in Palestine. The project's goal is to offer local diagnostic reference levels (DRLs) for Palestine, West Bank, and to contribute to national efforts in building national DRLs for our country.

1.2 **Problem Statement**

According to the annual health report of the Ministry of Health (MoH) in Palestine, the number of diagnostic radiographs performed in MoH hospitals in Palestine was 1,695,288 with 182,305 CT accounting for approximately 10.8% of total scans.

Radiation-induced carcinogenesis is widely acknowledged as a stochastic effect in which the chance of occurrence rises with increasing radiation dosage but has no effect on the severity of the effect. Because pediatrics' organs are still developing, they are more sensitive to ionizing radiation and more likely to suffer from its stochastic effects. Furthermore, compared to adults, pediatrics has a relatively lengthy remaining life span that allows for the development of possible radiation consequences. Also, because of their lower body size, children receive greater effective doses if specific pediatric CT managements are not used.

Governmental hospitals are more likely to adopt adult-calibrated CT methods than children's hospitals.

Regarding the previously mentioned reasons, the probability of developing cancer in pediatric patients who are exposed to high dose of ionizing radiation (like undergoing a CT) is considered a cause for concern, while there is substantial ambiguity on this topic.

1.3 **Study Justification**

Pediatric radiography necessitates specialized equipment, safeguards, and knowledge of the ionizing radiation dose effect. To safeguard the eyes, thyroid, and gonads during a CT scan. They also propose strategies for lowering absorbed doses of radiosensitive organs in children exposed to ionizing radiation on adult scanners, as well as methods for optimizing dosage in brain CT scans (Sherer et al., 2021).

In Palestine, this is a difficult challenge for many factors, such as poverty, underdevelopment and a scarcity of radiologists and hospitals. Several poor nations continue to employ early generation CT scanners. The goal of this study is to compare the dose received by pediatric patients in certain hospital units in Palestine to the European DRLs.

1.4 **Study Objectives**

1. To detect if the public hospitals use a standardized pediatric CT protocol for the pediatric patient.
2. To study if the types of manufacturers and models of CT scanning equipment affects the amount of patient dose

1.5 **Study Hypothesis**

1. The public hospitals don’t use a standardized pediatric brain CT protocol.
2. The types of manufacturers and models of CT machines do not affect the amount of patient dose.

1.6 **Study Fields**

1.6.1 **Participants**

141 Male and Female Pediatric patients

1.6.2 **Time Period**

January 2023 to October 2023

1.6.3 **Study Area**

Hospitals of Beit Jala Governmental Hospital (Al Hussain), Hebron Hospital (Alia), Martyr Dr. Khalil Suleiman Governmental Hospital (Jenin), Dr. Darwish Nazzal Governmental Hospital (Qalqilya), Tubas Turkish Governmental Hospital, and Martyr Abu Al-Hassan Al-Qassem Governmental Hospital (Yatta).

Chapter 2: Theory and Literature Review

This chapter offers a review of existing literature and scientific research on CT-dose assessment and related risk, as well as examples of various methodologies used to calculate effective dosage and associated brain danger.

2.1 **Theoretical Framework**

2.1.1 **Introduction**

Prior to the early 2000s, there was no differentiation between pediatric and adult patients, resulting in inadequate radiation dose and image quality management during CT scanning (Villemure-Poliquin et al., 2021).

Acquisition strategies were hardly ever altered based on body size throughout that period of time. Initial radiation dose reduction suggestions appeared, and were then amplified by the Image Gently Alliance in the United States and across the world (Villemure-Poliquin et al., 2021).

Education, hardware and software development, and accessible radiation dose indices have all contributed in increasing radiation awareness. These advancements have resulted from a shared aim among hospitals, international groups, and CT manufacturers to enhance health care for all patients, including pediatric CT patients.

Although CT imaging provide reliable diagnostic information, the use of ionizing radiation is controversial owing to its harmful consequences, which the International Committee on Radiation Protection (ICRP) divided its effects into two types: deterministic effects and stochastic effects. Deterministic effects, such as skin erythema or epilation, occur only when the radiation dose exceeds a tissue-specific threshold value. Deterministic effects in diagnostic imaging are uncommon and generally arise only after unusual occurrences. The stochastic effects, such as malignant tumors, are assumed to follow the linear no-threshold model (LNT).

