Sudan University of Science and Technology

College of Graduate Studies

Assessment of Radiation Dose During Computed Tomography for Brain

تقيم الجرعة الاشعاعية للدماغ في التصوير المقطعي

A Thesis Submitted for Partial Fulfillment of the Requirement of

M. Sc. Degree in Medical Physics

By:

Faiza Ali Dinar Mohammadein mahmoud

Supervisor:

Dr. Hussein Ahmed Hassan

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الآيه

قولة عزّ وجلَّ:

{وَإِذْ تَأَذَّنَ رَبُّكُمْ لَئِنْ شَكَرْتُمْ لَأَزِيدَنَّكُمْ..}

سورة إبراهيم

[آية 7]

Dedication

This thesis is dedicated to:

My great parents..

My beloved brothers and sisters..

My family.

My friends..

For all this people

I dedicate this research.

Acknowledgment

First and foremost, I must acknowledge my limitless thanks to Allah, the Ever-Magnificen, the Ever-Thankful, for His help and bless.

I am totally sure that this work would have never become truth, without his guidance.

I owe a deep debt of gratitude and grateful to my father Dr. Ali Dinar Mohammadein Mahmoud who worked hard with me from the beginning till the completion of the research he has been always generous during all my life..

And take this opportunity to say warm thanks to my beloved mother Jwaher Ahmed Abass, and express my whole hearted thanks to her..

For their generous support they provided me throughout my entire life and particularly through the process of pursuing the master degree.

Because of their unconditional love and prayers, I have this chance to complete this thesis.

And particularly I highly appreciate the efforts expended by my supervisor Dr. Hussein Ahmed Hassan without their support, this Study would not have been possible.

Researcher.

Abstract

The purpose of this study to assessment radiation dose of CT scanner on brain by calculate effective dose, then to confirm is there any difference between effective dose of male brain and female brain according to differences at anatomical structure of male brain and female brain, and to determine typical parameter that help to reduce overdose.

This study performed in Modern Medical Center, the study showed amount of average effective dose (1.26756±0.2mSv) and it's not equal or above than standard effective dose of brain (2mSv) that recommended by ICRP. Also there is no any difference between effective dose of male brain and female brain according to differences at anatomical structure of brain. The typical parameter of (Kvp and mAs) is (120Kvp) and (60-100mAs) for adult and pediatric.

المستخلص:

الغرض من هذه الدراسة هو تقييم الجرعة الاشعاعية للأشعة المقطعية علي المخ وذلك بحساب الجرعة المؤثرة، أيضاً للتاكد ما إذا كان هنالك اختلاف في الجرعة المؤثرة بين الرجل والمرأة بناءاً علي هذه الاختلافات التشريحية في تركيب المخ بين الذكر والأنثي، وأيضا تحديد نموذج معلمي للتقليل من الجرعة الاشعاعية علي المريض .

في هذه الدراسة التي تم اجراءها في المركز الطبي الحديث اتضح جليا أن الجرعة الاشعاعية ليست لها أي خطورة علي المريض وذلك بعد أن وجد أن قيمة الجرعة المؤثرة (1.26756±0.2mSv) غير مساوية أو زائدة عن القيمة المعيارية للجرعة المؤثرة الموصي بها من ICRP التي تساوي، (2mSv) وأيضاً ثبت أنه لايوجد اختلاف في الجرعة المؤثره بين الذكر والأنثي بناءاً علي الاختلافات في التركيب التشريحي للمخ لكل من الذكر والأنثي، كما تم تحديد نموذج معلمي وهو علي النحو الآتي: (kv120) و (60-100mAs) وذلك للكبار والصغار معاً.

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Abbreviations

CT	Computed Tomography
CAT	Computed Axial Tomography
C	speed of light, coloum
E	Energy of photon
h	Plank constant
f,v	Frequency of photon
λ	Wavelength
Gy	Gray unit of absorbed dose
J	Joule unit of energy
W_R	Radiation Weighting Factor
Sv	Sievert unit of equivalent dose, effective dose
Rad	Unit of absorbed dose
KeV	Kelo electron Volt
Mev	Mega electron Volt
R	Roentgen
KERMA	Kinetic Energy Release in Medium
dE_{tr}	Energy transfer into matter
dm	Mass of matter
Kg	Kilogram
BEIR	Biological Effects of Ionizing Radiation
ALARA	As Low As Reasonable Achievable
MRI	Magnetic Resonance Intensity
ACR	American College of Radiology
DLP	Dose Length Product
$CTDI_{vol}$	CT Dose Index volume
MDCT	Multi Detector CT scanners

BMI   Body Mass Index

ATCM   Automatic Tube Current Modulation

SIE   Surface Integral Exposure

DAP   Dose Area Product

GE   General Electric

ICRP   International Commission of Radiation Protection

Chapter One

Introduction

1.1. Introduction:

X-ray computed tomography, also computed tomography (CT scan), computed axial tomography (CAT scan) or computer assisted tomography is a medical imaging procedure that uses computer-processed X-rays to produce tomographic images or 'slices' of specific areas of the body. These cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines (Merriam-Webster on line dictionary). Digital geometry processing is used to generate a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation (Hermam, G. T. 2009).

Figure (1.1):shows computed tomography instrument

One of the most important functions of a computed tomography (CT) system is to reproduce a three dimensional structure and represent that structure as an accurate two-dimensional cross-section on a television monitor. There are several characteristics that effect how well a CT system performs this task. Spatial resolution, contrast resolution, linearity, noise and artifacts are the primary characteristics that effect image quality in CT (Will Reddinger, 1998).

Enhancing or suppressing any of these characteristics depends upon the imaging interests and the region of the body being scanned.

