Sudan University of Science and Technology

College of Graduate Studies

Estimation of Effective Dose for Pediatric Patients During Computed Tomography Examinations

تقدير الجرعة الفعالة للأطفال المرضى أثناء اختبارات الاشعة المقطعية المحوسبة

A thesis submitted in partial fulfillment for the requirements

Of Master degree in Medical Physics

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الايـة

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قال الله تعالى :

قُلْ لَوْ كَانَ الْبَحْرُ مِدَادًا لِكَلِمَاتِ رَبِّي لَنَفِدَ الْبَحْرُ قَبْلَ أَنْ تَنْفَدَ كَلِمَاتُ رَبِّي وَلَوْ جِئْنَا بِمِثْلِهِ مَدَدًا ﴿١٠٩﴾

سورة الكهف

Dedication

To my family

To My friends

To My colleagues

To All college staff

And

To all Physicist in the world

Acknowledgement

The great thanks to Prf .Mohamed elfadil Mohamed who always motivate me to go on and on.

I would like to express my sincere gratitude to Dr. Suhaib Mohamedsalih Ahamed who gave me great advices and help in whole process of my thesis.

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Abstract

This research aim to estimate the effective dose for pediatric during common Computed Tomography exanimations (brain , Chest , abdomen and pelvis) , at five different hospitals in Khartoum state – Sudan (Modern Medical Center , NeileenMedical Diagnostic Center , Police Hospital , Alzytouna Hospital and Ibn alhytham) by using equation , is presented, the gender distributed according to selected CT scan were the total number of patients was 1048 patients (1 − 18) years , approximately 45% of the patient for brain (386 ; 233 males and 153 female) , about 22% for chest (191 ; 121 males and 70 female), about 10% for CT abdomen (283; 163males and 120 female) and 21% for pelvis CT (188; 102 males and 86 female) with total number of male and female 619 and 429 respectively. The effective dose found 1.93 mSv for brain (1.98 mSv for male and 1.87 mSv for female),in CT Chest the effective dose was 3.58 mSv (3.57 mSv for male and 3.59 mSv for female), for abdomen was 5.69mSv (5.25 mSv for male and 6.13 mSv for female) and for pelvis the effective dose found 7.14 mSv (8.04 mSv for male and 6.23mSv for female). This study recommends that the CT technologist should be aware to achieving the optimization of patient's dose using the best strategies available for reducing radiation dose, and the patient's Dose must be monitored regularly.

مستخلص البحث

الهدف من هذا البحث هو تقييم الجرعة الفعالة للاطفال اثناء استخدام فحوصات (الراس , الصدر , البطن و الحوض) الاشعة المقطعية لدى خمس مستشفيات مختلفة فى ولاية الخرطوم – السودان (المركز الطبى الحديث , مركز النيلين الطبى للتشخيص , مستشفى الشرطة , مستشفى الزيتونة و مركز ابن الهيم) بواسطة المعادلة , عرض , توزيع النوع (ذكر , انثى) وفقا لاختيار المسح الاشعاعى المقطعى لمرضى عددهم الكلى1048 مريض (1–18) سنة , تقريبا 45 % من المرضى كانت لفحوصات فى الراس (386 ; 233 ذكور و 153 اناث) , حوالى 22 % فحوصات للصدر (191 ; 121 ذكور و 70 اناث) , حوالى 10 % لفحوصات البطن (283 ; 163 ذكور و 120 اناث) بالاضافة لحوالى 21 % من الفحوصات كانت للحوض (188 ; 102 ذكور و 86 اناث) مع رقم كلى للذكور و الاناث 619 و 429 على التوالى .وجدت الجرعة الفعالة للراس هى 1.93 ملى سيفر (1.98 ملى سيفر للذكر و 1.87 ملى سيفر للانثى) و ايضا الجرعة الفعالة للصدر كانت 3.58 ملى سيفر (3.57 ملى سيفر للذكر و 3.59 ملى سيفر للانثى) كما كانت الجرعة الفعالة للبطن 5.69 ملى سيفر (5.25 ملى سيفر للذكر و 6.13 ملى سيفر للانثى) و الجرعة الفعالة للحوض هى 7.14 ملى سيفر (8.04 ملى سيفر للذكر و 6.23 ملى سيفر للانثى) .توصى هذه الدراسة على تقنى الاشعة المقطعية يجب عليه ان يكون مدرك بتحقيق الامثلة لجرعة المريض (الوقاية الاشعاعية) باستخدام افضل الاستراتيجيات المتوفرة لتقليل جرعة المريض ما امكن , و يجب ان تكون الجرعة الاشعاعية للمريض مراقبة بانتظام .

Table of Contents

List of tables

List of abbreviations

Abbreviation	Meaning
D	Absorbed Dose
D_T	Organ and Tissue Dose
H_T	Equivalent Dose
ED	Effective dose
ε	Energy Imparted
CT	Computed Tomography
DLP	Dose Length Production
CNS	Central Nervous System
PNS	Peripheral Nervous System
CTDI	Computed Tomography Dose Index
$CTDI_{100}$	Computed Tomography Dose Index for a 100 mm length
$CTDI_{vol}$	Volume Computed Tomography Dose Index
$CTDI_W$	Weighted Computed Tomography Dose Index
MDCT	Multidetector Computed Tomography
MSAD	Multiple Scan Average Dose Pencil ion Chamber
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiological Unit
ALARA	As low As Reasonably Achievable
Kerma	Kinetic Energy Released Per Unit Mass
$P_{KL\ CT}$	Computed Tomography air kerma length product
FOV	Field Of View
J/ Kg	joule per kilogram
W_R	Radiation Weighting Factor
W_T	Tissue Weighting Factor
mSv	Mile Sievert
MeV	Mega electron Volt
Kvp	Kilo Voltage Peak
mAs	Milliampere per Second
Gy	Gray
Gy / S	Gray per Second

Chapter One

Introduction

Chapter One

Introduction

1.1 Introduction:

After its clinical introduction in 1971, computed tomography (CT) developed from an x ray modality that was limited to axial imaging of the brain in neuroradiology in to a versatile 3–D whole body imaging modality for a wide range of applications, including oncology vascular radiology, cardiology, traumatology and interventional radiology. CT is applied of diagnosis and follow–up studies of patients, for planning of radiotherapy, and even for screening of healthy sub populations with specific risk factors. (Dance, D, et al. 2014).

Since 1972 when the first head CT scanner was introduced, CT has matured greatly and gained technological sophistication .Concomitant changes have occurred in the quality of CT images .CT is one of the many technologies that were made possible by the invention of the computer. The clinical potential of CT became obvious during its early clinical use , and the excitement for ever solidified the role of computers in medical imaging .Recent advances in acquisition geometry , detector technology , multiple detector arrays , and x ray tube design have led to scan times now measured in fractions of a second .

The invention of the CT scanner earned godfrey Hounsfield of Britain and Allan Cormack of the united states the Nobel prize for medicine in 1979 .CT scanner technology today is used not only in medicine but in many other industrial applications , such as non-destructive testing and soil core analysis (Bushberg, J. , et al. 2003).

1.2 Principles of CT:

The mathematical principles of CT were first developed by Radon in 1917 .Radon’s treatise proved that an image of a unknown object could be produced if one had an infinite number of projections through the object.