2.1.2 **Radiation Dose**

Dosimetry is used in medical imaging to estimate the radiation exposure to patients. These quantities are classified as fundamental quantities, application-specific quantities, and quantities linked to radiation's stochastic or deterministic effects. With the fundamental quantities being kinetic energy produced per unit mass (KERMA) and absorbed dose (D), and the application specific quantities include descriptors such as the computed tomography dose index and dose length product (DLP). The quantities associated to radiation's damaging effects are equivalent dose and effective dose (Lowe et al., 2022).

2.1.3 **Absorbed Dose (D) and Kinetic Energy Produced per Unit Mass (KERMA)**

The energy imparted per unit mass by ionizing radiation to matter at a specified point. The International System of Units (SI) unit of absorbed dose is the joule per kilogram. The special name for this unit is the gray (Gy). For purposes of radiation protection and assessing dose or risk to humans in general terms, the quantity normally calculated is the mean absorbed dose in an organ or tissue.

KERMA and D are the fundamental quantities. KERMA is the total of the initial kinetic energy (dEtr) of all charged particles freed by uncharged particles in a mass of material (dm) (Alameen et al., 2021).

2.1.4 **Determination of Radiation Dose in CT**

Direct measurements of organ doses and effected dose are constrained by practical and ethical concerns; however, organ doses and effected dose can be calculated using phantoms or Monte Carlo computations. Effected dose can also be determined using coefficients from a scanner's dose display.

2.1.4.1 **Dose Reference Levels (DRLs)**

Dose Reference Levels (DRLs) are a set of values established for a particular group of standard-sized patients or standardized phantoms for broadly defined types of diagnostic medical procedures. They serve as a guide for medical professionals to compare their own dose levels during similar diagnostic procedures. Essentially, DRLs act as a benchmark for the most common examinations to ensure that the doses of ionizing radiation are kept as low as reasonably achievable (ALARA principle) while still obtaining the required image quality for diagnosis.

The use of DRLs helps in optimizing the protection of patients from unnecessary or excessive exposure to radiation. They are not dose limits, but rather reference points. If consistently exceeded, they signal a need for review and optimization of the protocols in use. DRLs are typically set for the whole examination and for specific parts of the examination, which might receive the highest dose.

Common CT parameters such as the computed tomography dose index (CTDIvol) and dose-length product (DLP) are too utilized to calculate DRLs (Almujally et al., 2022; Bawazeer et al., 2022).

2.1.4.2 **The Computed Tomography Dose Index CTDI**

CTDI is a standardized measure of radiation dose output used in the evaluation of CT scans in radiology. It provides a quantification of the dose a patient receives from a single CT slice and is expressed in milligrays (mGy). CTDI is critical for ensuring that dose optimization practices are in place, which is an essential aspect of patient safety in medical imaging.

The CT scanner shows the computed tomography dose index – volume (CTDIvol) esteem, which is additionally famous within the patient's restorative records (Almujally et al., 2022; Bawazeer et al., 2022).

2.1.4.3 **Dose-Length Product DLP**

DLP is a derived quantity used in assessing the amount of radiation exposure during a CT scan across the volume of tissue being imaged. DLP is calculated by multiplying the CTDIvol by the scan length (the extent of the patient's body that is scanned). The unit of DLP is milligray-centimeters (mGy-cm).

DLP is particularly useful because it considers the total amount of radiation for the complete series of CT slices, rather than just a single slice, providing a more comprehensive account of the total exposure (Almujally et al., 2022; Bawazeer et al., 2022).

2.1.5 **CT Scanners Covered in this Study**

2.1.5.1 **Philips**

Philips CT scanners demonstrate a commitment to innovation and patient care, offering a variety of solutions to meet the diverse needs of modern healthcare settings, Philips AEC system Brilliance CT 64 Power and CT 16 are used at some hospitals (Banihashemi et al., 2020). The Brilliance CT 16 is tailored for routine CT exams and specific applications offering fast scan and reconstruction times, as well as dose efficiency through Philips' Dose Wise approach. The Brilliance CT 64, however, offers advanced features such as low-dose cardiac imaging and 3D volume software, making it a more suitable option for complex and high-volume clinical settings. Both systems emphasize patient care and image quality, but the Brilliance CT 64's expanded capabilities and higher slice count provide a greater range and depth of diagnostic information, which may be essential for more comprehensive medical analyses (AAPM, 2015).