The radiation dose reported in the gray or mGy unit is proportional to the amount of energy that the irradiated body part is expected to absorb, and the physical effect (such as DNA double strand breaks) on the cells' chemical bonds by x-ray radiation is proportional to that energy (Polo SE, Jackson SP (March, 2011).

The sievert unit is used in the report of the effective dose. The sievert unit in the context of CT scans, does not correspond to the actual radiation dose that the scanned body part absorbs, but rather to another radiation dose of another scenario, in which the whole body absorbs the other radiation dose, and where the other radiation dose is of a magnitude that is estimated to have the same probability to induce cancer as the CT scan (Report of AAPM task group 23 (January, 2008)). Thus, the actual radiation that is absorbed by a scanned body part is often much larger than the effective dose suggests. A specific measure, termed the computed tomography dose index (CTDI), is commonly used as an estimate of the radiation absorbed dose for tissue within the scan region, and is automatically computed by medical CT scanners.

The equivalent dose is the effective dose of a case, in which the whole body would actually absorb the same radiation dose, and the sievert unit is used in its report. In the case of non-uniform radiation, or radiation given to only part of the body, which is common for CT examinations, using the local equivalent dose alone would overstate the biological risks to the entire organism.

The brain is one if this part consist of fore brain, mid brain and hind brain. The fore brain is composed of cerebrum (the tow cerebral hemispheres, each with cavity and lateral ventricle) and a deeper central portion. The diencephalon, whose main parts are the thalamus and hypothalamus, and

whose cavity is the third ventricle. The midbrain is small region whose cavity is adequate and which connect fore brain with hind brain, consisting of (the pons, medulla oblongata and cerebellum) and whose cavity is the fourth ventricle (Chummy, 1999).

The mid brain (pons and medulla) collectively from the brainstem. All parts of the brain are contained within the cranial cavity. The medulla passes through foramen magnum of the skull and changes it is name to spinal cord has central canal (Chummy, 1999).

1.2. Problem of the study:

Patient and staff exposed to high dose of CT radiation.

1. 3. Rational and importance of this study:

Optimization parameters to reduce patient and staff dose, also to optimize image quality and to avoid repetition projection.

1.4. Objective:

1.4.1. General objective:

To assess CT radiation dose on brain of male and female.

1.4.2. Specific objective:

●To estimate effective dose of CT projection.

●To compare effective dose on brain of male and female according to main differences at brain anatomical structure of male and female

1.5 Duration of research:

Six months.

1.6. Area of study:

Modern medical center.

Chapter Tow

Literature Review

2.1. Literature review

2.1.1. The discovery of a new kind of Ray:

About 120 years ago an event took place in Germany which was to have a dramatic effect on science and particularly in the field of medicine. On the evening of 8th November 1895 a physicist named Wilhelm Roentgen discovered radiation which passes through matter. (D. R. Hill, 1975) Roentgen's [new kind of ray] he called x-ray for the unknown. With these new rays he made a photograph of his wife's hand showing the bones and wedding ring. The exposure time require was some 30 minutes (D. R. Hill, 1975).

At the first public lecture by Roentgen on January 25th 1896, Professor Albert Von Kolliker proposed that [this new rays not be called x-rays] as Roentgen continued to name them throughout his life, [but should be named Roentgen rays in honour of the discover]. Both forms of nomenclature persist today. However, the accepted international unit of x-ray quantity become the Roentgen on in 1925(D. R. Hill, 1975).

2.1.2. Cathode Rays:

In 1837 Michael Faraday carried out research studies on the luminous effect produced by passing electric current through various gases. In 1838 he produce a discharge of electricity through space in partially evacuated glass tube. Such glass tubes were product by Heinrich Geissler (D. R. Hill,1975).

The observations of faraday led Wilhelm Hittor, in 1869, to describe (cathode rays) and the passage of electricity in a vacuum tube. Pluker had already noticed that objects placed between the negative electrode [cathode] and the glass wall would cast shadows on the glass wall. Plucker and Hittorf therefore announced that [cathode rays move straight from the negative electrode] (D. R. Hill, 1975).

2.1.3. The nature of cathode rays:

It was known that cathode rays were deflected by magnetic fields, produced thermal and mechanical effect on materials on their path and induced phosphorescence in certain materials (D. R. Hill,1975).

2.1.4. The nature of x-rays:

Roentgen, working on a wave theory, questioned whether the new rays [x-rays] should be ascribed to vibration in ether. Schuster was inclined to postulate that they were of a very short wavelength and that the radiation being produced, was most likely, not homogenous (D. R. Hill, 1975). Thomson showed that longitudinal waves might exist in a medium containing moving ions, [charged atomic residues]. He also commented that "transverse waves would not be refracted " and thus agreed with Schuster. Thomson was able to report on February 15th 1896 that the discharging effect of x-rays was not the same as that of ultraviolet light which had previously been observed. He wrote "…this, again, is in favour [of the theory] that these rays turn air into an electrolyte " consequently the ionization of air by x-ray was established. This principle will be met in the description of ionization champers for the measurement of x-ray intensity and radiographic exposure control (D. R. Hill, 1975).

2.1.5. The difference between x-ray and cathode rays:

Thomson and his pupil Rutherford reported on September 17th that {when a current is passing through a gas exposed to x-rays, the current destroys and the rays produce the structure which gives conductivity to the gas}. Schuster's first reaction on the nature of cathode rays was that they were corpuscular and he suggested that x-rays were produced {by an impact} on the wall of the tube. However, L. enard, eight months later was still opposed to the corpuscular theory, and the identification of the cathode

rays as stream of electrons was not proposed for another years (D. R. Hill,1975).