The process of CT image acquisition involves the measurement of x ray transmission profiles through a patient for large number of views .A profile from each view is a achieved primarily by detector are generally consisting of 800 – 900 detector element (detector row) by rotation of the x-ray tube and detector row around the patient, a large number of view can be obtained.

A beam of x-ray collimated into thin beam that only passes through the tissue to be imaged, its strikes in special detectors (detector row), and these detectors are quantitative and measure very small differences. The transmission beam pass through the different tissues are encountered with different linear attenuation coefficients (intensities) it can be seen that the basic data needed for C T are the intensities of the attenuated an un attenuated x-ray beam , the values that are a signed to the pixels in a C T image are associated with the attenuation of the corresponding tissue (linear attenuation coefficient) by digital computer which uses special algorithms (processing) to display(Diagnostic Radiology physics).

The advantage of tomographic image over projection image its ability to display the anatomy in a slice of in the absence of over – or under lying structures and improved to contrast resolution for better visualization of soft tissue . (Bushberg, J, et al. 2003).

There are three general rules to reduce a person's exposure to any type of ionizing radiation; reduce the time you are exposed to the radiation source , increase the distance between yourself and the radiation source and increase the shielding between yourself and the radiation source (James E . Martin 2013) .

1.3 Biological effects of radiation:

Rarely have beneficial applications and hazards to human health followed a major scientific discovery more rapidly than with the discovery ionizing radiation .Shortly after the discovery of x-ray in 1895 and natural radioactivity in 1896 , biologic effects from ionizing radiation were being observed . Two month after their discovery , x-ray were being used to treat breast cancer .Unfortunately, the development and implementation of radiation protection

techniques lagged behind the rapidly increasing use of radiation sources . Within the first 6 month of their use, several cases of erythematic, dermatitis and alopecia were reported among x-ray operators and their patients.

The first report of asking cancer ascribed to x-ray was in 1902, to be followed 8 years latter by experimental conformation. However , it was not until 1915 that the first radiation protection recommendation were made by the British Roentgen society , followed by similar recommendations from the American Roentgen ray society in1922 .The study of the action of ionizing radiation on healthy and diseased tissue began the scientific discipline know as radiation biology .

Radiation biologists seek to understand the sequence of events that occurs after the absorption of energy from ionizing radiation, the damage that is produced, and the mechanisms that exist to compensate for or repair the damage. A century of radiobiological research has amassed more information about the effects of ionizing radiation on living systems that about almost any other physical or chemical agent. (Bushberg, J., et al. 2003).

Biological effect of radiation in humans occur either in the irradiation individuals themselves (somatic effects) or in their descendants (hereditary or genetic effects) .Somatic effects divided in to deterministic effects and stochastic effects , where hereditary and genetic effects are all of stochastic origin only . (Dance, D., et al. 2014).

1.3.1 Deterministic and stochastic effects: -

Deterministic effects result from radiation induced cell loss or damage most organs or tissues of the body are un affected by the loss of a few cells ; however , if the number of cells lost is sufficiently large , there is observable harm and , hence , loss of tissue or organ function. Above a particular level of dose (threshold dose), The severity of effect necessarily increases with increasing dose.

This threshold varies from one effect to another. Deterministic effects may occur a few hours or days after exposure or many require months or years before expression (cataract of the eye lens). (Dance, D., et al. ‘ 2014).

A stochastic effects is one in which the probability of the effect, rather than its severity, increases with dose .Radiation induced cancer and genetic effects are stochastic in nature .Stochastic effect are believed not to have a dose threshold, because injury to a few cells or even a single cell could theoretically result in production of the disease. There for even minor exposures may carry, albeit small, increased risk. It is the basic assumption that risks increase with dose and there is no threshold dose below which risks cease to exist that is the basis of modern radiation protection programs .The goal of which is to keep exposures as low as reasonably achievable (ALARA).

Stochastic effects are regarded as the principal health risk from low – dose radiation, including exposures in the diagnostic radiology and nuclear medicine department. (Bushberg, J., et al. ‘ 2003).

There are many factors that determine the biologic response of radiation exposure .In general, these factors include variables associated with the radiation source and the system being irradiated.

The identification of these biologic effects depends on the method of observation. Radiation – related factors include the dose, type, and energy of the radiation as well as the dose rate and the conditions under which the dose is delivered. The radio sensitivity and complexity of the biologic system determine the type of response from agienexposure.

In general, complex organisms exhibit more sophisticated repair mechanisms. Responses seen at the molecular or cellular level may or may not result in adverse clinical effects in humans. Furthermore, although some responses’ to radiation exposure appear instantaneously, others take weeks, years, or even decades appear. (Bushberg, J., et al. 2003).

1.4 Problem of study:

Pediatric patients in general are more sensitive to the effects of ionizing radiation, Due to use C T scanning pediatric patients are exposed to more doses which may result in unintended health effects, to avoid unnecessary of high dose to the pediatric patient need to estimate the pediatric patient dose and effective dose which reduce biological effects of the pediatric patient.

1.5 Objectives of the study:

1.5.1 General objective: To estimate the effective dose for pediatric patients during CT examinations (brain , chest , abdomen , and pelvis) by using equation .

1.5.2 Specific objective:

- To evaluate volume computed tomography dose index ($CTDI_{vol}$).
- To evaluate dose length production (DLP).
- To evaluate effective dose (ED).

1.6 Thesis outline:

This study consisted of five chapters ,Chapter one includes ; introduction of computed tomography , principles of CT , biological effects of radiation , deterministic and stochastic effects , problem of study and objectives of this study also mentioned in this chapter . chapter two include ; introduction , generations of CT, anatomical of (brain,chest,abdominal,and pelvis) , paediatric radiology and Dosimetric quantities and unit .

Chapter three; this chapter describes the materials and methods used in this research to assess the effective patient dose .Chapter four; this chapter consists of: presentation of the results in tables.

Chapter five; Introduce the discussion and conclusion that had been derived out from the research and recommendations.

Chapter Two

Theoretical Background

Chapter Two

Theoretical Background

2.1 Computed Tomography:

After preclinical research and development during the early 1970s, CT developed rapidly as an indispensable imaging modality in diagnostic radiology .It is impressive to realize that most of the modern CT technology that is being used in clinical practice now a days had already been described by the end of 1983.The development of multidetector row CT (MDCT) and multisource CT had already been described in a patient from 1980. the patient describes what the authors call multiple purpose high speed tomographic x-ray scanner ''In the acquisition technique of helical CT , the patient states that'' the apparatus enables helical scanning to be effected by the continuous transportation of the table couch '' .The helix is the pathway of the continuously rotating x-ray source seen from the perspective of the patient . Volumetric CT with a scanner that was capable of imaging an entire volume within a fraction of a second was achieved with the installation of the dynamic spatial reconstructed in 1980 at the mayo clinic In the USA .Currently, most scanners are helical MDCT scanners, but the technologies of dual source and volumetric CT scanning have been implemented on wide scale. (Dance, D. et al. 2014).

2.1.1 First generation: Rotate / Translate, pencil beam

The first generation of CT scanners employed a rotate / translate , pencil beam system .Only two x- ray detectors were used , and they measured the transmission of x-ray through the patient for two different slices .The pencil beam allowed very efficient scatter reduction. (Bushberg, J., et al. 2003).