Table 2.1 various types of Philips scanners and their technical specifications

PHILIPS	Brilliance 16 slice	Brilliance 64 channel	Ingenuity CT	Brilliance iCT SP	Brilliance iCT
Scan Type	Axial	Axial	Axial	Axial	Axial
Rotation Time (s)	1.0/1.5*	0.75/1.5*	0.75/1.5*	0.4/0.5*	0.4/0.5*
Collimation	16 × 1.5 mm	16 × 0.625 mm	16 × 0.625 mm	16 × 0.625 mm	16 × 0.625 mm
kV	100	100	100	100	100
Manual mAs approach	0-1yr: 240 1-2yrs: 300 2-6yrs: 400 6-16yrs: 500 16+yr: 640	0-1yr: 215 1-2yrs: 260 2-6yrs: 340 6-16yrs: 440 16+yr: 550	0-1yr: 215 1-2yrs: 260 2-6yrs: 340 6-16yrs: 440 16+yr: 550	0-1yr: 180 1-2yrs: 220 2-6yrs: 300 6-16yrs: 375 16+yr: 480	0-1yr: 180 1-2yrs: 220 2-6yrs: 300 6-16yrs: 375 16+yr: 480
AEC approach	Not recommended	Not recommended	Infant DRI = 33 Child DRI = 36	Infant DRI = 33 Child DRI = 36	Infant DRI = 33 Child DRI = 36
Couch Increment (mm)	24	10	10	10	10
FOV (mm)	250	250	250	250	250
CTDI-vol (mGy)	0-1yr: 17.7 1-2yrs: 22.1 2-6yrs: 29.6 6-16yrs: 36.9 16+yr: 47.2	0-1yr: 20.8 1-2yrs: 25.2 2-6yrs: 32.9 6-16yrs: 42.6 16+yr: 53.2	0-1yr: 20.8 1-2yrs: 25.2 2-6yrs: 32.9 6-16yrs: 42.6 16+yr: 53.2	0-1yr: 20.2 1-2yrs: 24.7 2-6yrs: 33.7 6-16yrs: 42.1 16+yr: 53.9	0-1yr: 20.2 1-2yrs: 24.7 2-6yrs: 33.7 6-16yrs: 42.1 16+yr: 53.9

Table 2.1 various types of Philips scanners and their technical specifications displays a comparison of technical specifications for various Philips CT scanner models, including the Brilliance 16 slice, Brilliance 64 channel, Ingenuity CT, Brilliance iCT SP, and Brilliance iCT

models, highlighting differences in scan type, rotation time, collimation, voltage, and other key operational parameters. It serves as a guide for radiologists or healthcare professionals to assess and compare the capabilities and imaging options offered by each CT system (AAPM, 2015).

2.1.5.2 **GE**

Light Speed 16 CT scanners from GE are located in the radiology department at some hospital, and a Light Speed VCT is located in the radiology department at another county hospital. GE Light Speed VCT offers a superior data acquisition system than Light Speed16, which GE believes may result in higher image quality. As a result, Light Speed VCT can tolerate a higher noise index. Both scanners provide two options for how the algorithm should use the information for dynamic tube current modulation and consequently picture reconstruction. The information in full mode is based on a 360° X-ray tube rotation, and in plus mode on a 360° plus 45° X-ray tube rotation (Wang et al., 2020).

Table 2.2 various types of GE scanners and their technical specifications

GE	LightSpeed 16 BrightSpeed 16	LightSpeed Pro 16	Optima CT660	Optima CT660 w/ASiR
Scan Type	AXIAL	AXIAL	AXIAL	AXIAL
Rotation Time (s)	1*	1*	1*	1*
Detector Configuration	16 x 0.625 (10mm, 8i)	16 x 0.625 (10mm, 8i)	32 x0.625 (20mm, 8i)	32 x0.625 (20mm, 8i)
Table Feed/Interval (mm)	10	10	20	20
kV	120	120	120	120
Manual mA approach	0-1yr: 110 1-2yrs: 130 2-6yrs: 170 6-16yrs: 220 16+yrs: 280	0-1yr: 110 1-2yrs: 130 2-6yrs: 170 6-16yrs: 220 16+yrs: 280	0-1yr: 150 1-2yrs: 190 2-6yrs: 250 6-16yrs: 315 16+yrs: 400	0-1yr: 100 1-2yrs: 125 2-6yrs: 165 6-16yrs: 210 16+yrs: 265
Auto-mA approach	Not recommended	Not recommended	Not recommended	Not recommended
SFOV	HEAD	HEAD	HEAD	HEAD
ASiR	no	no	no	SS30
CTDI-vol (mGy)	0-1yr: 21.8 1-2yrs: 27.0 2-6yrs: 36.4 6-16yrs: 45.7 16+yrs: 58.2	0-1yr: 23.6 1-2yrs: 29.2 2-6yrs: 39.3 6-16yrs: 49.3 16+yrs: 62.8	0-1yr: 26.8 1-2yrs: 34.0 2-6yrs: 44.7 6-16yrs: 56.3 16+yrs: 71.6	0-1yr: 17.9 1-2yrs: 22.4 2-6yrs: 29.5 6-16yrs: 37.6 16+yrs: 47.4