2.1.6. Energy:

In physics energy is property of objects which can be transferred to other objects or converted to different forms, but cannot be created or destroyed. The common description for energy is {ability of a system to perform work}, but it is difficult to give one single comprehensive definition of energy because of it has many forms. For instance in SI units stander international units energy is measured in joules and one joule is defined mechanically being the energy transferred to an object by the mechanical work of moving it a distance of 1 meter against a force of 1 Newton, however, there are many other definitions of energy depending on the context such as thermal energy, radiant energy, electromagnetic, nuclear,. etc where definitions are derived that are the most convenient (Wikipedia Atom Feed).

2.1.6.1. Common energy forms:

● **Kinetic energy** of a moving object.

● **Radiant energy** carried by light.

● **Potential energy** stored by an object's position on a force field [gravitational, electric or magnetic].

● **Elastic energy** stored by stretching solid objects.

● **Chemical energy** released when a fuel burns.

● **Thermal energy** due to an object's temperature.

All of the many forms of energy are convertible to other kinds of energy, and obey the low of conservation of energy which says that energy can be neither created nor be destroyed, however, it can change from one form to another (Wikipedia Atom Feed).

2.1.6.2. Process of energy transfer:

Photon energy is transferred to matter in tow step process. First,energy is transferred to charged particle in the medium through various photon interaction [ex. Photoelectric effect, Compton scattering, pair production, and photodisintegration]. Next, these secondary charged particles transferred their energy to the medium through atomic excitation and ionizations (Podgorsak, 2005).

For low energy photons, Kerma, is numerically approximately the same as absorbed dose. For higher energy photons kerma is larger than absorbed dose because some highly energetic secondary electrons and x-rays escape from the region of interest before depositing their energy. The escaping energy is counted in kerma but not in absorbed dose. For low energy x-rays, this is usually negligible distinction. This can be understood when one looks at the components of kerma (Podgorsak, 2005).

2.1.7. Photons:

Photons [from Greek meaning light], in many atomic models in physics are particles which transmit light. In other words, light is carried over space by photons. Photon is elementary particles that it is own antiparticle. In quantum mechanics each photon has characteristic quantum of energy Photons have a rest mass of zero. However, Einstein's theory of relativity says that they do have a certain amount of momentum. Before the photon got its name Einstein revived the proposal that light consist of separate pieces of energy [particles]. These particle com to be known as photons (Wikipedia Atom Feed).

2.1.7.1. Properties of photon:

Photon are fundamental particles although they can be created and destroyed, their life time is infinite.

In a vacuum all photon moves at the speed of light [c] which is equal to [299,792,458m/s] [approximately 300000km/s].

A photon has a given frequency which determines it is color. Radio technology makes great use of frequency. Beyond the visible range frequency is less discussed, for example it is little used in distinguishing between x-ray photons and infrared. Frequency is equivalent to the quantum energy of the photon, as related by the Planck constant equation (E=hf).

Another property of a photon is its wavelength. The frequency (v) wavelength (λ) and speed of light (c) are related by the equation (C= vλ) Wavelength is used in many types of technology (Wikipedia Atom Feed).

2.1.7.2. Type of photon interaction with matter:

2.1.7.2.1. Photoelectric effect:

The Photoelectric effect is the observation that many metals emits electrons when light shines upon them. Electron emitted in this manner can be called photoelectrons. The phenomenon is commonly studied on electronic physics, as well as in field of chemistry, such as quantum chemistry or electrochemistry (Hufner, 2003).

2.1.7.2.2. Compton scattering:

The Compton scattering is inelastic scattering of a photon by a charged particle which usually an electron. It results in a decrease in energy of a photon {which many be x-ray or gamma ray photons} called Compton Effect. Part of the energy of the photon is transferred to the recoiling electron. Inverse Compton scattering exists, in which a charged particle transfer's part of it is energy to a photon (Comphausen, 2008).

2.1.7.2.3. Pair production:

Pair production is the creation of an elementary particle and it is antiparticle, for example creating an electron and positron, a muon and antimuon or proton and antiproton. Pair production often refers specifically a photon creating an electron –positron pair near a nucleus but can more generally refer to any neotral boson creating a particle – antiparticle pair. In order for pair production to occur, the incoming energy of the interaction must be above a threshold in order to create the pair-at least the total rest mass energy of the tow particle -and that the situation allows both energy and momentum to be conserved. However, all other conserved quantum numbers of the produced particles must sum to zero –thus the created particle shall have opposite values of each other. {ex: if one particle has electric charge of (+1)the other must have electric charge of (-1)}(Zdenka, 2013).

2.1.7.2.4. Photodisintegration:

(Also called photo transmutation) is a physical process in which an extremely high energy gamma ray is absorbed by an atomic nucleus and causes it to enter an excited state, which immediately decays by emitting a subatomic particle, A single proton, neutron or alpha particle is effectively knocked out of the nucleus by incoming gamma ray (Ahmed, 2007).

2.1.7.2.5. Coherent scattering:

 In this type the photon doesn't have enough energy to break bound state so no energy transfer occurs. The only change is change of direction of the photon. Coherent scattering is not a major interaction process encountered in radiography at the energies normally used (Radiopedia. Org).

2.1.8. Radiation dose quantities:

When ionizing radiation penetrates the human body or an object, is deposits energy. The energy absorbed from exposure to radiation is called a dose. Radiation dose quantities are absorbed, equivalent and effective (Wikipedia Atom Feed).

2.1.8.1. Absorbed dose:

The amount of energy deposited in substance (e. g. human tissue) is called the absorbed dose. The absorbed dose is measured in a unit called gray (Gy). A dose of one gray is equivalent to a unit of energy (joule) deposited in kilogram of substance (Wikipedia Atom Feed).