2.1.2 Second generation: Rotate / translate, narrow fan beam

The next incremental improvement to the CT scanner was the incorporation of a linear array of 30 detectors. This increased the utilization of the x-ray beam by 30 times , compared with the single detector used per slice in first generation system .Relatively narrow fan angle of 10 degrees was used . In principle, a

reduction in scan time of about 30 – fold could be expected. However , this reduction time was not realized , because more data (600 rays ' x 540 views = 324 , 000 data points) were acquired to improve image quality .The shortest scan time with a second generation scanner was 18 seconds per slice 15 times faster than with the first generation system . (Bushberg, J., et al. 2003).

2.1.3 The third generation: Rotate / Rotate:

wide fan beam the translational motion of first – and second – generation CT scanners was fundamental impediment to fast scanning .At the end of each translation , the motion of the x-ray tube / detector system had to be stopped , the whole system rotated , and the translation motion restarted. The success of CT as a clinical modality in its infancy gave manufacturers reason to explore more efficient, but more costly, a approaches to the scanning geometry The number of detectors used in third – generation scanners was increased substantially to more than 800 detectors, and the angle of the fan beam was increased so that the detector array formed an are wide enough to allow the x-ray beam to interrogate the entire patient. Because detectors and the associated electronics are expensive, this led to more expensive CT scanners. However, spanning the dimensions of the patient with an entire row of detectors eliminated the need for translation motion. (Bushberg, J., et al. 2003).

2.1.4 Fourth generation: Rotate / Stationary

Third generation scanners suffered from the significant problem of ring artefacts', and in the late 1970s fourth – generation scanners were designed specifically to address these artefacts'. it is never possible to have a large number of detectors in perfect balance with each other , and this was especially true 25 years ago, Each detector and its associated electronics has a certain amount of drift , causing the signal levels from each detector to shift over time . The rotate / rotate geometry of third – generation scanners leads to a situation in which each detector is responsible for the data corresponding to a ring in the image Detectors toward the center of the detector array provide data in the

reconstructed image in a ring that is small in diameter , and more peripheral detectors contribute to larger diameter rings . (Bushberg, J., et al. 2003).

2.1.5 Fifth generation: Stationary / Stationary

A novel CT scanner has been developed specifically for cardiac tomographic imaging. This ‘‘ cine – CT ’’ scanner does not use a conventional x-ray tube ; instead , a large are of tungsten encircles the patient and lies directly opposite to the detector ring . (Bushberg, J., et al. 2003).

2.1.6 Sixth generation: Helical

Helical CT scanners acquire data while the table is moving; as a result, the x-ray source moves in a helical pattern around the patient being scanned. Helical CT scanners use either third –or fourth generation slip ring designs. By a voiding the time required to translate the patient table, the total scan time required to image the patient can be much shorter (30 seconds for the entire abdomen). Consequently, helical scanning allows the use of less contrast agent and increases patient throughput. In some instances the entire scan can be preformed within a single hold of the patient, a voiding inconsistent level of inspiration. (Bushberg, J., et al. 2003).

2.1.7 Seventh generation: Multiple detectors a ray

X – ray tubes designed for CT have impressive heat storage and cooling capabilities , although the instantaneous production of x – ray (x-rays per milliampere – second (mAs) is constrained by the physics governing x-ray production .An approach to overcoming x-ray tube output limitations is to make better use of the x-rays that are produced by the x-ray tube .

When multiple detector a rays are used the collimator spacing is wider and therefore more of the x-rays that are produced by the x-ray tube are used in producing image data .With conventional , single detector a ray scanners , opening up the collimator increases the slice thickness , which is good for improving the utilization of the x-ray beam but reduces spatial resolution in the

slice thickness dimension .With the introduction of multiple detector a rays , the slice thickness is determined by the detector size and not by the collimator .
This represents a major shift in CT technology. (Bushberg, J., et al .2003).

2.2 Anatomy of the Brain:

The human brain is an amazing three – pound organ that controls all functions of the body , interprets information from the outside world , and embodies the essence of the mind and soul .Intelligence , creativity , emotion and memory are a few of the many things governed by the brain . Protected within the skull the central Nervous system the nervous system is divided in to two major section:
The Central Nervous System and the Peripheral Nervous System.
The central nervous system (CNS) consists of the brain and spinal code. The peripheral nervous system (PNS) consists of the nerve tracts that connect the rest of the body to the central nervous system. ((Shams,T., et al 2014)) .

2.3 Anatomy of the Chest:

The thoracic wall consists of a bony frame work that is held together by twelve thoracic vertebrae posterior which give rise to ribs that encircle that lateral and anterior thoracic cavity. The first nine ribs curve around the lateral thoracic wall and connect to the manubrium and sternum. Ribs 10 – 12 are relatively short and attach to the costal margins of the ribs just above them. Ribs 10 – 12 due to their short course, they do not reach the sternum.
The first seven ribs are termed true ribs and attach to the manubrium and directly attach to the body of sternum. Ribs eight to ten only attach to the inferior part of sternum via the costal cartilages. Ribs 11 – 12 are termed floating ribs because they do not attach directly to the sternum. Ribs eight to ten are known as false ribs because they lack direct attachment to the sternum .At the level of the spine, the ribs articulate with the costal facet of two opposing vertebrae. A particular capsule surrounds the head of each rib, and the attachment to the transverse process is made with the help of the radiate ligament. Once the ribs leave the vertebrae, they gently curve around the lateral

thoracic wall and approach the anterior wall of the thoracic cavity ((Donley E, et al 2018)).

The vertical bone of the chest, the sternum, defines the anterior chest wall. The three separate bone segments of different size and shape that make up the sternum include; the thick manubrium, long body of the sternum, and the xiphoid process. It develops independently of the rib. In sporadic cases, the sternum my not fully form, and the underlying heat may be exposed.

The most superior portion of the sternum is the manubrium, and it is also the first to form during embryogenesis. The sterna body and xiphoid process soon follow the manubrium in development .Anatomically, the manubrium is located at the level of thoracic vertebral bodies T_3 and T_4 .The manubrium is also the widest and thickest segment of the sternum. During a physical exam of the chest, one noticeable feature of the manubrium is the presence of the suprasternal notch .On either side of this notch; one will feel the thick attachment from the clavicles. for access to the superior mediastinum, suprasternal goitre or thymus , some thoracic surgeons will only make a midline incision in the manubrium .The sterna body is located at the level of vertebral bodies $T_5 - T_9$. it covers a significant portion of the mid-chest and is very strong . to access the chest cavity , surgeons usually cut through the sternum with a mechanical saw .

The xiphoid process is a thin and very small bone. Its size may vary from two to five cm, and its shape is also variable .The xiphoid may a ppearbifid, oval or be curved inwards / out wards. In younger individuals, the xiphoid is mostly cartilaginous but is nearly wholly ossified by age 40 .By the age of 60 and over, the xiphoid is almost certainly completely calcified. To perform pericardiocentesis safely the needle has to be placed directly underneath the xiphoid because the heart is just a fawning breadth below. ((Donley E, et al 2018)).