Table 2.2 various types of GE scanners and their technical specificationsshows specifications for various GE CT scanners, including the LightSpeed 16 Bright Speed 16, LightSpeed Pro 16, Optima CT660, and Optima CT660 w\ AsiR. It compares parameters such as scan type,

rotation time, detector configuration, table feed, kV settings, and dose measurements (CTDI-vol) across different age groups. This table is designed to provide healthcare professionals with critical information for evaluating the imaging capabilities and dose efficiency of each CT scanner model (AAPM, 2015).

2.2 **Literature Review**

2.2.1 **Radiation Dose Evaluation of Pediatric Patients in CT Brain Examination: Multi-Center Study**

This study evaluates the radiation doses received by pediatric patients during CT brain examinations in Cameroon, comparing them with France's Diagnostic Reference Levels (DRLs). It highlights the lack of regulatory pediatric DRLs in Cameroon and the necessity to adhere to international and European norms for dose management. The study focuses on patient-specific dosimetry in pediatric cranial applications, emphasizing the ALARA principle and the need for regular dose evaluation. It also discusses the use of older CT scanners in developing countries, the variability in dose parameters across different centers, and the importance of optimizing CT protocols for pediatric patients to minimize radiation exposure. The findings aim 11mperate radiology practices in dose estimation and contribute to educating medical staff and the public about radiation safety." (Eddy et al., 2021).

The result is 320 children, divided into four distinct age groups, underwent CT brain scans across three medical facilities. The study detailed variations in CT scanner settings like voltage, with notable differences in tube potential across the hospitals. Post-examination, each hospital provided a report detailing the radiation doses received, represented as CTDIvol and DLP. The study found that all three hospitals exceeded the established French Diagnostic Reference Levels for pediatric CT scans, indicating a need for standardization and optimization of CT scanning protocols to better align with international radiation safety standards (Eddy et al., 2021).

2.2.2 **Optimization of Pediatric CT Scans in a Developing Country**

A study published in 2021 by Department of Physics, Faculty of Science, University of DSc hang, Cameroon. The article discusses a study on optimizing CT scan protocols for pediatric patients in a developing country, focusing on minimizing radiation exposure. It highlights the challenges due to outdated equipment and lack of standardized protocols. The study involved a retrospective and prospective analysis of pediatric CT scans in three hospitals, examining parameters like CTDIvol and DLP. It found significant variations in radiation doses and protocols used, emphasizing the need for continued professional development for imaging technicians and the implementation of pediatric-specific protocols to ensure safer CT scans for children. The study underscores the importance of adapting CT scan settings to pediatric needs, reducing unnecessary radiation exposure, and aligning with international radiation protection standards.

312 pediatric patients were included to verify improved practices: A study was done in 2015 and 2018. Dose and scan parameters were available for prospective dose analysis the results are for every pediatric CT scan in 2015, a kV of 120 was used in the various hospitals. The mAs ranged from 57.75 to 283.33, slice thicknesses from 1.25 to 2.5 mm and pitch from 0.525 to 1.375 mm. In the study of 2018, implementing the strategy defined in the methodology and proposed in 2015. Conclusion, the reduction of doses during the pediatric CT examination is possible with the introduction of new optimization protocols or the acquisition of a new machine with a pediatric protocol" (Kamdem et al., 2021).

2.2.3 **Variation in CT Pediatric Head Examination Radiation Dose: Results from a National Survey's**

This study published in 2015 by the Radiological Society of North America, aimed to investigate the variability in radiation dose, specifically the CT dose index volume (CTDIvol), and dose-length product (DLP) for pediatric head CT examinations across different hospitals in the United States. The study involved conducting surveys to gather information about hospital characteristics (Kanal et al., 2015).

Surveys were distributed to a total of 751 hospitals, and out of these, 292 hospitals responded. After accounting for eligibility, 253 hospitals were considered eligible for the study, resulting in a response rate of 35.5% (calculated by dividing the number of hospitals completing surveys, 253, by the sum of eligible hospitals initially consenting, 712, and the estimated number of eligible hospitals among those who refused). The majority of respondents indicated the use of multi-detector CT (MDCT) scanners (99.2%) and reported having a dedicated pediatric head CT protocol (93%) (Kanal et al., 2015).