2.1.8.2. Equivalent dose:

When radiation is absorbed in living matter a biological effect may observed, however, equal absorbed doses will not necessarily produce equal biological effects. The effects depends on the type of radiation (e. g. alpha, beta, gamma …etc.) and the tissue or organ receiving the radiation. For example, 1Gy of alpha radiation is more harmful to tissue than 1Gy of beta radiation (Wikipedia Atom Feed).

A radiation weighting factor (WR) is used to equate different types of radiation with different biological effectiveness. This weighted absorbed quantity is called equivalent dose and is expressed in a measure called the seivert (Sv). The means that 1Sv of alpha radiation will have the same biological effect as 1Sv of beta radiation (Wikipedia Atom Feed).

2.1.8.3. Effective dose:

Different tissue and organs have different radiation sensitivities. For example, bone marrow is much more radiosensitive than muscle or nerve tissue. To obtain an indication of how exposure can affect overall health, the equivalent dose can be multiplied by a factor related to the risk for a particular tissue or organ. This multiplication provides the effective dose

absorbed by the body, the unit of effective dose seivert (Wikipedia Atom Feed).

2.1.9. Radiation unit:

When ionizing radiation interacts with the human body, it gives it is energy to the body tissues. The amount of energy absorbed per unit weight of the organ or tissue is called absorbed dose and it express in unit of gray (Gy). One gray dose is equivalent to one joule radiation energy absorbed per kilogram of organ and tissue weight. Ad is old and still used unit of absorbed dose. One gray is equivalent to 100 rads. 1Gy =100 rads (Vance, 2007).

Equal doses of all type of ionizing radiation are not equal harmful. Alpha particles produce greater harm than do beta particles, gamma rays and x-rays for a given absorbed dose. To account for this difference, radiation dose is expressed as equivalent dose in units of seivert (Sv). The dose in (Sv) is equal to (absorbed dose) multiplied by a (radiation weighting factor) WR. (Vance, 2007).

Table (2.1): Shows recommended radiation weighting factors

Type and energy rang	WR
Gamma rays and x-rays	1
Beta particles	1
Neutrons energy	
<10 kev	5
10kev to 100 kev	10
100kev to 2Mev	20
2Mev to 20Mev	10
>20Mev	5
Alpha particles	20

1Sv = 100 rem

1rem = 10 mSv

1 Gy air dose equivalent to 0. 7 Sv tissue dose.

1R (Rontgen) exposure is approximately equivalent to 10mSv tissue dose (Vance, 2007).

2.1.9.1. Air Kerma:

Kerma is an acronym for {kinetic energy released per unit mass} defined as the sum of initial kinetic energies of all the charged particles librated by uncharged ionizing radiation {indirect ionizing radiation such as photons and neutrons} in a sample of matter divided by the mass of sample (Podgardsak. E. B, 2005).

It is defined by the equation:

K=dEtr/dm

Where:

K is kerma, dEtr is energy transferred into the matter, dm is mass of matter.

The SI unit of kerma is the gray (Gy) or (j/kg), the same as the unit of absorbed dose. However, kerma dose is different from absorbed dose according to energies involved, partially because ionization energy is not accounted for. While roughly equal at low energies, kerma is much higher than absorbed dose at higher energies because some energy escapes from the absorbing medium in the form bremsstrahlung (x-rays) or fast moving electrons. (Podgardsak. E. B. 2005).

The word kerma can also be an acronym for kinetic energy released in material or kinetic energy released in matter (Podgardsak. E. B,2005).

2.1.10. Radiation exposure:

Exposure is measure of ionization air by ionizing radiation from photon, that gamma rays or x-rays. It defined to be the electric charge freed by the radiation divided by the mass of the air. As a measure of radiation damage it is less useful than the analogous concept of the absorbed dose never the less since exposure is convenient to measure directly in gaseous ionization detectors and since it is easely converted to dose,it is commonly used in the nuclear industry (Wikipedia Atom Feed). The (SI) unit of the exposure is (C/kg), however, the Rontgen is commonly used internationally in the nuclear industry. There are approximately 3876 Rontgen in (1C/kg) (Wikipedia Atom Feed). **1C/kg=3876 R.**

2.1.11. Radiation protection:

Radiation protection, sometimes known as radiological protection is the science and practice protecting people and environment from the harmful effect of ionizing radiation. Ionizing radiation is widely used in industry and medicine, and can present a significant health hazard. It causes micropic damage to living tissue, which can result in skin burns and radiation sickness at high exposures known as {tissue effects }and statistically elevated risks of cancer at low exposures (stochastic effects) (Wikipedia   Atom   Feed). Fundamental to radiation protection is the reduction of expected dose and the measurement of human dose uptake. For radiation protection dosimetry assessment the international committee on radiation protection (ICRP) and international committee on radiation unit (ICRU) have published recommendations and data which is used to calculate the biological effects on the human body, set regulatory and guidance limits(Wikipedia Atom Feed (Wikipedia Atom Feed).

2.1.11.1. Protection groups:

Radiation protection can be divided into occupational radiation protection which is the protection of workers, medical radiation protection which is the protection of patients, and public radiation protection which is the protection of individual members of public and of the population as a whole. The types of exposure as well as government regulations and legal exposure limits are different for each of these groubs, so they must be considered separately (Wikipedia Atom Feed).

2.1.12. CT radiation dose:

Radiologists will likely be increasingly confronted with clinical question related to CT radiation exposure. Since the early 1990s, use of diagnostic CT in the United States has risen nearly 20-fold. One accounting for 20%of the overall per capita effective radiation dose [ERD], medical imaging now accounts for more than 50% of radiation exposure in the united states,half of which is related to CT scanning. The rapid availability of CT, along with its diagnostic accuracy, has led to dramatically increased used in acute care. Early diseases detection, reduction in mean hospitalizations, and lowered health care costs have all been attributed to greater use of CT. With the current expansion of CT in medical practice, an increased understanding of cancer risks and strategies for reducing radiation does is most importance (E. Costello, 2013).