2.4 Anatomy of the Abdominal:

The abdominal wall encompasses an area of the body bounded superiorly by the xiphoid process and costal arch , and inferiorly by the inguinal ligament, pubic bones and the iliac crest .Visualization , palpation , percussion , and auscultation of the anterolateral abdominal wall may reveal abnormalities associated with abdominal organs , such as the liver , spleen , stomach , abdominal aorta , pancreas and appendix , as well as thoracic and pelvic organs .Visible or palpable deformities such as swelling and scars , pain and tenderness may reflect disease processes in the abdominal cavity or elsewhere .Pleural irritation as a result of pleurisy or dislocation of the ribs may result in pain that radiates to the anterior abdomen .Pain from a diseased abdominal organ may refer to the anterolateral abdomen and other parts of the body . The abdominal wall should be suspected as the source of pain in individuals who exhibit chronic and unremitting pain with minimal or no relationship to gastrointestinal function, but which shows variation with changes of posture. This is also true when the anterior abdominal wall tenderness is unchanged muscles. Abdominal wall pain can be the result of localized endometriosis, rectus sheath hematoma, or abdominal incision or hernia. ((Suleiman et al 2001)).

2.5 Anatomy of the Pelvis:

The pelvis is the region of the trunk that lies below the abdomen; pelvic anatomy remains the primary domain of the gynaecologic surgeon Bony pelvis:

The bony pelvis's main function is to transmit the weight of the body from the vertebral column to the femurs. in addition , it contains , supports , and protects the pelvic viscera and provides attachment for trunk and lower limb muscles. The bony pelvis is composed of four bones: the two hip bones, which form the lateral and anterior walls, and the sacrum and the coccyx, which are part of the vertebral column and form the back wall.

The two hip bones articulate with each other interiorly at the sacroiliac joints. The bony pelvis thus forms a strong basin – shaped structure that contains and protects the lower parts of the intestinal and urinary tracts and the internal

organs of reproduction .The pelvis is divided in to two parts by the pelvic brim, which is formed by the sacral promontory (anterior and upper margin of the first vertebra) behind, the iliopectineal lines laterally, and the symposia pubis anteriorly. Orientation of the pelvis: It is important to understand the correct orientation of the bony pelvis relative to the trunk, with the individual standing in the anatomic position. The front of the symposia pubis and the anterior superior iliac spines should lie in the same vertical plane. This means that the pelvis surface of the symphysis pubis faces upward and backward and the anterior surface of the sacrum is directed forward and downward. ((Richard s. Snell ‘ 2012)).

2.6 Paediatric Radiology:

The dosimeter for paediatric patients undergoing diagnostic radiology requires special consideration in addition to the general dissymmetric methodologies used for adult patients .The reasons why paediatric dissymmetry need to be addressed as a specific area of study include: the dosimetry for this patient group is more acute than for adults , data collection and analysis are complex , fundamentally due to the wide and continuous range of patient sizes present in the paediatric population , paediatric patient examination , and paediatric dosimetry requires different specialized phantoms. The principal Dosimetric quantilies for use in CT are the CT air kerma indices $C_{a,100}$[12] and C_w(CTDIw) . A further CT air kerma index C_{vol} ($CTDI_{vol}$) is derived from C_w for particular patient scan parameters. Patient doses for a complete examination are described in term of the CT air kerma length product $P_{KL,CT}$ (dose length product (DLP) in IEC terminology) .For paediatric dosimetry , the use of a displayed computed tomography dose index (CTDI) will most probably underestimate the dose to the patient when compared to the case for adults. If specific paediatric protocols are available, the calibration of the console can be either with a 32cm diameter phantom or with a 16cm diameter phantom. ((IAEA Human Health series 2013)).

2.7 Dosimetric Quantities and unit:

2.7.1 Fluence: ϕ

The fluency, ϕ, is the quotient dN by da, where dN is the number of particles incident on a sphere of cross – sexctional area da, Thus:

$$\phi = dN / da \qquad \text{The units is } m^{-2}$$

2.7.2 Energy fluence: Ψ

The energy fluence, Ψ, is the quotient dR by da, where dR is the radiant energy incident on a sphere of cross – sectional area da, thus :

$$\Psi = dR / da \qquad \text{the unit is } J/m^2$$

2.7.3 Kerma and kerma rate

Kerma is an acronym for kinetic energy released per unit mass. It is anon stochastic quantity applicable to in directly ionizing radiations such as photons and neutrons. It quantifies the average amount of energy transferred from in directly ionizing radiation to directly ionizing radiation without concern as to what happens after this transfer. The energy of photons is imparted to matter in a two stage process .In the first stage , the photon radiation transfers energy to the secondary charged particles (electrons) through various photon interactions (the photoelectric effect , the Compton effect ,pair production , etc . In the second stage , the charged particle transfers energy to the medium through atomic excitation and ionization .In this context , the kerma is defined as the mean energy transferred from the in directly ionizing radiation to charged particles (electrons) in the medium dE_{tr} per unit mass dm .

$$K = dE_{tr} / dm$$

The unit of kerma is joule per kilogram (J/ Kg). The name for the unit of kerma is the gray (Gy),

$$\text{Where} \quad 1\ Gy = 1\ J / Kg \ .$$

The kerma rate , $K^{\bullet}$, is the quotient dk by dt, where dk is the increment of kerma in the time interval dt , Thus : $K^{\bullet} = dk / dt$

The unit is J. kg^{-1} . s^{-1} . If the special name gray is used, the unit of kerma rate is gray per second (Gy / S). ((Podgorsak et al 2005)).

2.7.4 Energy Imparted: ε^{-}

The mean energy imparted , ε^{-} , to the matter in a given volume equals the radiant energy , R_{in} , of all those charged and uncharged ionizing particles which enter the volume minus the radiant energy , Rout , of all those charged and uncharged ionizing particles which leave the volume , plus the sum , εQ , of all changes of the rest energy of nuclei and elementary particles which occur in the volume , Thus :

$\varepsilon^{-} = R_{in} - R_{out} + \varepsilon Q$ The unit is J.

2.7.5 Absorbed Dose : D

The absorbed dose , D , is the quotient $d\varepsilon^{-}$ by dm , where $d\varepsilon^{-}$ is the mean energy imparted to matter of mass dm , Thus :

$D = d\varepsilon^{-} / dm$ The unit is J / Kg .

The special name for the unit of absorbed dose is gray (Gy) . ((Pernicka et al 2007)).

2.8 Quantities for CT dosimetry

2.8.1 Computed Tomography Dose Index (CTDI)

The CTDI is the primary dose measurement concept in CT ,

$$CTDI = 1 / NT \int_{-\infty}^{\infty} D(Z)dz \quad \ldots\ldots\ldots\ldots\ldots\ldots$$

Where

D (Z) = The radiation dose profile alonge the Z – axis , N = The number of tomographic sections imaged in a single axial scan .

This is equal to the number of data channels used in a particular scan . The value of N may be less than or equal to the maximum number of data channels available on the system, and

T = The width of the tomographic section along the Z – axis imaged by one data channel.

In multiple – detector – row (multislice) CT scanners, several detector elements may be grouped together to form one data channel. In single – detector – row (single – slice) CT, the Z- axis collimation (T) is the nominal scan width. CTDI represents the average absorbed dose, along the Z- axis, from a series of contiguous irradiation. It is measured from one axial CT scan (one rotation of the x – ray tube), and is calculated by dividing the integrated absorbed dose by the nominal total beam collimation. The CTDI is always measured in the axial scan mode for a single rotation of the x –ray source, and theoretically estimates the average dose within the central region of scan volume consisting of multiple, contiguous CT scan [Multiple scan Average Dose (MSAD)] for the case where the scan length is sufficient for the central dose to approach its asymptotic upper limit . The MSAD represents the average dose over asmallinterval (-1/2 , 1/2) about the center of the scan length (Z= 0) for a scan interval I , but requires multiple exposures for its direct measurement. The CTDI offered a more convenient yet nominally equivalent method of estimating this value, and required only a single – scan acquisition , which in the early days of CT , saved a considerable amount of time . ((Committee AAPM 2008)) .