The estimated mean reported CTDIvol values were 27.3 mGy (95% CI, 24.4–30.1 mGy), and the DLP values were 390.9 mGy × cm (95% Confidence Interval, 346.6–435.1 mGy × cm). These values did not significantly differ by region, trauma level, teaching status, CT accreditation, the number of CT scanners, or the presence of a dedicated pediatric CT protocol. However, children's hospitals reported an estimated CTDIvol that was 19% lower than that reported by general hospitals ($p < 0.01$) (Kanal et al., 2015).

2.2.4 **Monitoring Pediatric Head CT Scan Dose Levels: A Retrospective Study of Diagnostic Reference Levels in a Single Hospital in Abu Dhabi, UAE**

This study published in 2023 in Abu Dhabi that diagnostic reference levels (DRLs) are vital standards for overseeing radiological imaging parameters in hospitals to ensure patient safety. Regular reviews of DRLs are essential to optimize scanning equipment and protocol parameters (Abulail et al., 2023).

The objective of these standards is to decrease radiation exposure risks while still obtaining necessary diagnostic information. This underscores the importance of employing suitable imaging protocols and dose-reduction techniques, particularly in pediatric patients, to minimize radiation exposure (Abulail et al., 2023).

This review ponders collected information on the CT measurements record volume and dose–length item for "250 children who experienced head CT in Abu Dhabi, Joined together Middle Easterner Emirates. Expressive insights were utilized to show middle, extend, and interquartile extend values for each pediatric age gather, based on locale and convention. The 75th percentile was utilized as the reference point for nearby DRLs. The think about utilized clear measurements to set up middle, run, and interquartile run values for different pediatric age bunches, considering territorial and convention components. Nearby Symptomatic Reference Levels (DRLs) were decided utilizing the 75th percentile, coming about in proposed DRL values for distinctive age bunches: 304 mGy·cm (children < 1 year), 385 mGy·cm (children ≥ 1 year to <5 a long time), 441 mGy·cm (children ≥ 5 a long time to <10 a long time), and 568 mGy·cm (patient's ≥ 10 a long time to <16 a long time). The researcher moreover compared these nearby DRLs with already built up ones, examining any contrasts identified" (Abulail et al., 2023).

In conclusion, This study focused on assessing radiation doses in pediatric patients undergoing CT scans, specifically looking at CT dose index volume (CTDIvol) and dose-length product (DLP). The primary objective was to gather data from the largest CT scanner facilities in SEHA (Abu Dhabi's health system) and use this information to establish national Dose Reference Levels (DRLs). The study's findings indicate that radiation doses for different age groups in this region are within internationally accepted guidelines and safety protocols. It's 14mperativee to recognize potential 'ong-term impacts. Healthcare suppliers ought to hone safety measures when requesting CT filters for children and investigate elective imaging strategies at whatever point doable. This approach guarantees that children get high-quality care whereas minimizing their introduction to possibly harmful radiation (Abulail et al., 2023).

2.2.5 **Local Diagnostic Reference Levels for Paediatric Head CT Procedures**

This study was published in 2021 conducted by Birutė Gricienė, who is affiliated with Vilnius University in Lithuania. This research focused on evaluating the ionizing radiation doses in pediatric head CT scans and aimed to establish local DRLs based on various age groups. The study compared these local DRLs with existing national and European DRLs, as well as with data from other countries as shown in Table 2.3 Paediatric head CT local DRLs in comparison with national and Europian DRLs .

Table 2.3 Paediatric head CT local DRLs in comparison with national and Europian DRLs

Paediatric head CT local DRLs in comparison with national and European DRLs.

CT exam	Category	Number of CT exams	Setted local DRLs	National DRLs [13]	European DRLs [12]
			DLP, mGy·cm	DLP, mGy·cm	DLP, mGy·cm
Head	0–1 y	19	170	570	–
	1–5 y	65	300	630	–
	5–10 y	52	310	650	–
	10–15 y	40	320	830	–
	15–18 y	18	360	–	–
	0–3 m	8	130	–	300
	3 m – 1 y	10	210	–	385
	1–6 y	67	275	–	505
	6–18 y	81	320	–	650

The research included collecting scan parameters from single-phase head CT examinations and categorizing patients into specific age groups. The local age-based DRLs were calculated using the 3rd quartile of the median dose-length product (DLP). A thorough literature analysis was also performed as part of this study.