The committee to Assess Health Risks from Exposure to low level of ionizing Radiation, in its Biologic Effects of Ionizing Radiation (BEIR) report listed its preferred estimates of lifetime incidence and mortality for all solid cancers and for leukemia. Excluding leukemia, and assuming approximately equal numbers of male and female individuals in the population. (BEIR) predicted that 19800 of every 100000 individuals who

have not been exposed to ionizing radiation will die by cancer (E. C ostello, 2013).

2.1.13. Estimate effective dose in CT scan:

Calculated effective dose in CT is, at best, a rough estimate due to many factors, such as variations on patient size and limitations of dose measurement and calculation method. Consequently, the effective dose are based on published CT dose data adjusted for irradiated length, patient age, tube current reduction recommended by Image Gently and effective dose per dose length product (DLP) (E. costello, 2013).

Table (2.2): Shows average radiation dose for typical adult CT examinations.

CT examination	(mSv)average effective dose	Values reported in literature (mSv)
Head	2	0. 9 4. 0
Chest	7	4. 0 18. 0
Chest for pulmonary embolism	15	13. 0 40. 0
Abdomen	8	3. 5 25. 0
Pelvis	6	3. 3 10. 0
Spine	6	1. 5 10. 0

2.1.14. Dose reduction strategies:

To avoid unnecessary radiation exposure, the as low as reasonable achievable {ALARA} principle should always be applied. CT should be ordered only when the result are expected to affect patient care. Nonionizing alternatives, such as ultrasound and MRI, must also be considered. The ACR Appropriateness Criteria are specific evidence based recommendation for assisting providers in making the most

appropriate imaging decision based on the given clinical situation. After application of ACR appropriateness criteria to identify CT as the best clinical approach, the best measures that can be implemented to optimize Effective Radiation Dose [ERD] involve decreasing tube potential, automatic current modulation and CT. Post processing (E. Costello, 2013).

2.1.15. CTDI and DLP:

Specification of the amount of radiation in CT examinations is based on unique dose metric, which is measured in a cylindrical arylic phantom placed at the scanner isocenter. The CTDI is obtained by using a 100mm long pencil- shaped ionization chamber is one of two phantom sizes [16cm or 32cm in diameter]. Most manufactured use 16cm phantom to calculate CTDI for head examinations and 32cm phantom to calculate CTDI for body examinations (Mettler, 2011).

The CTDIvol specifies the radiation intensity used to perform a specific CT examination and is the metric used by American college of radiology [ACR] for CT practice accreditation. For identical radiographic techniques, CTDIvol values differ by about a factor of tow. During the past 20 years, the CTDIvol has increased ≈50% for the head phantom and ≈ 90% for the body phantom. Variation in CTDI with identical radiographic techniques result from differences in x-ray tube design, tube filtration and beam shaping filters (Mettler, 2011). In CT, the total amount of radiation incident on the patient, known as DLP, is the product of CTDIvol and scan length in cm and is measure in (mGy. cm). The DLP is the second dose metric that is easily accessible to radiologist and accounts for both radiation intensity and scan length in the CT examination. DLP data, there for indicate the amount of radiation

used there to perform the CT examination and are quantified in a cylindrical of specified size (Mattler, 2011).

2.1.16. Basic CT parameters:

Key CT parameters with which staff should be familiar include scan length and helical pitch. Scan length seems readily apparent and is often overlooked in a busy clinical setting; however, it is effect on patient dose can be significant. Campbell found that nearly 100%of chest CT examination performed over 2-week period at a large medical institution included additional supraopical and intrapulmonary images that were not clinically important and leading to unnecessary radiation exposure. Protocols must include the minimum body length needed to derive an accurate diagnosis, a concept that should be routinely discussed with technologist. Helical pitch is defined as the ratio of table feed per gantry rotation to the width of x-ray beam. Increases in table speed or beam collimation result in higher helical pitch, which reduces exposure time and decrease radiation dose. Higher pitch also results in increased production of noise such as helical artifacts and decreased special resolution. There for most modern Multi-Detector CT Scanners (MDCT) are automatically equipped with helical pitch setting that optimize dose and noise based on each body region (E. Costello,2013).

2.1.17. Tube potential:

Lowering tube potential [x-ray beam energy kilo voltage and peak kilovolt age] is particularly advantageous in tow subsets of patients: Slim patients with a small body mass index [BMI] and patients undergoing CT examinations with iodinated contrast medium. However, increased noise and variation in tissue contrast and accompanied by decrease in tube potential limit widespread application of this technique (E. Costello, 2013).

Because effective radiation dose (ERD) is proportional to square of kilo voltage, considerable decreases in dose can be achieved with relatively small decrements in tube potential. A reduction from 140 to 100 kvp would result in a greater than 50% overall reduction (ERD). Lowering tube potential is important tool for decreasing CT radiation exposure; however, many CT scanners have limited selection of tube potential setting [eg; 80, 100, 120, or 140kvp]. This restricts the ability to achieve delicate modifications in radiation dose compared with tube current methods. The capability of finer tube potential modulation may allow further application in imaging of larger patients in other body regions of adults, such as the abdomen and pelvis, where higher tube voltage settings are needed to limit image noise (E. Costello, 2013).

2.1.18. Automatic tube current modulation:

Lowering tube current is another method to reducing Effective Radiation Dose (ERD). This can be done by use of a low fixed tube current modulation (ATCM), which is included in most modern CT scanners. ATCM is similar to the auto exposure controlled used in conventional radiographic systems. Integrated CT software automatically adjusts tube current on the basis on differences in tissue attenuation. Therefore regions basis of the body that require fewer x-rays for adequate data acquisition receive lower tube current. This results is improved dose efficiency and lower overall ERD while maintaining and acceptable level of quantum noise (E. Costello, 2013).