2.8.2 $CTDI_{FDA}$

Theoretically, the equivalence of the MSAD and the CTDI requires that all contributions from the tails of the radiation dose profile be included in the CTDI dose measurement. The exact integration limits required to meet this criterion depend upon the width of the nominal radiation beam and the scattering medium .To standardize CTDI measurement (infinity is not a likely measurement parameter) , the FDA introduced the integration limits of ± 7 T where T represented the nominal slice width .Interestingly , the original CT scanner , the EMI Mark I , was a dual detector – row system .

Hence , the nominal radiation beam width was equal to twice the nominal slice width (I . e . , N X T mm) . To account for this, the CTDI value must be normalized to 1⁄NT:

$CTDI_{FDA} = 1 / NT \int_{-7T}^{7T} D(Z)dz$

Unfortunately, the limits of integration were not similarly expressed in terms of NT, allowing for the potential underestimation of the MSAD by the CTDI.

For the technology available circa, 1984 the use of NT in the integration limits was deemed un necessary at the time. The scattering media for CTDI measurement were also standardized by the FDA.

These consist of two polymethylmethacrylate (PMMA, e. g., acrylic or Lucite ™) cylinder of 14 – cm length .

To estimate dose values for head examinations, adimeter of 16 cm is to be used . To estimate dose values for body examination, adiameter of 32 cm is to be used. These are typically referred to, respectively , as the head and body CTDI phantoms . ((Committee AAPM 2008)).

2.8.3 $CTDI_{100}$: -

$CTDI_{100}$ represents the accumulated multiple scan dose at the center of a 100 – mm scan and underestimates the accumulated dose for longer scan lengths. It is thus smaller than the equilibrium dose or the MSAD.

The $CTDI_{100}$, like the $CTDI_{FDA,}$ requires integration of the radiation dose profile from a single axial scan over specific integration limits. In the case of $CTDI_{100}$, the integration limits are $+-50mm$, which corresponds to the $100 - mm$ length of the commercially available " pencil " ionization chamber .

$CTDI_{100} = 1 / NT \int_{-50mm}^{50mm} D(z)dz$. ((Committee AAPM 2008)) .

2.8.4 Weighted $CTDI_W$: -

The CTDI varies across the field of view (FOV). For example, for body CT imaging, the CTDI is typically a factor or two higher at the surface than at the

center of the FOV. The average CTDI across the FOV is estimated by the Weighted CTDI ($CTDI_W$), where

$CTDI_W = ⅓\ CTDI_{100,\ Center} + ⅔\ CTDI_{100,\ edge}$

The values of ⅓ and ⅔ approximate the relative areas represented by the center and edge values. $CTDI_W$ is a useful indicator of scanner radiation output for a specific Kvp and mAs. According to IEC 60601 – 2 – 44, $CTDI_W$ must use $CTDI_{100}$ as described above and an f-factor for air (0.87 rad/R or 1.0 mGy/mGy)

2.8.5 Volume $CTDI_{VOL}$: -

To represent dose for a specific scan protocol, which almost always involves a series of scans , it is essential to take in to account any gaps or overlaps between the X – ray beams from consecutive rotations of the X- ray source . This is accomplished with use of adose descriptor known as the volume CTDIW(CTDIVOL) , Where

$CTDI_{VOL} = N * T / I\ CTDI_W$ and

I = the table increment per axial scan (mm).

Since pitch is defined 19 as the ratio of the table travel per rotation (I) to the total nominal beam width (N_x T)

$$Pitch = 1 / N * T$$

Thus, volume CTDI can be expressed as

$$CTDI_{VOL} = 1 / pitch * CTDI_W$$

Whereas $CTDI_W$ represents the average absorbed radiation dose over the X and Y directions at the center of the scan from a series of axial scans where the scatter tails are negligible beyond the 100 – mm integration limit , $CTDI_{VOL}$ represents the average absorbed radiation dose over the X , Y , and Z directions .

It is conceptually similar to the MSAD, but is standardized with respect to the integration limits (+ - 50 mm) and the F – Factor used to convert the exposure or air kerma measurement in to dose to air. ((Committee AAPM 2008)).

2.8.6 Dose length Product DLP :-

To better represent the overall energy delivered by a given scan protocol , the absorbed dose can be integrated along the scan length to compute the dose – length product (DLP) , where

DLP (mGy – cm) = $CTDI_{VOL}$ (mGy) * scan length (cm)

The DLP reflects the total energy absorbed (and thus the potential biological effect) attributable to the complete scan acquisition .

Thus , an abdomen – only CT exam might have the same $CTDI_{VOL}$ as an abdomen / pelvis CT exam , but the latter exam would have a greater DLP , proportional to the greater Z – extent of the scan volume .

In helical CT, data interpolation between two points must be preformed for all projection angles. Thus , the images at the very beginning and end of a helical scan require data from Z axis projections beyond the defined ‘‘ scan ” boundaries (i.e. , The beginning and end of the anatomic range over which images are desired) .This increase in DLP due to the additional rotation (s) required for the helical interpolation algorithm is often referred to as ‘‘ over ranging ” . For MDCT scanners, the number of additional rotations is strongly pitch dependent, with atypical increase in irradiation length of 1.5 times the total nominal beam width .The implications of over ranging with regard to the DLP depends on the length of the imaged body region .For helical scans that are short relative to the total beam width, the dose efficiency (with regard to over ranging) will decrease. For the same anatomic coverage, it is generally more dose efficient to use a single helical scan than multiple helical scans. ((Committee AAPM 2008)).

2.9 Quantities Related to Stochastic and Deterministic Effect : -

2.9.1 Organ and Tissue Dose D_T

The mean absorbed dose in a specified tissue or organ is given the symbol D_T in ICRU 51 [3. 11] . It is equal to the ratio of the energy imparted, ε_T, to the tissue or organ to the mass, m_T, of the tissue or organ, Thus [3.1] :

$$D_T = \varepsilon / m_T$$

The mean absorbed dose in a specified tissue or organ is some time simply referred to as the organ dose. This simplification is adopted in this code of practice. ((Pernickaet al2007)).

2.9.2 Equivalent Dose H_T:-

The equivalent dose, H_T, to an organ or tissue, T, is defined in ICRP 60 [3.13] and ICRU 51 [3.11].

For a single type of radiation, R, it is the product of a radiation weighting factor, W_R, for radiation R and the organ dose, D_T, Thus:

$$H_T = W_R D_T$$

The unit is J / Kg. The special name for the unit of equivalent dose is sievert (sv) .The radiation weighting factor, W_R, allows for differences in the relative biological effectiveness of the incident radiation in producing stochastic effects at low doses in tissue or organ, T. For x ray energies used in diagnostic radiology, W_R is taken to be unity. ((Pernickaet al 2007)).