The results indicated that the newly established local DRLs were significantly lower, ranging from 2-4 times less than the national DRLs and approximately 2 times lower than the European DRLs (Gricienė et al., 2021).

Chapter 3: Methodology

3.1 **Introduction**

In this section, data collection methods, and statistical analysis techniques used to gather and analyze data related to pediatric dosing practices will be described.

3.2 **Study Duration**

The data were collected from patients who experienced brain CT in the period between January 2023 and October 2023.

3.3 **Study Design**

A multi-center review cross-sectional explanatory plan was carefully chosen for accomplishing the study's goals.

3.4 **Study Population**

141 pediatric patients of both genders who had at slightest one brain CT check have taken an interest in this research. Patients were included and avoided based on criteria.

In this study, the process of data collection was conducted in six public hospitals (Beit Jala Governmental Hospital (Al Hussain), Hebron Hospital (Alia), Martyr Dr. Khalil Suleiman Governmental Hospital (Jenin), Dr. Darwish Nazzal Governmental Hospital (Qalqilya), Tubas Turkish Governmental Hospital, and Martyr Abu Al-Hassan Al-Qassem Governmental Hospital (Yatta)).

Table 3.1 Descriptive analysis for demographic data

HOSPITAL	NUM OF PATIENT	AGE	MEDIAN OF CTDI	MEDIAN OF DLP	KVP	mAs	Equipmet	Protocol
Beit Jala	29	0-1y	55.2	916	100	120	philips	pediatric
		1y-6y	55.4	1049	100	120	philips	pediatric
		6y-18y	55.4	1132.4	100	120	philips	pediatric
Jenin	14	0-1y	31.2	570.5	100	120	GE	pediatric
		1y-6y	34.47	598.4	100	120	GE	pediatric
		6y-18y	38.1	705	100	120	GE	pediatric
Yatta	24	0-1y	66.95	1135.65	80	250	GE	Adult
		1y-6y	52.65	1010.05	80	250	GE	Adult
		6y-18y	81.3	1562.5	80	250	GE	Adult
Tubas	21	0-1y	69.1	1171	90	300	philips	pediatric
		1y-6y	45.5	1038	90	300	philips	pediatric
		6y-18y	55.4	1132.4	90	300	philips	pediatric
Qalqlia	29	0-1y	51.4	1131.5	100	230	philips	pediatric
		1y-6y	51.4	1131	100	230	philips	pediatric
		6y-18y	51.4	1117	100	230	philips	pediatric
Alia	24	0-1y	20	420	100	120	GE	pediatric
		1y-6y	33.55	670	100	120	GE	pediatric
		6y-18y	53.3	1869	100	120	GE	pediatric

3.5 **Inclusion criteria**

Patients in the selected hospitals and only had brain CT, Male and Female patients for Pediatric.

3.6 **Exclusion criteria**

Patients who performed their brain CT scans outside the selected hospitals. In addition to the patients who underwent any CT other than brain.

3.7 **Data collection and study tool**

The data about brain CT Pediatric was collected from six hospitals utilizing a preformatted protocol data and dose information report that contains patient's age, the tube voltage, tube current-time product, CTDIvol, and DLP in addition to the date of the CT scan and the type of CT machine. The CTDIvol was developed for brain CT scans using a 16 cm diameter phantom. The DLP is determined by multiplying the CTDIvol by the scanned volume length and is expressed in mGycm. For retroactive data gathering, patient permission is not required.

Mean and cumulative radiation dose values for patients who underwent brain CT scans during the study inclusion period were computed using CTDIvol and DLP. The study involved a comparison of dose values among patients, an examination of the variability in CT acquisition parameters, and an investigation into how CT acquisition parameters affected emitted radiation doses.

3.8 **Statistical analysis**

Microsoft Excel was used to assess and determine the significance of the protocol and the equipment in relation to the other parameters (CTDI, DLP, KVP, mAs). This involved statistical analysis, using ANOVA method, to find out if there are significant differences in these parameters based on the protocol and equipment.

3.9 **Ethical Consideration**

Ethical approval was obtained from the central research ethical committee REC at Al-Quds University, Approval from ministry of health (MOH) was granted. All patients' records were processed anonymously to ensure the patient's confidentiality.

See appendix V for the REC letter from AQU.