ATCM automatic tube current modulation can be applied with either angular (x and y axis) or z axis mod of modulation. Angular modulation adjusts current as a function of the projection angle. For low attenuation projection angles in the anteroposterior direction, current is reduced, and for high attenuation projection angles in the lateral direction current is

increased. The efficacy of angular modulation is greater in areas of the body with more pronounced asymmetry (E. Costello, 2013).

2.1.19. Helical CT scan:

Computed axial tomography scan (CAT scan or CT scan) is another name for CT scan, and is also called spiral CT scan (Medicine Net. com). Until approximately the mid to late 1990s, CT images were obtained one slice at a time with the patient tube moving step by step through the gantry. Scan obtained using this older technique often required 30 or 45 minutes and the patient held his or her breath for every slice. Helical or spiral CT scans are obtained usually with one breath hold and obtain a volume of x-ray tissue while the table moved rapidly with the gantry. Complete exams can be performed in less than five minutes. With the advent of helical or spiral CT scanning and rapid image acquisition, CT scanning has become the main diagnostic imaging tool in the radiology department (Medicine Net. com).

2.1.20. CT dosimetry in phantoms:

The standard phantom 160mm and 320mm diameter 150mm long phantoms have been used for 40y in CT dosimetry, and serve as the basis of CT dosimetric quantities such as CTDIvol, with the increasing sophistication of CT acquisition modes, as well as an interest in better characterizing the absorbed dose arising from the long scatter paths in CT, there is a need for longer phantom (Jicru. oxford journals. org). When a phantom is introduced into the x-ray beam in CT it becomes major sources a major source of scatter radiation that is responsible for absorbed dose in part of the phantom away from the collimated primary. Hence phantoms are an essential toll in understanding the distribution of absorbed dose in CT (Jicru. oxford journals. org).

2.1.21. Axial dose profiles in phantoms:

The axial or sequential CT scan involves the radiation of the x-ray tube head around the patient or phantom with no table motion during rotation. In this basic mode of operation it is instructive to understand the extent and shape of absorbed dose profile along the z-axis. It is released that for axial scanning the absorbed dose in the patient or phantom is essentially a summation of the absorbed dose distributions from individual axial scans spaced at equal intervals along z. Those profiles, which can be measured as air kerma or absorbed dose, can be computed using montcarlo techniques or can measured in physical phantoms using a number of different detector system. In many cases the relative shape of the absorbed dose profile only is of interest, and amplitude is arbitrarily normalized. In such cases, the quantity used to describe the profile shape can be either air kerma or absorbed dose (Jicru. oxford journals. org).

2.1.22. Surface integral exposure (SIE):

Since exposure expressed in Roentgens or coulombs per kilogram is a concentration,it does not express the total amount of radiation delivered to a body. The total radiation delivered or surface integral exposure (SIE), is determined by the exposure and dimensions of the exposed area. It is also referred to as the exposure area product (www. Sprawls. Org).

The surface integral exposure is expressed in the conventional units of roentgens −square centimeters (R/cm2). If the radiation exposure is uniform over the entire area, the (SIE) is the product of the exposure in roentgens (R) and the exposure area in square centimeters (cm2). If the exposure is not same at points in the exposed area,the (SIE) can be found by adding the exposure values for each (cm2) of exposed surface mathematically, this is the process of integrating the exposure over the surface area. The (SIE) can be measure during x-ray examinations by placing special type of ionization chamber in the x-ray beam. The

significance of (SIE) is that it describes total radiation imported to a patient whereas exposure indicates only the concentration of radiation at a specified point (www. Sprawls. Org).

2.1.23. Dose Area Product (DAP):

Dose Area Product (DAP) is similar in concept to surface integral exposure and exposure area product in that they all express total radiation delivered to a patient. The principle differences is in the unit using (DAP) is in dose units such as Gy. cm2. For a uniformly exposed area the (DAP) is just the product of the air kerma in (Gy or mGy) and the exposed aria in cm2. (DAP) provides a good estimation of the total radiation energy delivered to patient during a procedure (en. Wikipedia. org).

2.2. Previous study:

In this study by Khalid Alzimami (2014) calculated effective dose of CT scanner on brain at Nilien Medical Diagnostic Center on Sudan. This study performed on study group about (102 patient). He found that the effective dose (2. 05mSv) (Khalid, 2014).

In other study by MD. Ralaph Marcus, etc. (2008) calculated effective dose of CT scanner on brain at San Francisco Bay Area Institution in California. This study performed on (1119 patient). They found that the effective dose (2 mSv) (Marcus, 2008).

In other study by Ernest K. Ossei…etc (2012) calculated effective dose of CT scanner on brain at Department of physics and Astronomy,University of waterloo on Canada. This study performed on study group about (94 patient). They found that the effective dose (1. 45 mSv) (K. Ossei, 2012).

In other study by N. H. bert, etc. (2000) calculated effective dose of CT scanner on brain at Department of radio diagnosis, Christian Medical Collage on India. This study performed on study group about (101 patient). They found that the effective dose (0. 061 mSv).

Chapter Three

Material and Methods

3.1. Material:

3.1.1. Study Group (Population):

The study group consist of 50 cases (25 males and 25 females).

This group with age ranging from (4y to 93y) and with mean (48y).

3.1.2. Machine used:

CT/e,Dual G. E.   Installed (2004). The slice thickness option {1,2,3,4,5,6,7,8,9,10 mm}. The range of kv between {20kv-140kv} and range of mAs between {20mAs-200 mAs}

3.2. Method:

Random samples consist of 50 patients, male and female who underwent CT brain study the effective dose that result from x-ray beam pass through brain from CT machine is use to assess the potential effects that might occur.