Table. (2.1) : - Radiation weighting factors in publication ICRP 60 and Q in publication ICRP 60

Type and energy rang	W_T	Q
Photons (x ray and gamma ray) all energies	1	1

Electron , muons all energies	1	1
Neutrons < 10 kev	5	_
Neutrons 10 kev to 100 kev	10	_
Neutrons > 100 kev to 2 Mev	20	_
Neutrons > 2 Mev to 20 Mev	10	_
Neutrons > 20 Mev	5	_
Protons > 20 Mev	5	1
Alpha particles fission – fragment heavy nuclei	20	20

2.9.3 Effective Dose E : -

The effective dose , E , is defined in ICRP 60 [3.13] and ICRU 51 [3.11] . It is the sum over all the organs and tissues of the body of the product of the equivalent dose, H_T, for that organ or tissue , thus :

$$E \quad \Sigma_T W_T H_T$$

W_T = tissue weighting factor , H_T = tissue equivalent dose

The tissue weighting factor , W_T , for organ or tissue T represents the relative contribution of that organ or tissue to the total detriment arising from stochastic effects for uniform irradiation of the whole body .

The unit is J/kg. The special name for the unit of effective dose is sievert (sv).

The sum overall the organ and tissue of the body of the tissue weighting factors, W_T, is unity. ((Pernicka et al 2007)).

The remainder is composed of the following additional tissue and organs : adipose tissue , adrenals , connective tissue , extra thoracic airways , gallbladder , heart wall , kidney , lymphatic nodes , muscle , pancreas , prostate , small intestine wall , spleen , thymus and uterus / cervix .

Table (2.2) : Tissue weighting factors for different organs .

Organs	Tissue weight factors		
	ICRP 30(1979)	ICRP 60 (1990)	ICRP 103 (2007)
Gonads	0.25	0.20	0.08
Clon	_	0.12	0.12
Lung	0.12	0.12	0.12
Red bone marrow	0.12	0.12	0.12
Stomach	_	0.12	0.12
Bladder	_	0.05	0.04
Breast	0.15	0.05	0.12
Liver	_	0.05	0.04
Esophagus	_	0.05	0.04
Thyroid	0.03	0.05	0.04
Bone surface	0.03	0.01	0.01
Skin	_	0.01	0.01
Brain	_	_	0.01
Salivary	_	_	0.01
Remained	0.03	0.05	0.01

2.10 Previous Studies :

Alhadi Abakar (2011) studied : Evaluation of radiation Risks in computed tomography in Sudan . The purpose of this study was to evaluate the patient radiation dose in three different modalities of CT scanners (64 slices , 16 slices , and 2 slices for routine CT investigations) . A total of 108 patients were examined in this study in three different hospitals in Khartoum state. The data was collected from the following examinations: brain, chest, abdomen and pelvis. Dual slice scanner delivered the lowest radiation dose while 16 and 64 slice scanners delivered the highest radiation dose. The dose values of this study were comparable to the international reference levels CT examination. CT dose optimization protocol is not implemented in all hospitals.

Afrah Alsadeg, (2009) studied: "Measurement of Pediatric Radiation Dose in Computed Tomography Examination" The assessment of radiation dose to pediatric patient undergoing CT brain, abdomen and chest investigated. In this study variation in doses were observed, the radiation dose is higher in Al Ribat university hospital than in El-Nilein diagnostic centre, and in general the mean values of doses are higher for CT brain and lower for abdomen and chest compare to other studies. Different data in request form were responsible for these variations. The main contributor for this high dose was the use of different techniques and use for adult protocol, which justify the important of use child protocol. In addition the study has shown a great need referring criteria, continuous training of staff in radiation protection concepts especially for pediatric.

Abdelrahman Mohamed (2009) studied: "Optimization of Radiation Dose in Abdomen Using Computerized Tomography"Optimization could be achieved through optimal study, body region of interest being scanned , and patient size.

The author Fracis R et al (2008), CT radiation dose in children: survey to established age based diagnostic reference levels in Switzerland, were said; This work aimed at assessing the doses delivered in Switzerland to paediatric patients during computed tomography (CT) examinations of the brain, chest and abdomen, and at establishing diagnostic reference levels (DRLs) for various age groups. Forms were sent to the ten centers performing CT on children, addressing the demographics, the indication and the scanning parameters: number of series, kilo voltage, tube current, rotation time, reconstruction slice

thickness and pitch, volume CT dose index (CTDIvol) and dose length product (DLP).

Per age group, the proposed DRLs for brain, chest and abdomen are, respectively, in terms of CTDIvol: 20, 30, 40, 60 mGy; 5, 8, 10, 12 mGy; 7, 9, 13, 16 mGy; and in terms of DLP: 270, 420, 560, 1,000 mGy cm; 110, 200, 220, 460 mGy cm; 130, 300, 380, 500 mGy cm. An optimization process should be initiated to reduce the spread in dose recorded in this study. A major element of this process should be the use of DRLs. The frequency of paediatrics CT examinations and the typical values of the related dose quantities (CTDIvol and DRLs) were surveyed in the ten Swiss centers performing paediatrics CT. Mean values averaged over the participating centers were calculated and the corresponding DRLs were established by multiplying the mean values by 1.25. This investigation revealed that 4,000–5,000 CT examinations are carried out on children in Switzerland, with an average of 453 per centre performing pediatric CT. Significant variations of the radiation dose delivered to the pediatric population were found. An optimization process should be initiated in order to reduce this spread in dose (appropriate image quality requirements for a given indication, number of acquisition that are clinically relevant, etc.). A major element of the optimization process is consensus on the DRLs that need to be used. This becomes a priority in the light of contributions such as described in a recent article published in the Lancet. A set of DRL values for CT examinations of the brain, the chest and the abdomen and for the various age groups are proposed here for temporary use in paediatrics until a more extensive survey is organized to collect dose data on a large sample of patients and to establish empirical dose distributions.

G Breiki et al 2008 Computed tomography (CT), is an X-ray procedure that generates high quality cross-sectional images of the body, and by comparison to other radiological diagnosis, CT is responsible for higher doses to patients. The aim of this work is to study the CT practice in some CT units indifferent hospitals in Egypt, in order to investigate the radiation doses imparted to patients during CT examinations and image quality. Dose measurements were performed for the most common applied CT examinations covering radiation sensitive organs in the head and trunkregions.Selected CT examinations are; routine head, routine chest, routineabdomen and routine pelvis. Computed Tomography Dose Index (CTDI) wwas calculated for each scanner from an average of three measurements in the head phantom and another three measurements in the body phantom. DLP values were estimated for each type

of examination. Mean values of CTDIw had a range of 36.0-69.0 mGy for head and11.0-30.0 mGy for chest, abdomen and pelvis examinations. Organ dose and hence effective dose, calculated using Monte Carlo simulation technique. The effects of selecting tube KV and mAs on both spatial resolution and low contrast detectability were examined for two groups of KV values (90 and 120), the mAs values were degraded from 100 to 300 mAs in 100 mAs interval in first case, and from 50 to 300mAs, in 50mAs interval in second case.

(Smith-Bindman, R., Lipson, J., Marcus, R., Kim, K.P., Mahesh, M., Gould, R., De González, A.B. and Miglioretti, D.L., 2009) Were reported Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer "Radiation doses varied significantly between the different types of CT studies. The overall median effective doses ranged from 2 mille sieverts (mSv) for a routine head CT scan to 31 mSv for a multiphase abdomen and pelvis CT scan. Within each type of CT study, effective dose varied significantly within and across institutions, with a mean 13-fold variation between the highest and lowest dose for each study type. The estimated number of CT scans that will lead to the development of a cancer varied widely depending on the specific type of CT examination and the patient's age and sex. An estimated 1 in 270 women who underwent CT coronary angiography at age 40 years will develop cancer from that CT scan (1 in 600 men), compared with an estimated 1 in 8100 women who had a routine head CT scan at the same age (1 in 11 080 men). For 20-year-old patients, the risks were approximately doubled, and for 60-year-old patients, they were approximately 50% lower."