Chapter 4: Results and Discussion

4.1 **Results presentation and analysis**

The research aimed to detect if the public Hospitals use a standardized pediatric CT protocol, to study the effect of types, manufacturers and models of CT scanning equipment on the amount of patient dose and examining the extent of hospitals' compliance with international standards DRLs. This study took into consideration how different were the patients, including the following criteria: brain protocol, equipment type and model, manufacturer, CTDI and DLP.

In this chapter the participants' demographic characteristics, data representation, and a summary of the findings will be mentioned.

Table 4.1 the effect of types of protocols on the amount of patient dose

Parameter	Source of Variation	Sum of Squares (SS)	F-Value	P-Value
CTDI	C(Protocol)	1487.11	5.05	0.0211
DLP	C(Protocol)	168461.8	0.66	0.5315
KVP	C(Protocol)	825	27.5	<0.0001
mAs	C(Protocol)	25575	2.72	0.0979

- Table 4.1 the effect of types of protocols on the amount of patient doseincludes the sum of squares, degrees of freedom, F-value, and P-value for each parameter, comparing the variations by Protocol.

- Regarding the effect of types of protocols on the amount of patient dose, the result shows that all protocols was significant at $p \leq 0.05$ with the amount of patient dose but insignificant at the DLP.

- CTDI: Protocol: P-Value = 0.021083 (significant at the 0.05 level)
- DLP: Protocol: P-Value = 0.531486 (not significant at the 0.05 level)
- KVP: Protocol: P-Value = 0.000010 (highly significant)
- mAs: Protocol: P-Value = 0.097930 (not significant at the 0.05 level, but close)

Table 4.2 the effect of manufacturers of CT scanning equipment on the amount of patient dose

Parameter	Source of Variation	Sum of Squares (SS)	F-Value	P-Value
CTDI	C(Equipment)	343.92	1.64	0.2184
DLP	C(Equipment)	90624.44	0.73	0.4063
KVP	C(Equipment)	50	0.8	0.3844
mAs	C(Equipment)	12800	2.46	0.1362

- Table 4.2 includes the equipment relation to the parameters CTDI, DLP, KVP, and mAs.

CTDI: Equipment: P-Value = 0.218436 (not significant at the 0.05 level)

DLP: Equipment: P-Value = 0.406349 (not significant at the 0.05 level)

KVP: Equipment: P-Value = 0.384351 (not significant at the 0.05 level)

mAs: Equipment: P-Value = 0.136227 (not significant at the 0.05 level)

Regarding the effect of equipment on the amount of patient dose, the result shows that all Equipment models were insignificant at $p \leq 0.05$ with the amount of patient dose CTDI, DLP, mAs and KVP.

4.2 **Discussion**

The study's primary findings were as follows: CTDIvol and DLP values in the hospitals were much higher than European DRL values. Furthermore, due to the unmodified CT imaging protocols that would be standardized, dose parameters varied greatly between facilities.

Adult Protocol: shows higher median values of CTDI and DLP, which is expected due to the larger body size of adults compared to children. This leads to a need for higher radiation doses to achieve adequate imaging quality.

Pediatric Protocol: There are two variations of the pediatric protocol, indicating different levels of radiation used perhaps based on the age or size of the child. The first variation

(CTDI: 20.00, DLP: 420.00) represents a lower dose, likely for younger or smaller children. The second variation (CTDI: 53.30, DLP: 1023.75) is closer to the adult protocol values, possibly used for older or larger children.

Additionally, regarding the examined CT imaging parameters and dose products between different centers and CT machines in our hospitals in this retrospective multi-center investigation, the six centers' varying dosage levels and CT acquisition characteristics were more variable than predicted, highlighting the necessity of absorbed dose standardization.

The difference median values of CTDI and DLP between the two types of equipment:

• Philips equipment tends to have higher median values for both CTDI and DLP compared to GE equipment.

• There is a significant difference in the median mAs values, with Philips equipment showing higher values compared to GE.

The current study underscores the need of optimizing head CT scans since the ionizing radiation dose of brain CTs from three CT scanners differed substantially. When CT radiation doses were compared in terms of CTDIvol and DLP, Hospitals Yatta and Alia had significantly greater dose values than the other four facilities. Radiation dose reduction concepts include suitability criteria for imaging technique improvement. Despite the fact that the extreme dose values of Hospitals Qalqilya and Jenin were modest.

According to this study there is no national DRL are developed in Palestine to pediatric patients and the practices of all hospitals are not uniform.

The use of radiological protocols and methods those are not appropriate for pediatric assessment results in the use of high doses of radiation.