Assessing the radiation dose by calculate the effective dose

The effective dose {ED = dose length product DLP*Wt Or{ED} = sum of (organ dose*tissue wight factor) we focuse on radiation DLP who it influence by mAs, also compare ED on brain between male and female.

Chapter Four

Results

Results

The data shows assessment radiation dose of CT scan on brain for male and female finding included 50 patients analyzed in tables and figures that showed below:

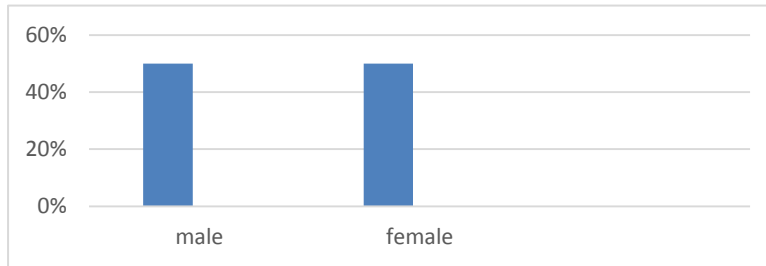**Table (4.1): Shows Patients ages distribution in frequency and percentage**

Age group in year	Frequency	Percentage
Less than 30	15	30%
31 - 50	09	18%
51-70	16	32%
More than 70	10	20%
Total cases	50	100%
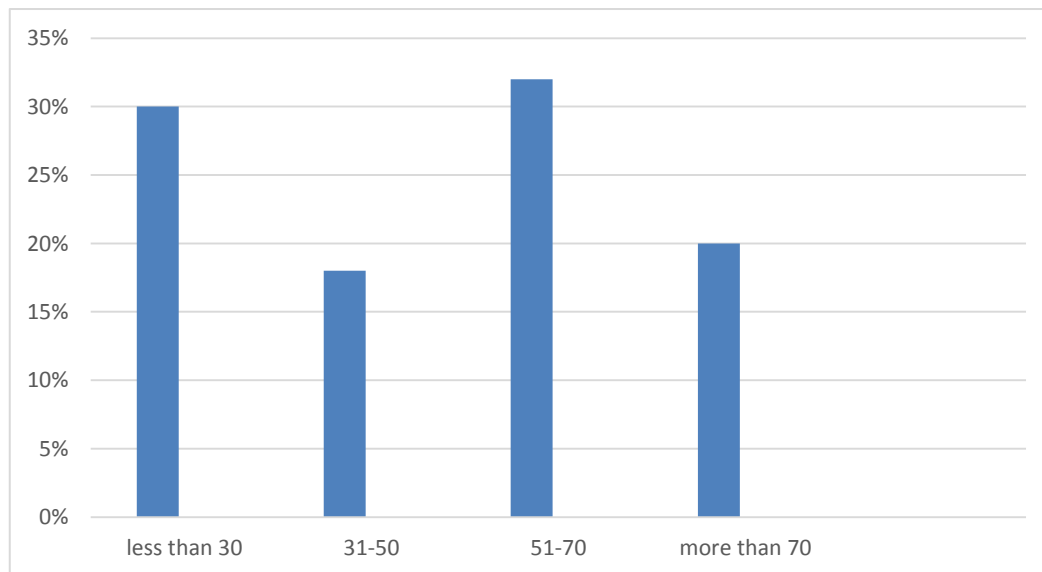
Figure: (4.1): Shows patient's age distribution in frequency and percentage.

Table (4.2): Shows patients gender distribution in frequency and percentage.

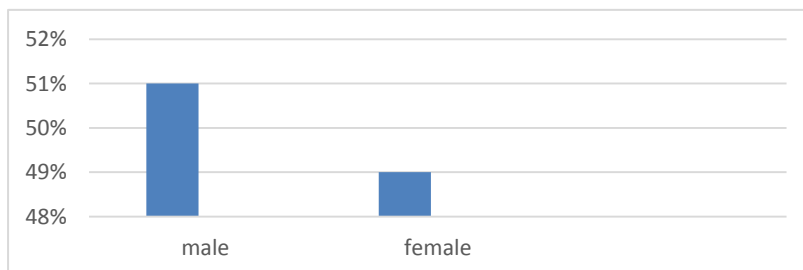| Gender	Frequency	Percentage
male	25	55%
female	25	50%
Total cases	50	100%

Figure (4.2): Shows the patients gender distribution in frequency and percentage.

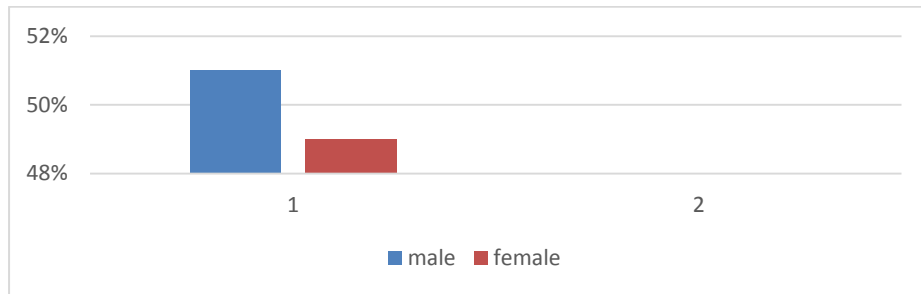**Table (4.3): Shows patients [DLP] of male and female in percentage.**

Gender	Averge ED mAs	Total ED mAs	Percentage
male	17901. 30	716. 052	51%
female	16595. 46	663. 8184	49%

Figure (4.3): Shows [DLP] of male and female in percentage.