Chapter Three

Materials and Methods

Chapter Three

Materials and Methods

3.1 Materials:

In this study the data were collected from the following radiological departments: (A)Alzytouna , (B) Ibn alhytham , (C) Modern Medical Center , (D) ALneileen Medical Diagnostic Center , and (E) Police hospital . The data of parameters used in CT procedures were taken during 2019 - 2020, .All quality control tests were performed to the machine prior any data collection .All the data were within acceptable range.

Table 3.1 demonstrates CT machines used in this study

Hospitals	No. of Slices	Manufacture	Detector type
(A)	16 Slices	Toshiba Aquilion	16 rows
(B)	16 Slices	Siemens	16 rows
(C)	16 Slices	GE Optima	16 rows
(D)	32 Slices	Siemens	32 row
(E)	16 and 128 Slices	Neusoft	16 and 128 rows

Table 3.2 Demonstrations the number of patient in the different multi detector.

Hospital	No. of slice	Brain	**Chest**	**Abdomen**	**Pelvis**	**Total**
(A)	16 Slices	**67**	**38**	**47**	**31**	**183**
(B)	16 Slices	**53**	**31**	**40**	**40**	**164**
(C)	16 Slices	**90**	**42**	**54**	**42**	**228**
(D)	32 Slices	**96**	**30**	**52**	**30**	**208**
(E)	16 and 128 Slices	**80**	**50**	**90**	**45**	**265**
Total		**386**	**191**	**283**	**188**	**1048**

3.2Place and time of study:

This study was performed at Radiology departments of Alzytouna , Ibn alhytham , Modern Medical Center , ALneileen Medical Diagnostic Center and Police hospital during the period from (2019 - 2020) .

3.3 Patient sample:

The sample of this study for the patient who scanned by CT machine to exam Brain (386) , Chest (191) , Abdomen (283) , Pelvis (188) .

3.4Methods:

For a given patient and a constant x-ray tube potential, the value of the effective dose from brain, chest, abdominal and pelvis CT examination depends on the tube current (in milliamperes), the scanning time(in seconds), the section thickness (T), and the total number of sections (N). These four factors were obtained for 1048 randomly selected patient's underwn tCT examinations on CT scanners (ToshibaAquilion 16 slices,2 Siemens machine (16 – 32) slices, 2 neusoft machine (16 – 128) slices and GE optima 16 slices).

3.5 CT dose measurements:

Radiation dose indicators CTDIvol and DLP where can be obtained from a dose summary page, which includes information about the CT exam. CTDIvoldoes allow the comparison of scan protocols or scanners andis useful for obtaining benchmark data to compare techniques, but it's not so good for estimating patient dose (Castronoovo FP. 1993).

DLP, an indicator of the dose imparted to the patient, is calculated by multiplying CTDI*vol*timesthescan length. In addition to being affected by the issues associated with CTDIvol, DLP can be problematic in a limited scan range (Ridely 2012).

3.6 Calculation of Effective Dose

CT scanners record the radiation exposure as DLP in mGy.cm. The determination of external exposure to the patient is basically from the CT scan that generates the x-ray. As referred to ICRP publication 102 ((ICRP 2007)) , external exposure will determine using the CT Dose Index (CTDI) and Dose Length Product (DLP) value which can have obtained direct from screen computer scan. The effective dose, E fore external exposure was then calculated according to equation (ICRP 2007) , E= k × DLP Where k is coefficient based on empirical weighting factor, which functional of the anatomical region scanned (mSv.mGy-1.cm-1) in ICRP 102 and (ICRP 2007) .

K = 0.015 for turn

3.7 Data Analysis :

The data were analyzed using Microsoft Office (Excel 2019) and statistical package for social science (spss) version 21.

Chapter Four

Results

Chapter Four

Results

4.1 Results

Table 4.1 show frequency of gender according to the CT exam:

Gender	*Brain*	*Chest*	*Abdomen*	*Pelvis*	*Total*
Male	233	121	163	102	619
Female	153	70	120	86	429
Total	386	191	283	188	1048

Table 4.2 show demographic information for all patients by gender and exams:

Exam	*Gender*	*Age years*	*High cm*	*Weight kg*
Brain	***Male***	8.7± 5.5 1-18	119.9±38.7 15-188	30.35±19.2 3-80
	Female	9.2±5.6 1-18	121.7±37.2 20-170	31.2±17.8 5-73
Chest	***Male***	10.8±6.8 1-18	135.15±40.9 53-180	42.5±28.98 5-152
	Female	10.33±6.5 1-18	129.5±35.8 55-185	34.8±20.2 6-73
Abdomen	***Male***	9.6±6 1-18	129.1±54.9 36-618	35.29±24.82 3-160
	Female	11.24±5.9 1-18	133.8±34.1 34-180	37.2±19.3 6-75
Pelvis	***Male***	10.37±6.4 1-18	130.18±38.7 60-185	38.15±24.6 8-76
	Female	11.4±6.2	135.3±35.5	38±20.18

		1-18	15-178	7-74

Table 4.3 show statistical parameters for radiographic information in Alzytouna:

Exam	***kV***	***mA***	***CTDIvol***	***DLP***	***ED***
Brain	119.10±4.17 100-120	142.84±81.35 48-721	82±19.87 26.1-93.3	1387.31±432.49 487.4-2795.1	2.91±0.9 1-5.87
Chest	118.95±4.53 100-120	187.63±107.69 18-544	8.56±5.87 2.6-31.3	280±211.48 35.1-1193.4	3.92±2.96 0.49-16.71
Abdomen	118.72±6.47 80-120	168.1±92.61 22-300	5.62±3.75 1.3-20.9	210.89±152.67 1.7-889.5	3.16±2.29 0.03-13.34
Pelvis	120±0.0	157.61±98.15 22-300	4.91±3.3 1.3-20.9	154.75±71.68 1.7-200.4	2.32±1.08 0.03-4.51

Table 4.4 show statistical parameters for radiographic information in Ibn alhytham:

Exam	***kV***	***mA***	***CTDIvol***	***DLP***	***ED***
Brain	121.13±10.86 100-130	182.94±60.58 29-267	31.86±13.24 1.9-52.4	565.48±280.37 19.1-1053.4	1.19±0.59 0.04-2.21
Chest	119.03±10.12 110-130	32.03±4.3 24-34	3.23±1.43 1-6.2	62.95±20.79 40.1-145.6	0.88±0.29 0.56-2.04
Abdomen	120.5±10.12 110-130	40.35±13.79 24-82	3.86±1.61 1-8.1	112.73±80.84 48.1-426.3	1.69±1.21 0.72-6.39

Pelvis	120.5±10.12 110-130	40.35±13.79 24-82	3.86±1.61 1-8.1	112.73±80.84 48.1-426.3	1.69±1.21 0.72-6.39

Table 4.5 show statistical parameters for radiographic information in Modern Medical Center:

Exam	***kV***	***mA***	***CTDIvol***	***DLP***	***ED***
Brain	120±0.0	151.1±44.25 40-280	37.89±12.42 13.8-99.5	649.93±336.38 42.1-2449.2	1.36±0.71 0.09-5.14
Chest	120±0.0	110.96±42.91 48-220	7.37±5.33 4-38	241.61±122.93 67.3-544.7	3.38±1.72 0.94-7.63
Abdomen	120±0.0	98.43±45.77 32-272	7.19±6.7 3-49	298.49±208.69 73.3-1416.3	4.48±3.13 1.1-21.24
Pelvis	120±0.0	108.97±57.26 19-250	7.87±6.97 3-40	268.9±176.29 73.3-837.4	4.03±2.64 1.1-12.56

Table 4.6 show statistical parameters for radiographic information in Neileen Medical Diagnostic Center:

Exam	***kV***	***mA***	***CTDIvol***	***DLP***	***ED***
Brain	120.63±10.03 110-130	144.03±61.83 11-323	31.29±46.02 1.6-467.9	397.64±238.69 7.4-1351.5	0.84±0.5 0.02-2.84
Chest	120±10.17 110-130	42.37±27.23 17-114	2.85±1.33 0.6-7.1	85.09±56.9 10.9-228.5	1.19±0.79 0.15-3.20
Abdomen	122.88±11.09 80-130	42.08±23.23 19-120	3.56±1.59 0.9-11	126.39±75.99 29.3-467	1.89±1.14 0.44-7.01

Pelvis	119.67±9.64 110-130	40.07±24.68 15-113	3.87±2.75 1.1-12	127.05±126.62 1.3-578.5	1.91±1.89 0.02-8.68

Table 4.7 show statistical parameters for radiographic information in Police hospital :

Exam	***kV***	***mA***	***CTDIvol***	***DLP***	***ED***
Brain	120±0.0	475.26±52.43 150-490	72.99±8.42 18.6-76.7	1710.17±485.6 220.9-3049.3	3.59±1.02 0.46-6.40
Chest	120±0.0	188.86±55.46 62-339	13.35±5.82 3.8-27.2	471.27±241.27 120.8-1205.9	6.59±3.38 1.69-16.88
Abdomen	118±7.53 90-120	257.68±110.6 41-360	18.04±9.98 2.6-27.6	771.1±471 83-1508.9	11.57±7.07 1.24-22.63
Pelvis	119.33±4.47 90-120	330.10±118.72 41-490	35.93±26.33 2.6-75.2	1467.1±1220.47 83-4548.7	22±18.31 1.24-68.23

Table 4.8 show statistical parameters of effective dose for all patients:

Exam	***Gender***	***Mean***	***STD***	***Median***	***Min***	***Max***	***3d Quartile***
Brain	***Male***	1.98	1.37	1.42	0.11	6.40	3.28
	Female	1.87	1.26	1.36	0.02	5.14	2.99

Chest	***Male***	3.57	2.84	2.89	0.37	11.49	4.76
	Female	3.59	3.64	2.60	0.15	16.88	4.39
Abdomen	***Male***	5.25	5.79	2.70	0.03	22.63	6.52
	Female	6.13	6.26	3.34	0.59	21.71	6.48
Pelvis	***Male***	8.04	14.11	2.40	0.02	68.23	7.04
	Female	6.23	9.73	2.93	0.02	52.23	6.53

Table 4.9show comparison of effective dose for all hospitals per exam:

Hospital	***Brain***	***Chest***	***Abdomen***	***Pelvis***
A	***2.91***	***3.92***	***3.16***	***2.32***
B	***1.19***	***0.88***	***1.69***	***1.69***
C	***1.36***	***3.38***	***4.48***	***4.03***
D	***0.84***	***1.19***	***1.89***	***1.91***
E	***3.59***	***6.59***	***11.57***	***22***

Where :

(A) = Alzytouna , (B) = Ibn alhytham , (C) = Modern Medical Center ,

(B) = (D) ALneileen Medical Diagnostic Center , and (E) = Police hospital .

Chapter Five

Discussion, Conclusion andRecommendations

Chapter Five

Discussion, Conclusion and Recommendations

5.1Discussion:

An overview of patient information and scan parameters used for Computed Tomography CT At five different hospitals in Khartoum state – Sudan, is presented, the gender distributed according to selected CT scan were the total number of patients was 1048 patients, approximately 45% of the patient for brain , 22% for chest , 10% for abdomen and 21% for
pelvis CT with total number of male and female 619 and 429 respectively. CT examinations in pediatric patients have contributed greatly to the diagnosis of different diseases; however, the radiation exposure to the patient is significantly higher compared with other radiologic examinations. An overview of patient information and scan parameters used for Computed Tomography CT At five different hospitals in Khartoum state – Sudan, is presented Table (4.1) show the gender distributed according to selected CT scan were the total number of patients was 1048 patients, approximately 45% of the patient for brain (386; 233 males and 153 female), about 22% for chest (191; 121 males and 70 female), about 10% for CT abdomen (283; 163 males and 120 female) and 21% for pelvis CT (188; 102 males and 86 female) with total number of male and female 619 and 429 respectively. Mean and standard deviation, Maximum and minimum, of demographic information for all patients age years, weight kg and high cm, and for male and female patients separately Shown in table (4. 2) . Tables (4.3) , (4.4) , (4.5) , (4.6) and (4.7) Show radiation dose parameters tube voltage (kV), tube current –time (mAs), CTDIvol (mGy), DLP (mGy.cm) and effective dose per mSv for all patients to all departments and for male and female patients separately.

The effective dose consider the important unit of patients dose, here we present the statistical parameters for effective dose shown as mean, median, standard

deviation, minimum, maximum and third quartile for all patients and for male and female patients separately in table (4.8) ,The effective dose found 1.93 mSv for brain (1.98 mSv for male and 1.87 mSv for female), in CT Chest the effective dose was 3.58 mSv (3.57 mSv for male and 3.59 mSv for female), for abdomen was 5.69 mSv (5.25 mSv for male and 6.13 mSv for female) and for pelvis the E found 7.14 mSv (8.04 mSv for male and 6.23 mSv for female).

5.2Conclusion:-

Estimation of radiation effective dose for pediatric from CT procedures, in five main hospitals in Khartoum state-Sudan, total number of patients included in this study were 1048 patients (1 – 18) years , the effective dose was slightly variety for patients according to gender and patient's age, Different technician's habits and lack of training among hospital staff responsible from these variations. Dose estimation for patients according to gender has been found. The effective dose found 1.93 mSv for brain (1.98 mSv for male and 1.87 mSv for female), in CT Chest the effective dose was 3.58 mSv (3.57 mSv for male and 3.59 mSv for female), for abdomen was 5.69 mSv (5.25 mSv for male and 6.13 mSv for female) and for pelvis the E found 7.14 mSv (8.04 mSv for male and 6.23 mSv for female). The main contributor for this difference between the hospitals because the use of a larger scan length due to lack of proper training to CT operators in Sudan.

5.3Recommendations:

- The large observable variation of effective dose among hospitals and relatively high effective dose in Sudan hospitals call for the need to optimize CT protocols.
- Regular and continuous training for the technologists who works in CT departments.
- To achieve optimal radiation dose of patient that will needed to use optimization techniques and best training for technologist.
- Future studies must use correlation between effective dose and age , effective dose and wieght

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Appendix:

Sample of data collection sheet:

Gender	Age	Weight	High	Exam	KV	mAs	$CTDI_{VOL}$	DLP