In reality, the technicians do not adhere to the radiation safety principles, as the doses are cumulative, exposing children.

This investigation revealed the significance of dose reduction software, dose reconstruction techniques, and the effect of acquisition settings on the decrease of the dose received by patients, particularly young patients. This research found dosimetry exceedances when compared to the European DRL. These exceedances were not previously observed because in the absence of regulatory duties, yearly quality control evaluations of the radiation doses administered to our patients on a regular basis are not conducted.

Chapter 5: Conclusion and Recommendations

5.1 **Conclusion**

After the process of analysis and comparison with the main research objectives related to detect if the hospitals use a standardized pediatric CT protocol, and study the effect of types of CT scanner on the amount of patient dose, it was observed that the governmental hospitals do not use a standardized pediatric brain CT protocol, as the analysis underscores the criticality of protocol choice in medical imaging.

It highlights the need for careful consideration and customization of radiological parameters to balance image quality and patient safety.

Understanding these variations is essential for clinicians and radiological technicians to make informed decisions, optimize imaging practices, and ensure patient-centric care.

The findings advocate for ongoing reviews of imaging protocols and continual assessment of equipment performance to maintain high standards in diagnostic imaging.

This analysis provides valuable insights into the operational aspects of radiological imaging, pointing towards a need for precision in protocol application and an understanding of equipment-specific characteristics in clinical settings.

5.2 **Recommendations**

- In Palestine, a quality control system would be required, as well as continuous training for medical and paramedical staff in radiology in terms of dose reduction software, dose reduction procedures, and their implementations in current practice.
- In addition, it is recommended to establish a national DRL.

5.3 **Limitations**

- The data set lacked information regarding children's weight and height because these characteristics were unavailable at the participating centers
- The study was confined to only two manufacturers since these two manufacturers are the most popular in Palestine and the local geographical region. Inclusion of other

manufacturers, particularly those offering the most recent CT scanner types, would have strengthened the results.

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تقييم الجرعة الاشعاعية للمرضى الأطفال من التصوير المقطعي المحوسب للدماغ كدالة للبروتوكول المستخدم ونوع الجهاز المقطعي المحوسب في المستشفيات الحكومية في فلسطين

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ملخص الدراسة

التصوير الطبي، وتحديداً فحوصات التصوير المقطعي المحوسب ، تلعب دورًا حيويًا في تشخيص وعلاج مختلف الحالات الطبية، مثل الأورام الدماغية ألافات والسكتات الدماغية. ويكون ذلك ذا أهمية خاصة في حالات الأطفال حيث يمكن أن يساعد في التشخيص وإنقاذ الأرواح . ومع ذلك، يثير سوء استخدام التصوير المقطعي المحوسب مخاوف بشأن التعرض الزائد للإشعاع.

هدف هذه الدراسة هو تقييم وجود مستويات مرجعية تشخيصية (DRLs)في فلسطين، والمساهمة في الجهود الوطنية لإقامة مستويات مرجعية تشخيصية وطنية . تم اختيار تصميم تحليلي مستعاد تقاطعي متعدد المراكز بعناية لتحقيق أهداف الدراسة. تم استخدام بروتوكول مناسب وتقارير جرعة تحتوي على معلومات من نظام الأرشفة والتواصل الصوري (PACS) ونظام معلومات المستشفى (HIS)لجمع البيانات في مستشفيات مختلفة في فلسطين. تم استخدام جدول بيانات Microsoft Excel spread Sheet لتحليل البيانات المجمعة. فيما يتعلق بتأثير أنواع البروتوكولات على كمية جرعة المريض، أظهرت النتائج أن جميع البروتوكولات تأثرت بكمية جرعة المريض ولكن بشكل غير مهم عند استخدام منتج طول الجرعة. بينما بالنسبة لتأثير المعدات على كمية جرعة المريض، أظهرت النتائج أن جميع نماذج المعدات كانت غير ذات دلالة مهمة بكمية جرعة المريض، بما في ذلك مؤشر جرعة التصوير المقطعي (CTDI vol)، ومنتج طول الجرعة (DLP) و (kVp, mAs)

أظهرت النتائج أن قيم مؤشر جرعة التصوير المقطعي ومنتج طول الجرعة (CTDIvol and DLP)في المستشفيات الحكومية كانت أعلى بكثير من قيم منتج طول الجرعة الأوروبية، مما يثبت أن المستشفيات الحكومية لا تستخدم بروتوكولًا موحدًا لفحص الدماغ بالتصوير المقطعي للأطفال.