**Table (4.4): Shows patients [ED] of male and female in percentage.**

Gender	Averge ED mAs	Total ED mAs	Percentage
male	1. 5037	37. 59273	51%
female	1. 39401	34. 850466	49%

Figure (4.4): Shows [ED] of male and female in percentage.

Table (4.5): Shows compare DLP between (10 cases) scan by more than 170 mAs and (10 cases) scan by less than 170 mAs in percentage

Parameter mAs	Total DLP(mGy)	Average DLP (mGv)	Percentage
More than 170	13453. 39	1345. 339	69%
Less than 170	6134. 67	613. 467	31%
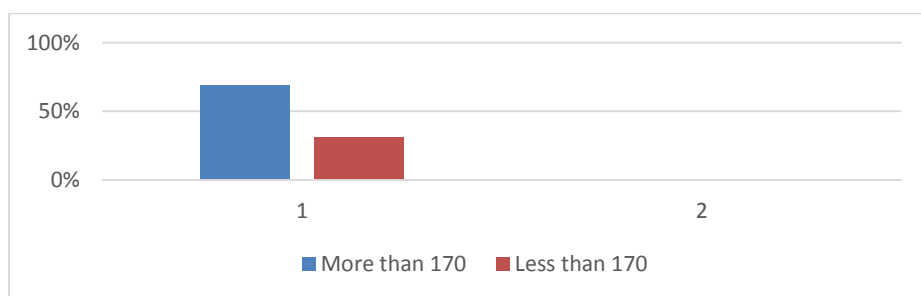
Figure (4. 5): Shows compare [DLP] between 10 cases scan by more than 170 mAs and 10 cases scan by less than 170 mAs in percentage.

Table (4.6): Shows compare ED between (10 cases) scan by more than 170 mAs and (10 cases) scan by less than 170 mAs in percentage
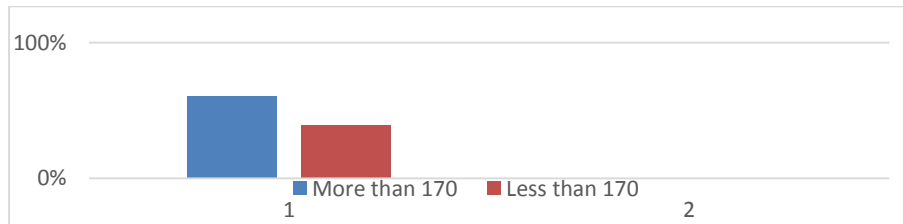
Parameter mAs	Total ED(mSv)	Average ED (mSv)	percentage
More than 170	25. 14060	2. 514060	61%
Less than 170	16. 257478	1. 6257478	39%

Figure (4.6): Shows compare ED between (10 cases) scan by more than 170 mAs and (10 cases) scan by less than 170 mAs in percentage.

Table (4.7): Shows ED of (10 cases) for male and female who scan by same parameter (mAs) in percentage.

Gender	Averge ED mAs	Total ED mAs	Percentage
male	1. 314060	13. 14060	50%
female	1. 314060	13. 14060	50%
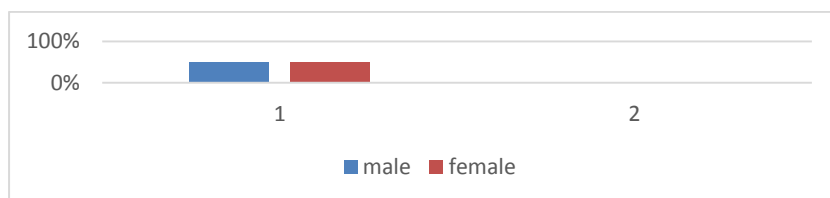
Figure (4.7): Shows ED of (10 cases) for male and female who scan by same parameter (mAs) in percentage.

Chapter Five

Discussion, Conclusion and Recommendation

5.1. Discussion:

In this study the average effective dose of CT scanner on brain is acceptance amount (1.5037mSv) because it is not equal or above than standard amount of effective dose for CT scanner on brain 2 mSv that recommended by (ICRP).

When compare this average effective dose in this study with other effective dose in previous study can be say (this average effective dose in this study is suitable and low when it compare with average effective dose that calculated by Khalid Alzimami (2.05 mSv) at (2014), MD. Ralph Marcu, etc. (2mSv) at (2008) and Ernest K. ose, etc. (1.45)mSv at (2012). But it is not suitable and high when it compare with average effective dose that calculated by N. Hbert, etc. (0.61 mSv) at (2000). There is small different between average effective dose of male and female (0.10969) mSv table (4.4), figure (4.4) this different not according to differences of brain anatomical structure for male and female due to difference of brain.

The main parameter that control to radiation dose is mAs Using mAs above 170 mAs give averge ED (2. 54060) more than standerd amount of effective dose for CT scanner on brain 2 mSv that recommended by (ICRP). Using mAs above 170 mAs give averge ED (1.625747)less than standerd amount of effective dose for CT scanner on brain 2 mSv that recommended by (ICRP).

For that to reduce over dose of CT machine must be reduce mAs according to ALARA principle (As Low as Reasonable Achievable) table (4.6), figure (4.6).

Also to reduce effective dose mAs must be reduce because ED has proportional relation with DLP and mAs table (4.5), figure (4.6).

5. 2. Conclusion:

There is normal radiation dose of CT scanner on brain in Modern Medical Centre compared to international recommendation. Also there is no different between effective dose of male brain and female brain according to differences in anatomical structure of brain.

5. 3. Recommendation:

● The range of Kv must be not less and increase than (120Kv).

●The range of mAs must be between (60–100 mAs) for pediatric and adult.

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